POTTERY TECHNOLOGY AT THE DAWN OF THE METAL AGE

Exploring Dynamics within Vinča Material Culture

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Cover: (above) drawing by Elisa Norina Solera; (below) Toplica River along the archaeological site of Pločnik (photo by Julka Kuzmanović-Cvetković). Back cover: Pottery from the archaeological site of Pločnik (photo by Silvia Amicone).

A mio figlio Francesco, che cresce
mentre cresco anch’io.

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Preface

"*The question of how and why behaviors, beliefs, and ideas are learned and shared among a group of people and transmitted from one generation to the next lies at the heart of our discipline*." With these words, Stark *et al.* (2008) set the stage for a theoretical approach that has profoundly shaped my research. At the core of this work is an exploration of how technological knowledge, particularly in ceramic production, is acquired, practiced, and transmitted. To address these questions, I adopt an interdisciplinary perspective that merges insights from the anthropology of technology, practice theory, and neo-Darwinian models of cultural evolution. Rather than treating these frameworks in isolation, I bring them into dialogue to better understand how pottery traditions reflect both social continuity and innovation. In this view, ceramics become more than functional artefacts: they are vessels of cultural memory, skill, and identity, formed through both material engagement and shared experience.

Pottery Technology at the Dawn of the Metal Age: Exploring Dynamics within Vinča Material Culture is the result of years of research into the technological choices, expertise, and social practices of pottery-making communities during the Late Neolithic and Early Chalcolithic in the central Balkans. The project began with my doctoral research on pottery from the sites of Belovode and Pločnik—two key locations for understanding the emergence of metallurgy in prehistoric Europe—within the framework of the Arts and Humanities Research Council-funded (AHRC) project *Rise of Metallurgy in Eurasia: Evolution, organisation and consumption of early metal in the Balkans* (AH/J001406/1). It was later expanded through postdoctoral research at the Eberhard Karls University of Tübingen. Throughout, I aimed to investigate how pottery production evolved over time and how it might be connected with broader technological developments, particularly in pyrotechnology and early metalworking.

The results presented in this book are the product of a multidisciplinary approach that combines macroscopic ceramic analysis with archaeometric techniques, including petrography, WD-XRF, XRPD, and SEM. These analyses are framed within theoretical models drawn from the anthropology of technology and cultural transmission studies, allowing the integration of material science data with social and cognitive interpretations of technological practice. The overarching aim is to understand how knowledge was transmitted within and between communities, how production was organised, and how potters engaged with materials, tools, and traditions in ways that were both technically skilled and socially embedded.

Belovode and Pločnik offer unique insights into these questions. The stratigraphic integrity of the trenches, the rich ceramic assemblages, and the exceptional contextual data from recent excavations allowed a detailed reconstruction of ceramic "recipes" and production strategies over nearly 1,000 years. These findings are discussed within a broader regional framework, highlighting both continuity and innovation across the Vinča cultural sphere.

This project was made possible thanks to the contributions of many institutions and individuals. Foremost among them, I am grateful to Julka Kuzmanović-Cvetković, Gordana Grabež, Duško Sljivar, and the National Museum in Belgrade for securing access to materials. My sincerest gratitude goes to my former supervisors, Miljana Radivojević, Patrick Quinn, and Thilo Rehren, whose guidance and insights were instrumental during the formative years of the research that inspired this book. I am also deeply grateful to my PhD examiners, Evangelia Kiriatzi and Tobias Kienlin, for their valuable feedback and encouragement. I would also like to thank Kate Sharpe for her help with language editing, warm encouragement, and invaluable support throughout this journey.

I am deeply grateful to the teams working at Belovode and Pločnik, whose fieldwork provided the foundation for this research. I am also indebted to the AHRC project team, especially Miroslav Marić, Neda Mircović Marić, and Benjamin Roberts, for their collaboration, intellectual generosity, and crucial help, without which this research would not have been possible.

I wish to express sincere gratitude to the colleagues who supported this work at every stage. In particular Enrica Bonato, Mike Charlton, Marcos Martinón-Torres, Lara Maritan, Sébastien Manem, Giovanni Vezzoli whose guidance helped shape both my analytical approach and broader conceptual thinking, and Christoph Berthold, Enrico Croce, Attila Kreiter, Noemi Müller and Michela Spataro who shared their time, expertise, and encouragement. This book also owes much to the peer reviewers and fellow researchers such as Agnese Benzonelli, Ştefan Cristian Eduard, Nina Drakulović, Vanessa Forte, John Gait, Aleksandar Jablanović, Edyta Marzec, Elisa Perego, Giulia Russo, Paola

Sconzo, Andrea Squitieri, Jugoslav Pendić, Milan Radovanović, Milica Rajičić, Marija Savić, Carmen Ting, Esther Travé, Federica Ugliano as well as to our students, especially Efraim A. Andreadakis, Marika Ciela, Bianca Costi Farias, Maria Diakatou, Giulia Deimichei, and Francesca Cicarella, who offered critical feedback and enriched the discussion with their perspectives.

Special thanks go to those who introduced me to archaeometric methods and supported the laboratory phases of this work. The analytical programme was supported by the AHRC project, and by institutional support from the Wolfson Archaeological Science Laboratories (UCL), the Fitch Laboratory at the British School at Athens, and the Competence Center Archaeometry Baden-Württemberg. I would also like to acknowledge the financial support that made this work possible, including grants from the AHRC, Funds for Women Graduates, the UCL Institute of Archaeology, the UCL Graduate School, the UCL the Institute for Archaeo-Metallurgical Studies (IAMS) and the Excellence Initiative at the University of Tübingen.

On a more personal note, this project has shaped not only my academic path but also my understanding of how archaeological research can connect the deep past with present questions about technology, identity, and community. Working on the pottery of the Vinča culture has been both an intellectual journey and a deeply human experience, one that brought me into contact with talented researchers, generous mentors, and enduring friendships. I am grateful for all the conversations, challenges, and shared discoveries that have accompanied this work.

I also wish to thank my family for their patience, support, and belief in this project, especially during the most demanding periods. To Lars Heinze, who has been by my side through it all, thank you for your constant encouragement and presence.

Finally, I hope this book will serve not only as a contribution to the study of Vinča ceramics but also as an invitation to further explore the complex world of prehistoric technologies, and the people behind them.

Chapter 1
Introduction

The Late Neolithic in the Balkans represents one of the most dynamic phases in European prehistory. This period witnessed the establishment of fully sedentary settlement systems evidenced by the rise of large tell-settlements, the intensification of agricultural and herding activities, and significant technological advancements (**Bailey 2000**). Notably, this period in the region was marked, not only by substantial progress in established technologies such as pottery production, but also by the emergence of metallurgy (**Radivojević *et al.* 2010** and literature therein), seamlessly transitioning into the subsequent Chalcolithic period.

The Late Neolithic/Chalcolithic phenomenon, today known as the 'Vinča culture' (*c.* 5350/5300–4500 BC), emerged over an extensive area encompassing parts of the northern and central Balkans (**Roberts *et al.* 2021; Vasić 1932–1936**) and played a crucial role in these technological advancements. Pottery from Vinča culture sites is particularly noteworthy for its abundance and the variety of styles that demonstrate the technological expertise of these communities. Vinča culture ceramics have consistently attracted significant attention from both national and international scholars (**Amicone *et al.* 2021a** and literature therein). The chronology of the culture was initially established based on ceramic typology, and pottery has been central to debates concerning the origins of the phenomenon—specifically, whether it developed locally or had roots in Anatolia (**Garašanin 1954**). Furthermore, advances in pyrotechnology, exemplified by dark-burnished ware and graphite-painted pottery, have been hypothesised to be essential prerequisites for the independent development of metallurgy in Eurasia (**Amicone *et al.* 2020a** and literature therein).

The emergence of metallurgy is regarded as a crucial advance in human history, forming the basis of historical narratives explaining the evolution of social complexity (e.g. **Childe 1944**; **Craddock 1995**; **Renfrew 1973**; **Wertime 1964**). Debates have focused on when and where early humans first learned to use fire to extract metal from naturally occurring ores (**Gourdin and Kingery 1975; Jordan and Zvelebil 2009; Jovanović and Ottaway 1976; McDonnell 2001**; **Roberts *et al.* 2009**; **Wu *et al.* 2012** and literature therein). One of the most influential publications on this topic, by Childe (**1944**), argues that Near Eastern prehistoric communities were the sole inventors of extractive metallurgy, which then spread to other regions. This perspective was challenged by Renfrew (**1969**), who posited multiple independent inventions of metallurgy across different centres in Eurasia, based largely on artefact typology and C14 dating.

Recent excavations at the 7000-year-old Vinča culture site of Belovode in eastern Serbia, and analyses of archaeometallurgical artefacts have revealed the earliest known evidence for copper smelting in Eurasia (**Radivojević *et al.* 2010; Radivojević 2013**). At Pločnik, another Vinča culture settlement in southern Serbia, the recovery of a well-contextualised tin bronze foil, dated to *c.* 4650 BC, suggests the presence of an early, though short-lived tradition of tin bronze production in the region, technologically connected to early copper metallurgy by Vinča culture communities (**Radivojević *et al.* 2013**). These discoveries reinforce the theory of multiple independent origins of metallurgy across Eurasia, with Iran and possibly the Iberian Peninsula cited as other potential metallurgy hubs contemporary to the Balkans. Radivojević and Rehren (**2016**) propose that the development of copper metallurgy in this region was linked to the understanding of material properties of black and green manganese-rich copper minerals, which served as raw materials for both copper and tin bronze production. This knowledge is thought to have developed locally and spread across the Balkans over approximately 2000 years, from the late 7th millennium to the mid-5th millennium BC (**Radivojević and Rehren 2016**).

On a global level, advances in pottery firing technology, which predate metallurgy in many parts of the world, have been proposed as precursors to the development of metal extraction (**Wertime 1964** and literature therein). According to this theory, metallurgists acquired transferable skills from potters, including the ability to reduce metal oxides (**Wertime 1964: 1264–1266**). This notion is supported by archaeological evidence from the Balkans where, alongside other decorative techniques (e.g. cinnabar, calcite, black-topped), dark-burnished and graphite-painted pottery were prominent products. The high firing temperatures—reaching approximately 1000°C or higher—and predominantly reducing atmospheres believed to be necessary for producing these types of pottery, suggest that Late Neolithic Balkan potters already possessed a sophisticated understanding of pyrotechnology and of the behaviour of inorganic materials at high temperatures (**Gimbutas 1976: 173–176; Kaiser *et al.* 1986; Renfrew 1969**). For this reason, as previously mentioned, the expertise exemplified in dark-burnished ware and graphite-painted pottery has been recognised as a crucial precursor to the development of copper smelting technology in this region.

Ceramic studies in the Balkans

Pottery studies in the Balkans remain predominantly focused on extensive chrono-typological classifications, often utilised as the primary basis for di stinguishing co-existing archaeological cultures in this region from the 7th to the 5th millennia BC (**Childe 1929**). These cultures are frequently equated with social groups or even ethnic identities. The prominence of this approach is understandable, as the culture-historical model has been the dominant theoretical framework in Balkan archaeology since the late 19th century (**Maran 2017: 17**). This model also forms the foundation of diffusionist theories (e.g. **Childe 1929; Garašanin 1954**), which positioned the Balkans as a conduit between Northern Europe and the Near East, with the latter regarded as the cradle of civilisation and technological innovations such as agriculture and metallurgy.

While the culture-historical model has declined in popularity, the complex geopolitical landscape of the Balkans during the 20th century reinforced a persistent focus on the concept of 'archaeological culture', delaying the full adoption of new theoretical approaches that emerged elsewhere in the second half of the century (**Gori and Ivanova 2017: 3**). The notion of an 'archaeological culture' remains a significant element of Balkan studies, providing a framework within which to analyse relationships between different material cultures and develop broader syntheses. An increasing body of research however, whilst continuing to use this traditional concept, also highlights the importance of pottery as a crucial tool for exploring human behaviour and social interaction (**Amicone 2019** and literature therein). In this sense, the term 'archaeological culture' in these works is often used as a synonym for 'material culture', and it is in this meaning that it is adopted in this book. These studies reflect the influence of interdisciplinary approaches to material culture, inspired by the pioneering work of Shepard (**1956**). Shepard's work profoundly impacted pottery studies in Anglo-American archaeology from the mid-20th century onwards and contributed to the broader theoretical developments initiated by the 'New Archaeology' movement (e.g. **Binford 1965; Binford 1972; Clarke 1973**). The diverse approaches to ceramics within archaeology illustrate how advancements in theory, technology, and interdisciplinary collaboration have transformed the study of ancient material culture.

The influence of these theories on the study of prehistoric pottery in the Balkans became evident in the 1970s, following international excavations at Selevac and Opovo (**Tringham and Krstić 1990; Tringham *et al.* 1992**) and the contributions of American and British scholars such as Gardner (**1978**), Chapman (**1981**), and Kaiser (**1984; 1990; Kaiser *et al.* 1986**). Despite these significant studies, research into ceramic technology in the prehistoric Balkans did not progress in the same manner as in neighbouring regions like the Aegean where, particularly since the 1980s, technological studies of pottery have consistently been integrated into archaeological research (e.g. **Day 1989; Day *et al.* 1998; Whitbread 1989**). The broader geopolitical tensions and isolation experienced in the Balkans during the 1990s played a substantial role in marginalising ceramic technology research, with culture-history and diffusionist models maintaining dominance, while anti-diffusionist arguments emerged mainly in debates regarding the independent invention of metallurgy (**Jovanović and Ottaway 1976**; **Radivojević *et al.* 2010; Renfrew 1969; Roberts *et al.* 2009**; **Todorova 1978**). However, with the decline of culture-historical approaches and the opening of the Balkans to other theoretical developments in the early 21st century, there has been a renewed focus on pottery technology studies. This shift is exemplified by the work of scholars such as Gheorghiu (e.g. **Gheorghiu and Nash 2007**), Salanova (e.g. **Salanova 2012; Salanova *et al.* 2010**), Miloglav (**2012**), and Vuković (e.g. **2013, 2015**), who have explored various aspects of ceramic technology, including manufacturing techniques, production organisation, and craft specialisation. Additionally, recent decades have witnessed the growth of ethnographic approaches to pottery technology and production in the region (e.g. **Carlton 2014; Djordjević 2007, 2014**).

The study of ceramics in the Balkans has also benefitted from the application of archaeometric methods, with significant research projects including my own research (e.g. **Amicone *et al.* 2020a**), Burke (**2022**), Dzhanfezova (e.g. **Dzhanfezova *et al.* 2020**), Gajić-Kvaščev (e.g. **Gajić-Kvaščev *et al.* 2012a, 2012b**), de Groot (**2019**), Koutouvaki (**Koutouvaki *et al.* 2021**), Kreiter (e.g. **Kreiter 2010**; **Kreiter *et al.* 2009; 2017**), Opriş (**Opriş *et al.* 2022**), and Spataro (e.g. **2014, 2017, 2019b**). These studies, alongside numerous other recent interdisciplinary projects, demonstrate that the Balkans has become a fertile ground for experimenting with innovative approaches to ceramic research. This progress is beginning to influence pottery studies across Europe and beyond.

Structure of the book

This book aims to shed new light on the critical role of pottery technology within the broader narrative of Vinča culture advancements, showing how these developments facilitated the early stages of metallurgy. It originates from my PhD undertaken within the framework of the AHRC research project 'The Rise of Metallurgy in Eurasia': Evolution, organisation and consumption of early metal in the Balkans' (hereafter 'RoME'), which investigated the emergence of metallurgy in the Balkans during the 6th–5th millennia BC (**Radivojević *et al.* 2021a**). This book offers a comprehensive synthesis of research results previously published (**Amicone 2021a, Amicone 2021b, Amicone et al. 2020a, Amicone *et al.* 2020b, Amicone et al. 2021a**), bringing them together within a unified framework enriched by previously unpublished data and new interpretations. These additions critically reassess and expand upon the original studies, offering an integrated perspective and deeper theoretical insights that were beyond the scope of the earlier work. The book provides an in-depth analysis of the technological evolution and cultural dynamics of pottery production within the Vinča culture, with a particular emphasis on the key archaeological sites of Belovode and Pločnik. This extensive study is structured across ten chapters, each focusing on distinct thematic aspects that together construct a comprehensive narrative of pottery-making traditions spanning approximately 1000 years. By exploring the transition from pre-metallurgical to metallurgical periods, the account unveils the nuanced processes involved in the development, transmission, and transformation of technological practices over time.

The initial chapters present the archaeological and environmental context of the sites, drawing from previous excavations and recent research conducted within the framework of the 'RoME' project, setting a robust historical and geographical stage. Detailed descriptions of excavation methods illustrate the rigorous approaches taken, incorporating advanced techniques such as GIS and systematic sampling to ensure comprehensive data collection. This background serves as a foundation for the subsequent analytical chapters.

Chapter 4 outlines the theoretical framework that underpins the study, integrating perspectives from the anthropology of technology, neo-Darwinian evolutionary theory, and cultural transmission models. By applying concepts such as *chaîne opératoire* and 'recipes', the chapter explores how knowledge and practices related to pottery-making were transmitted, adapted, and transformed over time. This discussion provides a crucial interpretative lens for understanding the technological and social dynamics examined in the following chapters.

In **Chapter 5**, the diverse array of investigative techniques employed are outlined, including macroscopic examination, thin section petrography, wavelength dispersive X-ray fluorescence (WD-XRF), X-ray powder diffraction (XRPD), and scanning electron microscopy (SEM). These methods facilitated a thorough characterisation of the ceramic assemblages from Belovode and Pločnik, shedding light on the choices made by potters regarding raw material selection, tempering, and firing conditions. The integration of these approaches exemplifies the interdisciplinary approach of the study, allowing a multi-dimensional understanding of the material culture.

Chapters 6–8 document the findings from macroscopic and archaeometric analyses, revealing distinctive technological characteristics of pottery production at both sites. Notably, the data highlights differences and commonalities in raw material use, decorative techniques, and vessel types, mapping out changes across various settlement horizons. These observations are contextualised within the broader framework of Vinča and related Balkan cultures, offering comparisons that enhance understanding of regional and temporal variations in pottery-making practices.

The following chapters (**Chapters 9 and 10**) delve into the implications of these findings for cultural transmission within Vinča communities. The analysis identifies both continuity and innovation in pottery production, emphasising the stability of technological traditions and the social mechanisms that facilitated the transfer of knowledge across generations. Concepts such as vertical and direct transmission are explored, illustrating how apprentices learned through close interaction with more experience individuals.

In **Chapter 10** the discussion is broadened to examine how the local practices revealed by the analysis intersected with wider networks of exchange and influence within the Neolithic and Chalcolithic periods. The relationship between pottery and the emergence of metallurgy is also scrutinised, highlighting how pyrotechnological expertise in ceramic production may have laid the groundwork for early metallurgical developments. This concluding chapter synthesises these themes, drawing attention to both the enduring nature of pottery-making traditions and the subtle shifts that marked the evolution of Vinča material culture, thus offering a richly detailed narrative of technological and cultural change in prehistoric Southeast Europe.

Chapter 2
Archaeological background

The Late Neolithic and Chalcolithic in the Balkans

The end of the 6th millennium BC saw significant developments in Southeast Europe, including the acceleration of agricultural (planting and processing of cereals) and herding activities. It also witnessed an intensification of pottery and lithic production and, finally, the emergence of metallurgy (**Bailey 2000: 209; Radivojević *et al.* 2010**). These transformations took place slowly across this region from the mid-6th millennium BC onwards, ultimately resulting in the establishment of a fully sedentary settlement system. This gradual change is recognisable in the material cultures from the Early Neolithic into the Late Neolithic/Early Chalcolithic, in an area covering the lower Danube, large parts of Bulgaria, Serbia, southern and eastern Hungary, and northern Greece (**Bailey 2000: 153**). In this period, the region is roughly defined by Vinča and Sopot-Lengyel material culture to the west, Precucuteni-Tripolye A to the east, Tisza and Szaklhát to the north, and Sitagroi I–III and Karanovo IV–V to the south.

Significant changes across the east of Europe are visible in the development of large tell sites, especially in Greece and Bulgaria, with a continuity of occupation evidenced by the superimposition of structures (**Bailey 2000: 191**). These settlements were surrounded by arable land that provided food for the inhabitants and probably also a production surplus (**Chapman 1981**). Living spaces also underwent significant changes. In several cases, buildings became larger and were constructed from more durable materials. Several sites within the lower Danube Basin and settlements such as Ovcharovo, Polyanitsa, Targovište, Golyamo Delchevo, Gomolava and Divostin, were characterised by dwelling structures regularly measuring about 10 × 10m, connected by pathways (**Brukner 1980; McPherron and Srejović 1988; Todorova 1978; Todorova *et al.* 1975, 1983**); this type of structure also occurred later in the Transylvania and Banat regions (**Lazarovici 2006: 277–278**).

A new emphasis on the production of plant and animal resources perhaps resulted from intense pressure on natural resources, increasing the potential for conflict within communities and, in turn, encouraging the pursuit of prestige materials like gold and copper (**Bailey 2000: 190–191**). In addition, exchange networks became larger with the circulation of polished axes, obsidian from the Carpathians, spondylus shells from the Aegean, as well as copper items and salt (**Sherrat 1997: 139**).

Ultimately, these developments led to changes in burial customs, with the emergence of rich burial grounds of exceptional size during the Chalcolithic period in the Lower Danube area. Here, cemeteries associated with settlements tended to be smaller; when set apart from villages, they were generally larger and richer (**Bailey 2000: 197**). In north-eastern Bulgaria, at Durankulak and Varna, burials dated to the mid-5th millennium BC yielded more than a thousand pieces of gold (**Ivanov 1988: 200–203; Ivanov and Avramova 2000; Leusch *et al.* 2015; Todorova 2002**). Evidence for gender or age-related differentiation in burial practices is also observed in small cemeteries, such as Delchevo, Devnja, Golyamo, Vinitsa, Targovište (**Angelova 1986; Bailey 2000: 202; Raduncheva 1976; Todorova 1971, 1986; Todorova *et al.* 1975**). It is important to note, however, that evidence for burials in other areas of south-central Bulgaria and the western Balkans has not yet been detected.

In terms of pottery production, dark wares became predominant in an area extending from wider Anatolia to the Balkans (**Todorova 1995: 88**). Very often, within the ceramic assemblages from this period, dark-burnished ware, also known as black burnished ware, is associated with graphite decoration, which gives the pottery a highly reflective black surface (**Jones 1986: 768**). Vessels with geometric patterns painted in graphite, dating from the 5th millennium BC, are found across the Balkans (e.g. **Gaul 1948: 98–99; Leshtakov 2005; Martinon 2017; Todorova 1986: 107**). The decorative motifs were executed in 'positive' or 'negative' fashion and included a range of geometric

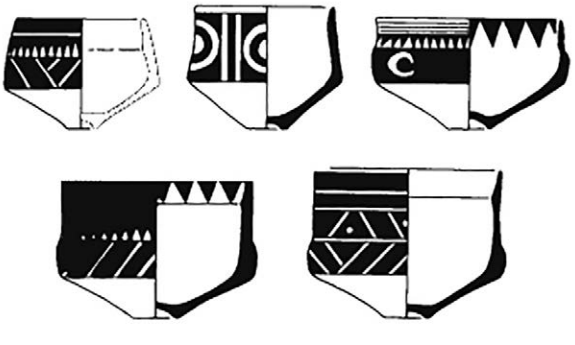


Figure 2.1. Graphite-painted pottery (modified after Bailey 2000, fig. 6.6, 225).

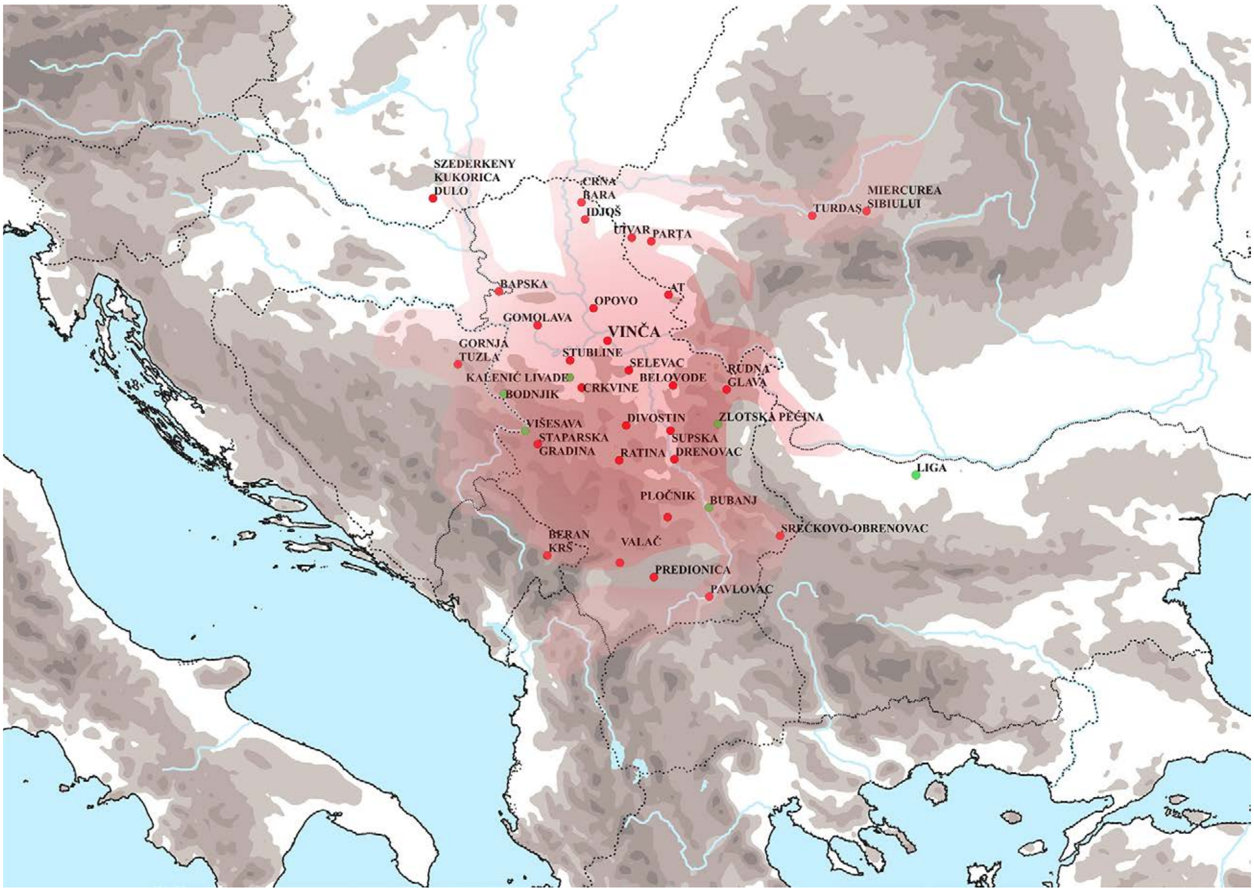


Figure 2.2. The distribution of the Vinča culture (shaded) with Vinča sites (red dots) and later Middle Chalcolithic settlements (green dots) (from Radivojević *et al.* 2021a: 39; prepared by J. Pendić and M. Marić).

patterns such as parallel lines, spirals, meanders, circles, triangles, and rhomboids (**Figure 2.1**).

The use of this technique of decoration spread, particularly in the Stara Zagora district in the vicinity of the ancient Ai Bunar mine (**Todorova 1978: 28–32**). Graphite decoration is also found at the site of Sitagroi (phase III, around 4650 BC) and Dikili Tash in Greek Macedonia, as well as at Paradeisos, Paradimini and Makri in Thrace, all dating to around the same period (**Bonga 2013: 195; Renfrew 1971: 276**). In Sitagroi, there is also evidence for Graphite Wash Pottery from phase I, an all-over graphite wash on vessels with a dark surface, representing the earliest use of graphite at this site (**Bonga 2013: 196**). The earliest documented application of graphite decoration, however, comes from Promachon-Topolnica in the Struma valley and is dated to the very beginning of the 5th millennium (**Vajsov 2007**). The technique became more frequent in eastern Serbia, southern Romania and Bulgaria only during the second half of the 5th millennium BC and it was used extensively in the Kodjadermen-Gumelniţa-Karanovo VI culture (KGK VI) complex (**Gaul 1948: 98–99**).

Both dark-burnished ware and the graphite decorative technique have been closely associated with the emergence of early metal production techniques. They exhibit evidence of a specialised crafting knowledge, also reflected in the general trend towards increasingly elaborate surface treatments and decorations that characterise this period **(Bailey 2000: 228)**. Whilst this is an attractive and convenient interpretation, it has only recently been rigorously tested (**Amicone *et al.* 2020a**). In the study presented here, an in-depth investigation was undertaken into the technology involved in the production of dark-burnished and graphite-painted pottery within the Vinča culture. This is considered in the context of the most recently reported, detailed technological studies on the emergence and evolution of metallurgy within this particular material culture.

The origin of the Vinča phenomenon and its chronology

The Vinča culture is a Neolithic/Chalcolithic phenomenon that emerged at the end of the 6th millennium BC and lasted from *c.* 5350/5300 BC to *c.* 4500 BC (**Porčić 2020; Roberts *et al.* 2021** and literature therein; **Whittle *et al.* 2016**). It covered a vast area (**Figure 2.2**) comprising parts of the northern and central Balkans: eastern Macedonia, Serbia, eastern parts of Croatia (Slavonia) and Bosnia, Banat, and Oltenia, as well as the west Transylvania region in Romania, southern Hungary (Baranya) and western Bulgaria. The name 'Vinča' refers to the eponymous site of Vinča-Belo Brdo, a large tell settlement discovered in 1908 by the Serbian archaeologist, Miloje Vasić. Since the discovery of this site, the culture has been the subject of continuous national and international research (e.g. **Chapman 1981; Garašanin 1951, 1979; Jovanović 1971; Renfrew 1970; Roberts *et al.* 2021** and literature therein; **Srejović 1963; Tasić *et al.* 2015; Tringham 1991**).

The Vinča phenomenon shows strong links with the contemporaneous Karanovo culture (phase III to Kodžadermen-Gumelniţa-Karanovo VI) in Bulgaria, the Precucuteni-Tripolye A culture in Moldavia and Ukraine, the Dimini culture in Greece, and late manifestations of the Starčevo culture and the early Sopot culture in eastern Croatia. Definitions and relative chronologies have been based largely upon the typological studies of the abundant pottery finds at several archaeological sites of Southeast Europe (**Roberts *et al.* 2021** and literature therein).

Characterisation of the transition from the Early/Middle to the Late Neolithic in Southeast Europe is closely linked to debates about the Starčevo and Vinča material cultures. Initially, the culture-historical model dominated the discussion, exemplified by the 'diffusionist paradigm' in which Garašanin developed the idea of the migration of a population, labelled 'Vinča', who were assumed to be the originators of the later Vinča phenomenon (**Garašanin 1954**). The assumption of a 'Vinča migration' led to the hypothesis of a violent encounter between these newcomers and people of the pre-existing 'Starčevo' material culture (**Dimitrijević 1974: 91**). According to this view, movement of people in the central Balkans led to the displacement of the earlier indigenous population, who were thereafter pushed towards the north and the northwest. These events then triggered the decline or loss of the cultural individuality of these Early/Middle Neolithic groups (**Dimitrijević 1979: 257–258**).

New perspectives have since come to dominate the debate on the origin of the Vinča culture. According to more recent hypotheses, the Vinča phenomenon arose from the Starčevo culture without any external influences (e.g. **Bogdanović 2006; Leković 1990**). A third model combines an autonomous development with a migration process, with the later phases of the Starčevo phenomenon occurring alongside the earliest Vinča phases. This model of 'successive migration' (**Garašanin 1964, 1979; Jovanović 1968**) involves a gradual movement in several waves rather than a violent encounter, with interactions between the newcomers and indigenous populations leading to the development of new cultural groups whilst older Neolithic cultures gradually disappeared.

This debate remains ongoing. The lack of a satisfactory resolution could perhaps be attributed to an excessive emphasis on typological studies, in which pottery is treated as a completely autonomous element disconnected from people and society. Recent studies (e.g. **Spataro 2014, 2019b; Vuković 2015**) have, however, employed approaches based on the analysis of technological styles, in which pottery is regarded as a source of information about socially constructed practices like techniques of production and transmission of knowledge. These types of approach seem more appropriate to the study of this transitional process because they focus on the transmission of cultural elements such as pottery making techniques, and do not try to explain material culture transformation simply through migration phenomena. But to shed new light on the full development of the Vinča phenomenon, technological studies need to be combined with a more systematic application of information gained from stratigraphic excavations and radiocarbon dating (e.g. **Tasić *et al.* 2016a, 2016b**)

Several chronological systems have been developed (e.g. **Garašanin 1951, 1979, 1993; Holste 1939; Lazarovici 1981; Lenneis and Stadler 1995; Milojčić 1949; Schier 1996**; for a detailed review and re-dating see **Whittle *et al.* 2016**). Currently, the most widely used are those created by Garašanin and Milojčić respectively (**Figures 2.3** and **2.4**). Garašanin divided the Vinča culture into an early phase named Vinča-Tordoš (I and II), followed by the Gradac phase and three phases of Vinča Pločnik (I, IIa, IIb). The periodisation created by Milojčić is instead based on that of Holste (**1939**), who simply assigned subsequent letters to the four phases of the Vinča phenomenon (Vinča A–D).

From the 1970s onwards, the increasing application of radiocarbon dating reshaped the international debate on Vinča chronologies. The critical review and modelling of existing radiocarbon dates for Vinča ceramics carried out by Whittle *et al.* (**2016**) together with the extensive radiocarbon dating and Bayesian modelling of Vinča Belo Brdo (**Tasić *et al.* 2015, 2016a, 2016b**) and Uivar (**Draşovean and Schier 2021**), as well as Belovode and Pločnik, were crucial (**Marić *et al.* 2021d**). According to these studies, Vinča A began in *c.* 5400/5300 BC, Vinča B in around 5200 BC with the most likely end date for Vinča B1 being *c.* 5000/4950 BC. This marks the beginning of the Gradac phase, which at Vinča Belo Brdo lasted 50–100 years, followed by Vinča

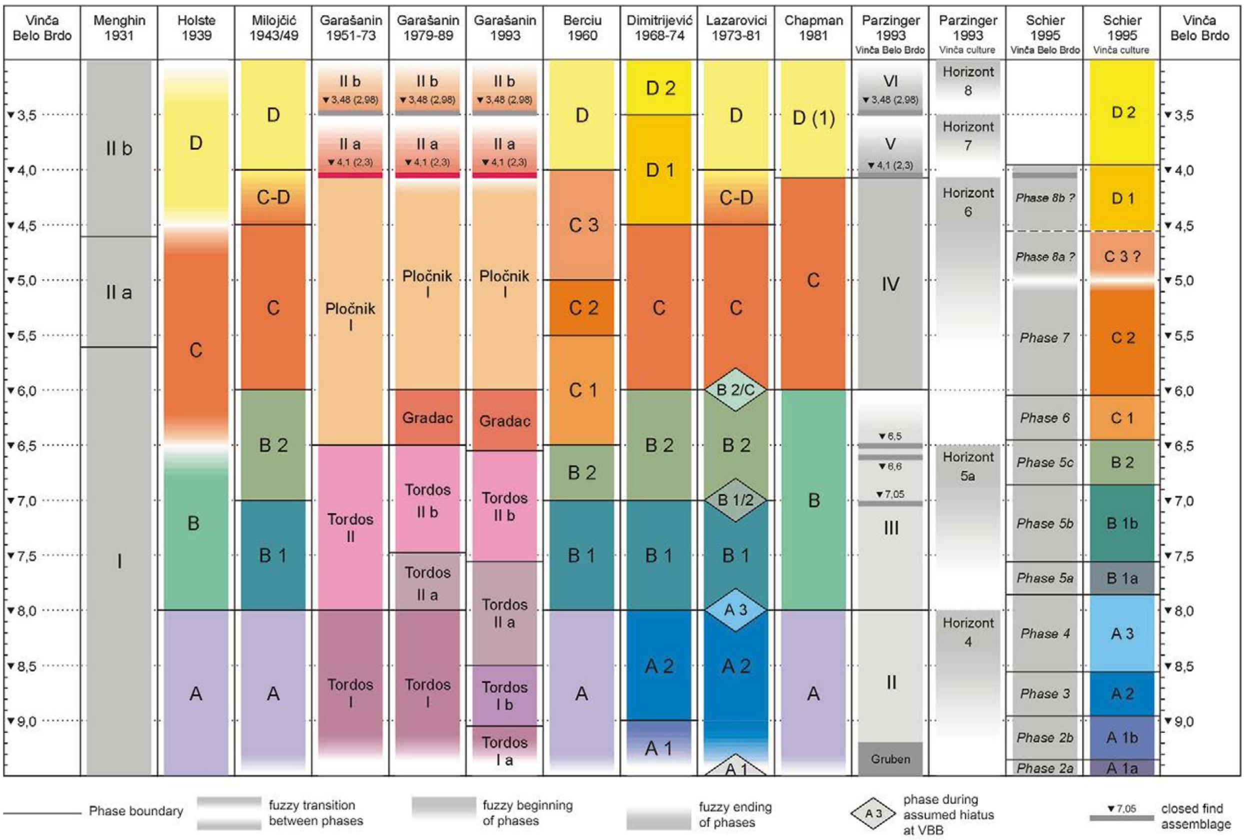


Figure 2.3. Overview of alternative typological schemes for Vinča ceramics (from Radivojević *et al.* 2021a: 40; after Schier 1996; Whittle *et al.* 2016: fig. 2).

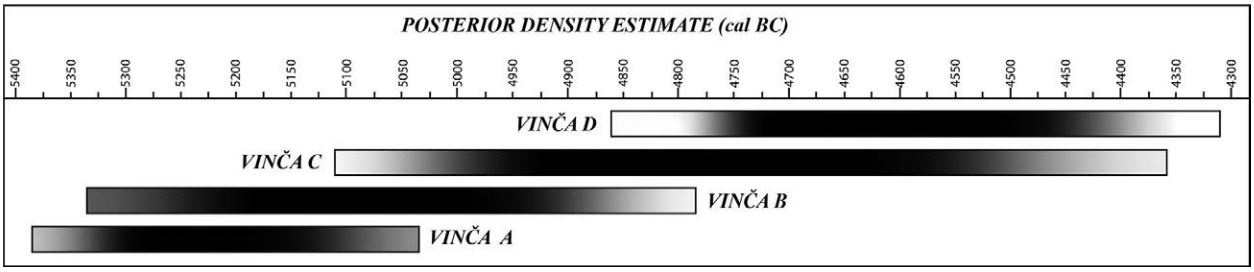


Figure 2.4. Schematic diagram showing the chronology of the different phases of Vinča ceramics proposed by Milojčić (1949). The darker the shading, the more probable that a ceramic phase was present in a particular 25-year period (derived from Model 1) (from Radivojević *et al.* 2021a: 42; after Whittle *et al.* 2016: fig. 37).

C which ended in *c.* 4850/4800 BC. The Vinča culture ended in around 4500 BC.

The Gradac phase and the appearance of metallurgy

One of the most remarkable phenomena within Vinča material culture development is the Gradac phase (*c.* 5000–4800 BC), first recognised in the stratigraphy of Vinča-Belo Brdo by Garašanin (**1973: 103, 1979: 152, 1990: 12–13**). In his detailed study of the Vinča culture's eponymous site, Garašanin established the existence of an interphase between early and late Vinča (between ▼6.5m and ▼6.1m), which corresponded to the transition between Vinča-Tordoš IIb (B2) and Vinča Pločnik I (C1). He also observed that this phase was especially evident in southern variants, whereas in the Danube valley the change was typologically unclear. Recognising the importance of the southern influence driving the transition, Garašanin named this phase after the site of Gradac in the vicinity of Leskovac in southern Serbia (**Garašanin 1990: 11–12**). The most distinctive elements of the Gradac phase are ceramic vessels with rounded shoulders and high, funnel-shaped necks (**Figure 2.5a**) and increasing numbers of vessels with thickened rims. These vessels usually have black to grey burnished/polished surfaces decorated with horizontal channels. Also typical of this phase are jugs with carinated or rounded profiles and a 'one-strap' handle, which joins the upper part of the neck and the shoulder without surmounting the rim (**Figure 2.5b–f**). This phase also sees the first appearance of graphite-decorated pottery (**Garašanin 1979: 174**). Other distinctive elements of the Gradac phase are Vidovdanka figurines (**Figure 2.5g**), voluptuously modelled, with polygonal faces and moulded eyes (**Jovanović 1994: 1, 2006: 222**) and stone altars decorated with deer or ram protomes and meander motifs (**Figure 2.5h**).

In the broader region, the Gradac phase is contemporary with several material culture phenomena such as Maliq I(a) (in Albania), Gradeshnitsa III A–B, Maritsa V (in Bulgaria), Hamagia III, Vidra - Boian III (in Bulgaria and Romania), Pre-Cucuteni (in Romania), Dikili Tash II, Paradimini IV, classic (late) Dhimini, and Sitagroi II (in Greece) (**Garašanin 1995: 15–16**). Gradac one-handled jugs are recorded as far as east Bulgaria (Durankulak) and on the Turkish Thracian coast in Toptepe (e.g. **Jovanović 2006**). Triangular altars with ram heads have been found in central Bulgaria and the Lower Danube area (**Gimbutas 1976: 88–89**).

The turning point in the understanding of the Gradac phase came when a Vinča culture copper mine was discovered in eastern Serbia at Rudna Glava near Majdanpek (**Jovanović 1982**). The discovery convinced Jovanović that this phase corresponded to the beginning of mining activities and consequently denoted the beginning of the use of metal by this culture. The common thread connecting the various material cultures mentioned above is the emergence of mining activity at Rudna Glava and Aibunar (Maritsa) and metallurgical activities that further developed in the Varna groups in eastern Bulgaria in the mid-5th millennium BC (**Jovanović 2006**).

Jovanović did, however, recognise that towards the end of the Vinča Pločnik I phase, important changes occurred in the south Morava area (**Garašanin 1979: 204**). In general, according to Jovanović, the developments corresponding to the appearance of the Gradac phase clearly denoted significant social changes at a time that he linked with the beginning of the Chalcolithic period in the Vinča culture and the Balkans (**Jovanović 1994**). On the other hand, Garašanin asserted that no significant changes in material culture, social relations or structures resulted from the appearance of metallurgy in the Gradac phase; in his view, the Vinča culture retained its Neolithic characteristics.

One aspect that is especially controversial is the extent of the influence exerted by the appearance of metal within the Vinča culture. It is therefore necessary to expand here on the periodisation of the Gradac phase as developed by Jovanović (**1994**). He divided this phase into three stages. Gradac I phase was recognised in the material found in layer V of Supska, Rudna Glava VI, in the VII horizon of Selevac, in the earlier horizons of Medvednjak, Predionica, and in Črnokalačka Bara. Gradac I was thereafter synchronised with Vinča B2/C1 (**Jovanović 1994**). Gradac II (Vinča C2, D1–2 i.e. Vinča-Pločnik I–IIb) was represented by the site of Divostin, the later horizon at Medvednjak, layers 3 and 4 at Supska and the final horizons at Predionica and Valač. Finally, Gradac III was associated with sites in the southern areas of the Vinča culture and with the Kosovo variant; in terms of relative chronology, this corresponded to the period in which the Danube (classic) variant ceased to exist. This periodisation was developed to explain the lack of pottery elements characteristic of the Gradac phase in the lower reaches of the Danube: Jovanović argued that these elements were missing because, according to his hypothesis, this was the first zone of disappearance of the Vinča phenomenon. This is supported by more recent radiocarbon dating as discussed below (**Roberts *et al.* 2021**).

Vinča settlement and subsistence

Vinča sites range between 1 and 35ha in size and are usually located on river terraces or plateaux, although settlements are also found on hill slopes near streams, and on waterlogged hillocks; examples of dominant hillfort settlements are very rare (**Garašanin 1979**). The settlements were built on a range of soils, varying from those ideal for agricultural activities, to those subject to seasonal flooding. Some sites, like Vinča Belo Brdo (**Vasić 1932–36**) or Gomolava (**Brukner 1988**), might be described as 'tell-types', typically having a prominent mound-like central area surrounded by thinner archaeological layers. However, most of the multi-layered sites, such as Pločnik (**Šljivar and Kuzmanović-Cvetković 1998a**) or Selevac (**Tringham and Krstić 1990**), appear to have expanded in a more horizontal fashion. Most of the settlements were established during the Vinča A–B1 period, but during the Gradac phase there was an increase in satellite settlements, as seen at Pločnik and Belovode (**Kuzmanović-Cvektović 1998; Šljivar and Jacanović 1996a**). A few sites, like Divostin (**McPherron and Srejović 1988**), existed only in the later Vinča culture sequence.

Evidence of settlements includes pit structures and wooden framed, wattle and daub houses grouped in larger settlements with longer durations of occupations. Structures and dwellings usually had a footprint of 10m^2; subsidiary structures with agricultural and

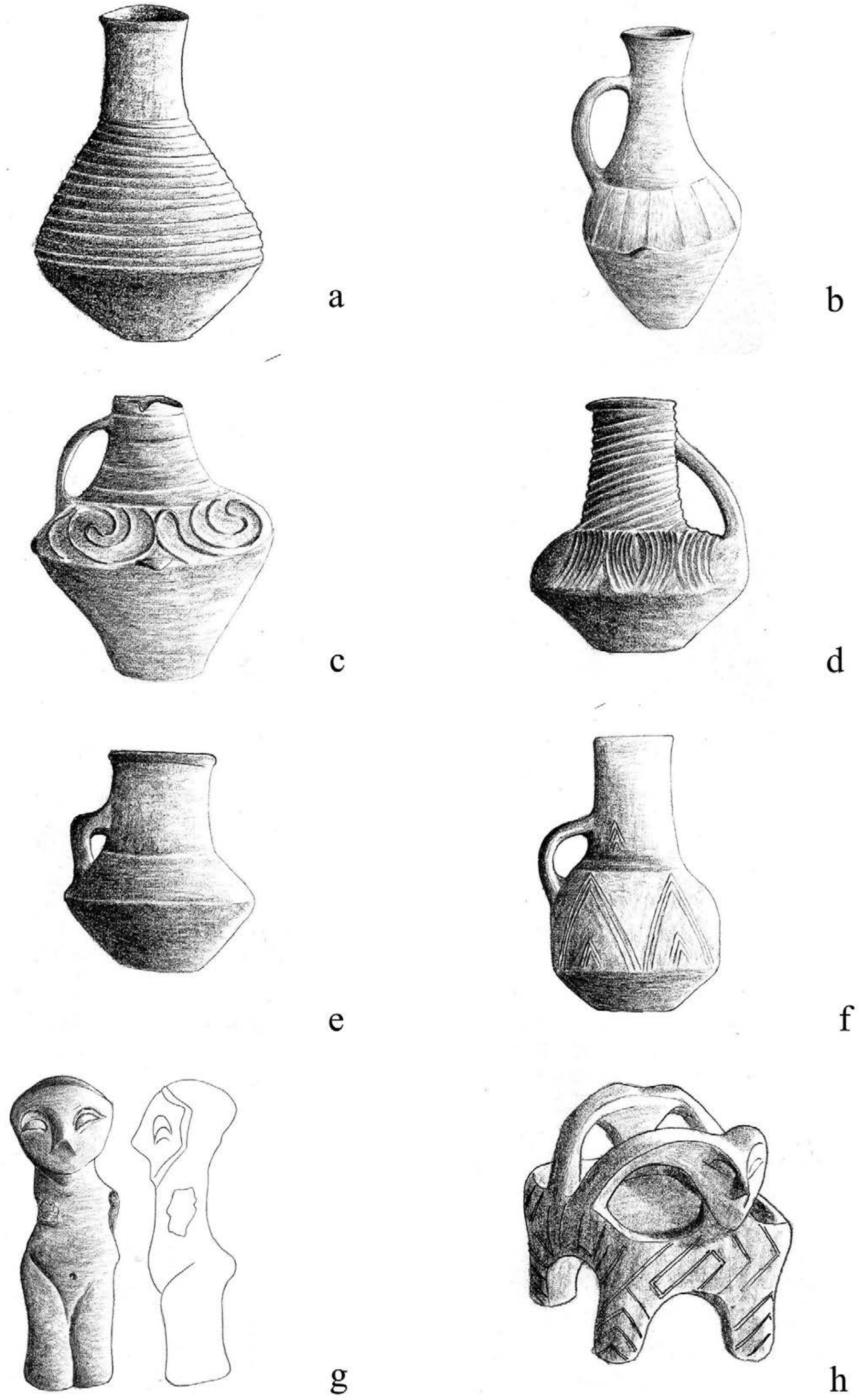


Figure 2.5. Elements of the Gradac phase: a) a vessel with a high funnel-shaped neck; b-f) jug with carinated or rounded profile; g) Vidovdanka figurine; h) altar with protomes and meander motives (modified after Jovanović 2006: figs. 2–8).

social functions were sometimes attached to the main building. Food preparation was normally conducted near ovens and silos, whilst crafts were carried out inside the structures or in their yards (**Chapman 1981: 63–68**). An increase in the size of structures over time can be observed at sites like Gomolova and Divostin, where the buildings could be multi-roomed and sometimes extended over 100m^2 (e.g. **Brukner 1988; McPherron and Srejović 1988**).

The Vinča culture communities were a farming society, with larger settlements such as Divostin, Belovode and Pločnik, and possibly Vinča-Belo Brdo, having populations of around 1000 people, but probably never more than about 2000 (**Porčić 2019**). They supplemented farming and herding activities with hunting and the procurement of plants. Domesticated crops included einkorn, emmer, barley, lentil, pea and flax/linseed (**Filipović 2021**). Wild animals still played an important dietary role, but herded cattle, pigs, sheep, and goats became increasingly important (**Orton *et al.* 2021**). The possession of cattle probably became an expression of wealth, symbolised in forms of *bucrania* displayed in houses (**Orton 2008**). Salt also played an important role in these societies. It has been noted that the settling of the Starčevo groups may have been related to the location of soils rich in salt or the presence of saline (**Tasić 2000**). The Vinča site of Gornja Tuzla, in Bosnia, was very likely connected to the presence of salt. A series of conical elongated vessels, which date to the Vinča phase at this site, may relate to the retrieval of salt (**Benac 1961: 50**). Similar vessels are found on other sites along the Sava River, and even in the Lower Danube area, where they are associated with the Late Neolithic Boian culture (**Milojčić 1949: pl. 23, 8**). Secure evidence for salt exploitation has also been recovered at the sites of Lunca-Poiana Slatini and Provadija Solnicata (**Dumitroaia 1987: 253; Nikolov 2010**).

Burial practice and the afterlife

Burial evidence is extremely rare. Apart from a few sporadic finds from Vinča, Potporanj (**Garašanin 1979**), Parţa (**Lazarovici *et al.* 2001**) and Belovode (**Šljivar *et al.* 2006**), only two cemeteries containing a total of 63 individuals have been discovered. The earliest, belonging to the phase of Vinča B1, was located at Botoš in Vojvodina; the other, dated to Vinča D2, was excavated in Gomolava in northern Serbia. Analysis of these burials highlighted variations in the goods given to the dead, probably related to gender differentiation (e.g. **Grbić 1934; Stefanović 2008**).

Physical anthropological studies have shown no elements suggesting a Near Eastern origin for the individuals found in Gomolava (**Živanović 1977; Zoffman 1987, 1988: 96**). In addition, analysis carried out by Stefanović **(2008)** found that all the individuals were male and included both adults and sub-adults with possible signs of a kinship relationship. Hierarchical differences were highlighted by distinctions in the wealth of goods, some richer graves being endowed with copper jewellery. The degree of wealth exhibited was unrelated to the age of the individuals. A malachite bead necklace found in one child's burial led to the hypothesis that, in Vinča society, prestige was gained by birth rather than by age.

Material culture

The material culture of the Vinča sites is characterised by a great abundance of pottery, in a huge variety of shapes and decorative styles. Also frequently present are chipped stones, large stone tools, figurines, copper artefacts and other precious materials, all of which exhibit the wealth of the occupants of these villages.

Pottery has always played a very significant role in studies of the Vinča culture, both because the chronology of the phenomenon was initially established from ceramic typology and because hypotheses regarding its origin were based on ceramic typological parallels. Vinča pottery reflects a combination of different traditions; the incised band decoration is related to the Linearbandkeramik (LBK) and the Moldavian-Ukranian complex; the dark-burnished ware is linked to a general Anatolian-Balkan tradition; and the impressed and barbotine decoration is derived from the local Starčevo culture (**Chapman 1981: 53; Garašanin 1951: 63; Milojčić 1949: 106**). Despite the appearance of new vessel types, some ceramic styles found in the early sequences of Vinča culture sites (e.g. Vinča-Belo Brdo)—such as coarse ware with impressed and incised barbotine decoration or painted wares—still retain links with the Starčevo material culture (**Chapman 1981, Leković 1990**). In early Vinča phases (A–B1), vessel shapes are dominated by biconical bowls that sometimes show pedestals and are decorated with shallow channels or incised decorations, such as ribbons (**Figure 2.6**).

Another important pottery phenomenon in the early Vinča period is the emergence of dark-burnished ware (**Figure 2.6**) which appears in a variety of shades and patterns (e.g. black polished and black-topped). To achieve this effect the pottery is fired in a reducing atmosphere. The use of this technique was widespread throughout an area extending from the central Balkans to Anatolia during the Late Neolithic/Chalcolithic period. This fact inspired the previously mentioned 'diffusionist model', which was used to explain the origin of the Vinča culture (**Garašanin 1954**). The model (which, until recently, dominated the debate),

Figure 2.6. Vinča culture pottery: a) amphora decorated with incised ribbon; b) shallow channelled amphora; c) black polished three-legged bowl; d) black-topped 'fruit stand' (modified from Radivojević *et al.* 2021a: 41; after Nikolić 2008: Cat. 261, 264, 176, 166).

maintains that the dark-burnished ware traditions of Yugoslavia, Greece and Anatolia are the result of various similar conditions (economic, environmental, cultural, and chronological) in the Late Neolithic 'Balkan Anatolian' complex, which later became a core region for the transmission of innovations to peripheral regions.

Dark-burnished pottery was the first ceramic class to become extensively distributed from the Peloponnese to Northern Greece; it has been termed a 'koine' of Late Neolithic Greece (**Demoule and Perlès 1993: 392**). Some scholars think that Late Neolithic dark-burnished ware evolved in Greece (**Bonga 2013: 13; Childe 1936/1937: 29, 8**), being an indigenous development with no link to the northern Balkan Neolithic. Childe argued that dark-burnished pottery already occurred in Early Neolithic Corinth. Kunze (**1931: 30**) supported the theory of a local, indigenous development of dark-burnished wares in Greece but noted that certain elements like channels, and the presence of biconical shapes with button-shaped feet, and black-topped vessels, show strong parallels with Vinča or Karanovo style pottery. Özdoğan (**1993: 179, 1999**) maintained the hypothesis of a common zone of development lying between the Balkans and Anatolia. More recently, Chapman has argued that dark-burnished wares could have evolved independently in the Balkans (**Chapman 2006**). This type of pottery is one of the main characteristics of Vinča material culture and is found from its earliest appearance, *c.* 5350 BC; its colour and brightness fit well with the Neolithic Balkan visual identity, which is based on striking and dark colours (**Chapman 2006, 2007; Radivojević and Rehren 2016**). The debate remains open and further research is necessary to understand where this phenomenon first appeared and in which direction(s) the influence spread.

Recent studies (**Amicone *et al.* 2020a**) show that the distinctive black or dark grey decoration of the Balkan dark-burnished pottery could have been produced by the carbon black technique as previously suggested by Letsch and Noll (**1978**). Other methods to achieve a black colouration, such as iron reduction (**Cuomo di Caprio 2007: 121; Jones 1986: 762; Maritan 2004; Noll 1991: 121**) and the application of manganese-rich mineral phases such as pyrolusite (**Jones 1986: 762; Noll 1991: 140; Spataro 2019a**) can be ruled out for the present.

Carbon black is typically produced by adding organic material and firing under reducing conditions, resulting in the formation of a layer of charcoal or soot (**Jones 1986: 763–764; Letsch and Noll 1978, 1983; Noll 1991: 175**). A typical method involves 'smudging' (**Jones 1986: 763–764**), i.e., the deposition of carbon on the surface of the vessel and within open pores during the firing process. This is achieved, for example, by smothering the pots with fine-textured fuel at the end of the firing. The coating is composed of a very fine crystalline or amorphous carbon (**Jones 1986: 763**) producing a shiny 'Glanzkohlenstoff' (lustrous carbon) finish (**Letsch and Noll 1978, 1983**). Significant technological skill is required to produce carbon black as timing is crucial and it is essential to maintain reducing conditions to prevent the coating being burnt off.

As mentioned above, within the Vinča material culture, dark-burnished pottery is sometimes associated with graphite decoration, which first appears during the Gradac phase (**Perić 2006: 238**). Graphite is a crystalline form of carbon that occurs naturally in highly metamorphic rocks such as marble, schist, and especially gneiss. It was ground to a fine powder, mixed with water and perhaps clay, then applied, often onto a burnished surface. The reduction during the firing had to be well controlled to preserve the graphite layer (**Kreiter *et al.* 2014**).

It has been suggested that the use of graphite decoration on pottery was closely related to the emergence of early metal production. The light-reflective qualities of graphite produce a metallic sheen that may have been aesthetically appealing to prehistoric communities (**Todorova 1981**). Further, acquisition of graphite would have required participation in specialist trade networks comparable to those involved in copper exploitation (e.g. **Leshtakov 2005; Radivojević and Grujić 2018**). Another proposed link is that the high temperatures necessary for copper metallurgy (around and exceeding 1100ºC) would also have been required to produce graphite-painted pottery (**Renfrew 1969**). This theory will be further discussed in the light of the new results presented in this book and studies recently published by **Amicone *et al.* (2020a, 2021a**)

Figurines are another material form of expression typical of the Vinča culture (**Figure 2.5g**). The general shape of the figurines' faces varies throughout the different periods (**Garašanin 1979; Gimbutas 1982; Hansen 2007; Kuzmanović-Cvetković 2021**). In the early phases, they have triangular or flattened faces; in the Gradac phase they are polygonal, with more realistic bodies often depicted in various poses or seated; and in the later phase they are more schematic, with few details. The Gradac to Vinča C phase (Gradac to Vinča Pločnik) saw the greatest creativity and quality in the production of figurines (**Tasić 2008**). The function of these figurines is unclear. Some scholars interpret them as offerings for deities (**Gimbutas 1982**), others see them as symbols of fertility (**Letica 1964**). It is interesting that some zoomorphic figurines bear children's and adults' fingerprints, suggesting their use as toys and reflecting the collaborative interplay between generations, with childhood playing a key role in shaping traditions and skills (**Balj 2017**).

Vinča material culture also encompasses a rich lithic industry, including ground and chipped stone tools (**Dimić and Antonović 2021; Ibragimova 2021**). Various raw materials were employed, including abrasive magnesite stones. Antonović (**2003**) argues that the lithic industry may have been devalued after the adoption of metal during the Gradac phase. The use of obsidian from Carpathian sources (**Tripković and Milić 2008**) and of Spondylus shells to produce jewellery are also well attested as outstanding achievements of the Vinča craftspeople. The production of ritual objects in the form of figurines, prestige items made from precious materials, and the use of fine ceramics may have had a social and symbolic meaning in these communities, as their occurrence has generally been observed more often on larger sites with longer occupations (**Chapman 1981: 68–71**).

Metal is, of course, another important element that appeared during the development of the Vinča culture. Malachite beads and copper minerals have been found on several sites from the earliest Vinča phases. These have been recovered in domestic contexts from Belovode, Pločnik, Fafos II, Grivac, and Opovo (**Antonović 2006; Radivojević and Kuzmanović-Cvetković 2014**) as well as in burial contexts, such as among the grave goods at Gomolava (**Brukner 1980**).

Malachite was initially used in its natural form to produce beads and jewellery. Unequivocal evidence for intentional metallurgical activity is rare. Small pieces of possible slags are reported from Selevac, Vinča, Gornja Tuzla, Anzabegovo VI, and Stapari (**Glumac and Todd 1991**). The samples from Selevac have been analysed and definitely show the presence of copper prills. A study carried out by Radivojević on slag samples from Belovode (**Radivojević *et al.* 2010**) provides the earliest direct evidence for copper smelting at this date (*c.* 5000 BC), contributing significantly to the understanding of Vinča metallurgical activities. Evidence for metallurgical installations is so far unconfirmed, but the recovery, at Gornja Tuzla, of three hearths lined with fragments of ceramic is noteworthy. Metal droplets and copper artefacts found on the same site have also been related to smelting activity (**Radivojević and Rehren 2016**). Ultimately, the copper artefacts themselves are the clearest evidence of metallurgical craftsmanship within the Vinča culture. Among those known so far are four assemblages comprising a total of 34 artefacts, found at Pločnik (**Grbić 1929; Šljivar 1999; Stalio 1960, 1962, 1964**). These include copper hammer-axes, whose type has been named after the site (**Radivojević 2006; Schubert 1965; Todorova 1981**). Initially these objects were connected to the Chalcolithic Bubanj-Hum phenomenon which, according to the traditional interpretation, followed the collapse of the Vinča culture (e.g. **Srejović 1988**). More recent excavations provide evidence for well-contextualised chisels that are identical to those found in the Pločnik hoards already present in the Gradac phase. This suggests that the chronological and cultural attribution of the 34 metal implements found at Pločnik should also be attributed to the Gradac phase of the Vinča phenomenon (e.g. **Šljivar 1996; Šljivar *et al.* 2006**).

Overall, the analytical research carried out on copper minerals and metallurgical materials from the sites of Belovode and Pločnik, including the analysis carried out on the evidence from the most recent set of excavations (2012 and 2013), has shown specific aspects that characterise the metallurgical activities at both sites. These include the persistent selection of black and green manganese-rich copper ores for metal extraction as well as similar engineering parameters involved in the early smelting technology (**Radivojević 2013, 2015; Radivojević and Rehren 2016; Radivojević *et al.* 2010, 2021b**).

When considered in the context of the wider Balkans, detailed analysis of the technology and provenance of the metallurgical evidence from Belovode and Pločnik reveals a connectivity across the Vinča culture with trade and exchange along the known communication routes, such as the Lower Danube. Shared access to copper sources and knowledge of metal making created a wide and complex network of interactions between metal producing and consuming communities in modern day Bosnia, Serbia, and Bulgaria (**Radivojević *et al.* 2021b**).

The end of the Vinča culture

The mid-5th millennium BC is characterised by the development of new cultural phenomena (**Todorova 1995: 87–88**). This period led to the rise of two large cultural complexes in the central Balkans: Kodžadermen-Gumelniţa-Karanovo VI (KGK VI) and Krivodol-Salcuţa-Bubanj Hum I–III (KSBH) (**Boyadžiev 1995: 170–171; Hansen *et al.* 2008: fig. 86; Lazarovici 2006: 282**). This is also the period of the Varna culture, with the eponymous cemetery dated to *c.* 4560–4450 BC (**Ehrich and Bankoff 1992: 344; Reingruber and Thissen 2009: 764**). The KGV VI complex extends over a geographical area that includes modern Muntenia, north-eastern Bulgaria and northern Thrace. The KSBH is found in Oltenia, eastern and western Serbia, western Bulgaria and the lower Strymon valley, whilst Varna covers Dobrudja along the western Black Sea coast. The development of these material culture phenomena was probably driven by metallurgical activities. Chernykh (**1978: 119–125**) suggests that each culture had its own production centres, characterised by different types of objects. The copper bearing culture of Tiszaplogár, dated to *c.* 4500–4000 BC, emerged during the same period (**Kalicz 2002: 388**; **Lazarovici 2006: 280**); to the east, the Cucuteni A–Tripolye B1–Ariuşd complex (**Lazarovici 2006: 281**) shows very strong links with the Varna culture (**Todorova 1995: 89**).

The nature of the transition from the Early to Middle Chalcolithic in the Balkans—and therefore the appearance of the complexes mentioned above—remains a subject of debate and has received insufficient attention. Several theoretical approaches have influenced the interpretation of this transitional period. The increasing number of excavated sites and the employment of absolute dating are currently reshaping understanding. It is not possible to examine here the detailed character of this cultural change, but the following observations focusing on the Vinča culture are included, both because this phenomenon is at the core of the research presented here, and because this culture played such an important role in the northern and central Balkans.

Between the 1960s and the 1990s, Hungarian and Serbian scholars developed traditional interpretations of the end of the Vinča culture, rooted in the culture-historical approach (e.g. **Bognár-Kutzián 1963, 1972; Jovanović 1994; Tasić 1979**). According to these narratives, changes were the result of external stimuli from a newly developed Middle Chalcolithic cultural phenomenon, defined as the Proto-Tiszapolgár or Tiszapolgár groups, later followed by the Middle/Late Chalcolithic Bodrogkeresztúr group, identified based on new pottery shapes. The arrival of the latter group coincided with the proliferation of decorative tools and copper items. The Tisza River was regarded as their spatial centre. According to Jovanović (**1994**), the Tiszapologár groups later spread gradually southwards, replacing established Vinča groups in the region. In this context, he also hypothesises a greater persistence of Vinča sites in present-day southern Serbia. By contrast, Garašanin (**1973**) and Srejović (**1988**) argued that the Vinča groups in the southern Morava valley and in other southern areas disappeared before the groups of the classical Vinča variant, under the influence of the Bubanj-Sălcuţa-Krivodol complex. Irrespective of the opinions regarding the first area to be affected by the supposed movements of Middle Chalcolithic groups in the Vinča territory, at the core of culture history interpretations was a 'catastrophic' view of the end of Vinča society. This was further supported by the extensive presence of burnt building horizons in almost all recovered Vinča sites (**Tasić 1995**).

Alternative interpretations were first developed in the late 1970s when members of the Anglophone schools, such as Ruth Tringham (**1992)** and John Chapman (**1981**), started to work on the Balkan Neolithic. Influenced by processual and postprocessual approaches, their interpretation of the end of the Vinča culture was based largely on internal developments rather than possible external events; they suggested that the end of this phenomenon could have been connected to the long-term internal social dynamics of continuous transformations (**Tringham 1992: 135**). According to Tringham's model, Vinča settlements were organised as autonomous households, but when population growth reached the limit of the carrying capacity of settlement territories, new solutions were necessary. This situation triggered disintegrative processes that brought about a schism, with some members of the community leaving to create new settlements situated in the lowlands, or in a variety of other landscapes, regardless of their agricultural potential. Animals were exploited in new ways, with an increasing dependence on secondary products and hunted game. Tringham (**1992**) also hypothesised that this division led to the establishment of contacts over larger areas, thus favouring change and innovation triggered by exchange with neighbouring groups. These changes led to the nucleated tell settlement pattern being replaced by a dispersed distribution of lowland sites. It should be noted, however, that the evidence of burnt houses observed in many Vinča culture settlements is now interpreted as a form of ritual, in which the process of burning closes the life cycle of a household (**Chapman 1999; Stevanović 1997; Tringham 1991**; see below).

John Chapman is also the main advocate of a third interpretation for the end of the Vinča culture, which is connected to post-processual narratives. In his view, the Late Neolithic/Early Chalcolithic society was characterised by closely-knit communities with solid social networks, whereas the following period shifted towards a household-based society. He also proposes, for example, that the dispersed farmsteads of the Middle Chalcolithic were connected by regional networks based on exogamous breeding (**Chapman 2000: 75**).

Increased use of radiocarbon dating has contributed new insights to the debate about the end of the Vinča culture. Until recently, published evidence suggested that the culture flourished between 5400 and 4650/4550 cal. BC (**Borić 2009; Orton 2012**). Most sites seem to end around the 47th century BC but a few, including Vinča-Belo Brdo and Selevac, were probably occupied until the end of 46th century BC. New radiocarbon results now suggest that, at least in its southern development, Vinča material culture lasted at least 200 more years (**Marić *et al.* 2021d**).

Dating studies indicate that many of the sites attributed to the Vinča culture ended broadly contemporaneously, possibly earlier than previously thought. This has very important consequences for understanding the mechanisms that led to the transition between the Late Neolithic and the Chalcolithic periods. Narratives elaborated by culture historians suggest that Vinča culture communities were gradually replaced from north to south by Tiszapolgár groups (e.g. **Jovanović 1994**). If, however, the end of the occupation of several sites was largely concurrent, this argument fails unless the conquest rapidly spanned the whole area. Significantly, radiocarbon dating of material from Vinča-Belo Brdo suggests that the site was abandoned *before* the arrival of Tiszapolgár groups. A small group of Tiszapolgár inhumation burials dates to the Early and Middle Chalcolithic (**Tasić 1995**), indicating that 200–350 years elapsed between the final phase of the settlement and the burial event (**Borić 2015: 177**).

Other arguments raised by culture historians to sustain the catastrophic end of Vinča communities also no longer seem plausible. As highlighted above, the presence of burnt houses was used by culture historians to argue for a violent end for many settlements. An alternative account now views the activity as intentional and connected to the end of the life cycle of the house and thus permeated with a strongly symbolic meaning (**Chapman 1999; Stevanović 1997; Tringham 1991**). In addition, evidence of house burnings in earlier parts of the stratigraphic sequence at Vinča-Belo Brdo suggests that this practice was performed throughout the Late Neolithic, perhaps with a practical purpose: when a new house was needed, the old one was burnt and the area levelled to prepare the surface for the construction of the new building. Whatever the ideological meaning of this activity, some kind of norm must have regulated the practice because structures were very often packed closely together, making burning events potentially hazardous. Some form of social consensus/control would have been required. Taking these considerations into account, the hypothesis of a catastrophic fire caused by invaders destroying multiple Vinča culture sites between the 47th and the 46th BC seems less likely.

The presence of fortification features is also an unconvincing argument for a catastrophic end to these communities. Such structures could reflect the need to mark clear boundaries and perhaps had purely practical purposes (e.g. agriculture, herding), in addition to providing defence against possible invaders. Finally, even if the evidence from cemeteries is scant, the burials at Gomolava which, according to radiocarbon dating are correlated to the last phase of this settlement, do not exhibit any clear traces of violence on the bodies (**Zoffman 1987**). It should be stressed, however, that we cannot draw general conclusions on the basis of this single necropolis.

If we try to understand the end of the Vinča culture phenomenon by looking at the broader region, it immediately becomes clear that evidence for Early/Middle Chalcolithic occupation in south-eastern Europe remains limited. Only a few absolute dates are available, but the data so far does seem to suggest that the 45th century BC was a crucial period for the development of Chalcolithic sites and represented a clear cultural break. Nevertheless, some continuity with preceding periods is attested, although a variety of new shapes, styles and decorations enters the ceramic repertoire. The dramatic changes that affect various parts of Southeast Europe are expressed in different ways across the wider region. In the eastern Carpathian Basin and the northern/central Balkans, evidence can be seen in the transformation of settlement types, such as the replacement of tell sites by dwellings with a more dispersed distribution, normally located on hilltops. In this period, large cemeteries become common in the eastern Balkans (e.g. Varna, Durankulak), the eastern Carpathian Basin and in Transdanubia (**Borić 2015: 18**). Finally, this phase witnessed important developments within the networks for the exchange of raw materials, and metallurgical activity increased considerably.

The radiocarbon data, together with the more nuanced interpretations of the archaeological evidence (e.g. burnt houses, fortification etc.) provided by processual and post-processual narratives, has contributed to a substantially remodelled vision of the transition from the Neolithic to the Chalcolithic, which no longer explains the end of the Vinča culture solely as the outcome of external stimuli. The new evidence and absolute dates remain very limited, however, and although the majority of the Vinča settlements seem to end in the 46th century BC, it is not possible to exclude late survivals of Vinča material culture traditions that might be contemporaneous with the new settlements of the Middle Chalcolithic. For example, the new radiocarbon dates at Pločnik, obtained within the framework of the AHRC 'RoME' project, suggest occupation of this Vinča site ended in 4400 BC, providing the first evidence of possible contemporaneity between Vinča and Bubanj types of settlements (**Marić *et al.* 2021d**).

At the same time, in western Serbia pottery assemblages from the Chalcolithic site of Bodnijk, near Koceljeva, suggest both the continuity and discontinuity of the preceding Vinča traditions and might illustrate possible contemporaneity between late Vinča culture in the south of Serbia and the emerging BSK communities (**Palavestra *et al.* 1993, 1996**). This site is a single-layered settlement located on a hilltop near the town of Koceljeva. It was researched over several campaigns in the mid-1990s giving evidence of two rectangular burnt daub structures with chipped stones that shows a clear break from the previous tradition. Nevertheless, pottery material typical of early BSK complex also exhibits strong elements of continuity with Vinča pottery styles. The site is particularly important since the radiocarbon analysis places it around the middle of the 5th millennium BC. More precisely, the sample submitted for AMS dating (OxA-26309, 5579BP, +/-35) was calibrated to 4466–4347 cal. BC at 95% probability, or 4448–4369 cal. BC at 68.3% probability (**Živanović 2013: 54**). This value overlaps with the modelled values obtained from dates for the end of Horizon 1 in trench 24 at Pločnik (**Marić *et al.* 2021d**), strongly indicating the contemporaneity of late Vinča and early BSK communities in the central Balkans. Also in central Serbia, the repertoire of pottery forms in the early Chalcolithic phases at Blagotin (**Stanković and Redžić 1996**) suggests some continuity between the late Vinča and Bubanj pottery styles, similar to that observed in Bodnjik in western Serbia, but radiocarbon dating would be necessary to confirm the exact chronology.

On the other hand, a set of early radiocarbon dates similar to those for Bodnjik was obtained in northeast Bulgaria, at the site of Lîga (about 180km northeast of Pločnik). This site is located 1km north of the modern village of Telish in the Cherven Briag municipality of Bulgaria (**Merkyte 2005: 9**). Of its three horizons, two (Liga 2 and 3) could be correlated to the Bubanj-Hum Ia phase (**Merkyte 2005: 16, fig. I.5**) in Serbia. In this context it is interesting to notice that the modelled highest posterior density for the start of Lîga 2 is

4837–4357 cal. BC (95% prob.) or 4566–4386 cal. BC (68% prob.), placing it safely in the very late Vinča D2 period. This period is associated with the conflagration of Danubian late Vinča sites. Additionally, the end of this horizon indicates that occupation of the Lîga 2 settlement extends well into the 44th century BC. The results clearly indicate that the Middle Chalcolithic Lîga 2 horizon existed in parallel to the final phase of Late Neolithic occupation at Pločnik, further corroborating the possibility of contact between the two communities.

The above examples suggest that the transition from the Late Neolithic to the Early Chalcolithic in the central Balkans was a complex process that cannot be reduced to a simple population replacement caused by the invasion of external groups, which perhaps explains why earlier culture history narratives were unable to provide a comprehensive account of the phenomenon. Borić **(2015)** suggests the application of Shennan's model (**1989, 2000, 2013**), which proposes that material culture changes may be related to population dynamics, with shrinkage of populations affecting the cultural transmission process. If we see the abandonment of Vinča culture sites and the subsequent rise of smaller dispersed settlements as evidence for a decline in population, this would also reduce the number of people involved in learning, compromising the transmission of knowledge and traditions, and perhaps leading to the creation of a new material culture. This interpretation contrasts directly with the theory formulated by Tringham, who postulated a schism within the Vinča communities triggered by population growth, however this hypothesis is not supported by the current archaeological evidence so the nature of the breakdown of the Vinča material culture, which thrived for almost 1000 years, remains obscure. Only future micro-regional surveys and excavations, and an extensive programme of radiocarbon analysis hold the potential to shed new light on this unresolved problem.

Summary

The 5th millennium in the Balkans was a very dynamic period marked by the emergence and collapse of various material culture phenomena. These were characterised by a very rich and complex material expression and showcased by the variety of pottery styles. Significantly, this was also the period during which metallurgy was adopted. The archaeological review provided in this chapter demonstrates that the area where the Vinča culture flourished was a core region of technological development, from which metallurgy finally spread all over the European continent. The presence of abundant copper deposits was crucial but advances in pottery production and decoration were also critical for the development of this metal-producing culture. In particular, dark-burnished ware and graphite decoration required techniques similar to those necessary to smelt copper (e.g. **Gimbutas 1976; Renfrew 1969**) but, as shown above, this theory is not yet sufficiently supported scientifically, via comparative technological analyses of both pottery and metal production processes.

As we have seen, both the origins and demise of Vinča culture remain elusive. The exclusively chrono-typological approach to pottery research, that has traditionally dominated central Balkan prehistory, may have been a major obstacle to the understanding of pottery as an expression of more complex and socially entangled phenomena. The chrono-typologies established by scholars in previous decades are undoubtedly valuable. Indeed, they still constitute an important framework. But they do not, alone, help to elucidate important aspects, such as the establishment, transmission and disappearance of pottery making traditions that are crucial for the understanding of material culture developments and social changes in one of the most dynamic periods of European prehistory.

Chapter 3
Environment and archaeology of the studied sites

In this chapter, aspects of the environment, geology and history of the archaeological sites of Belovode and Pločnik (**Figure 3.1**) derived from previous archaeological research will be presented and the archaeological contexts from which ceramic samples were collected will be discussed. Since the focus of this study was the material retrieved from trenches recently excavated within the framework of the AHRC 'RoME' project, these contexts will be covered in greater detail.

The new trenches excavated during the project were investigated with a rigorous stratigraphic method and documented digitally with GIS software (**Marić *et al.* 2021a**). Pottery retrieved during the excavation was processed by a team of experts. Special finds (metal, malachite beads, copper minerals, figurines, loom weights, stone tools, obsidian, chipped stones, and bone tools) were recorded individually on site, their position being measured with an electronic distance meter; they were later processed separately from the pottery. Wet sieving was also conducted to find smaller fragments of metal and other remains (e.g. copper minerals). Environmental samples and animal bones were also collected for study. In addition, 37 samples (20 from trench 18 at Belovode and 17 from trench 24 at Pločnik) were taken for AMS radiocarbon dating analysis. A full account of the excavations methods results, and the

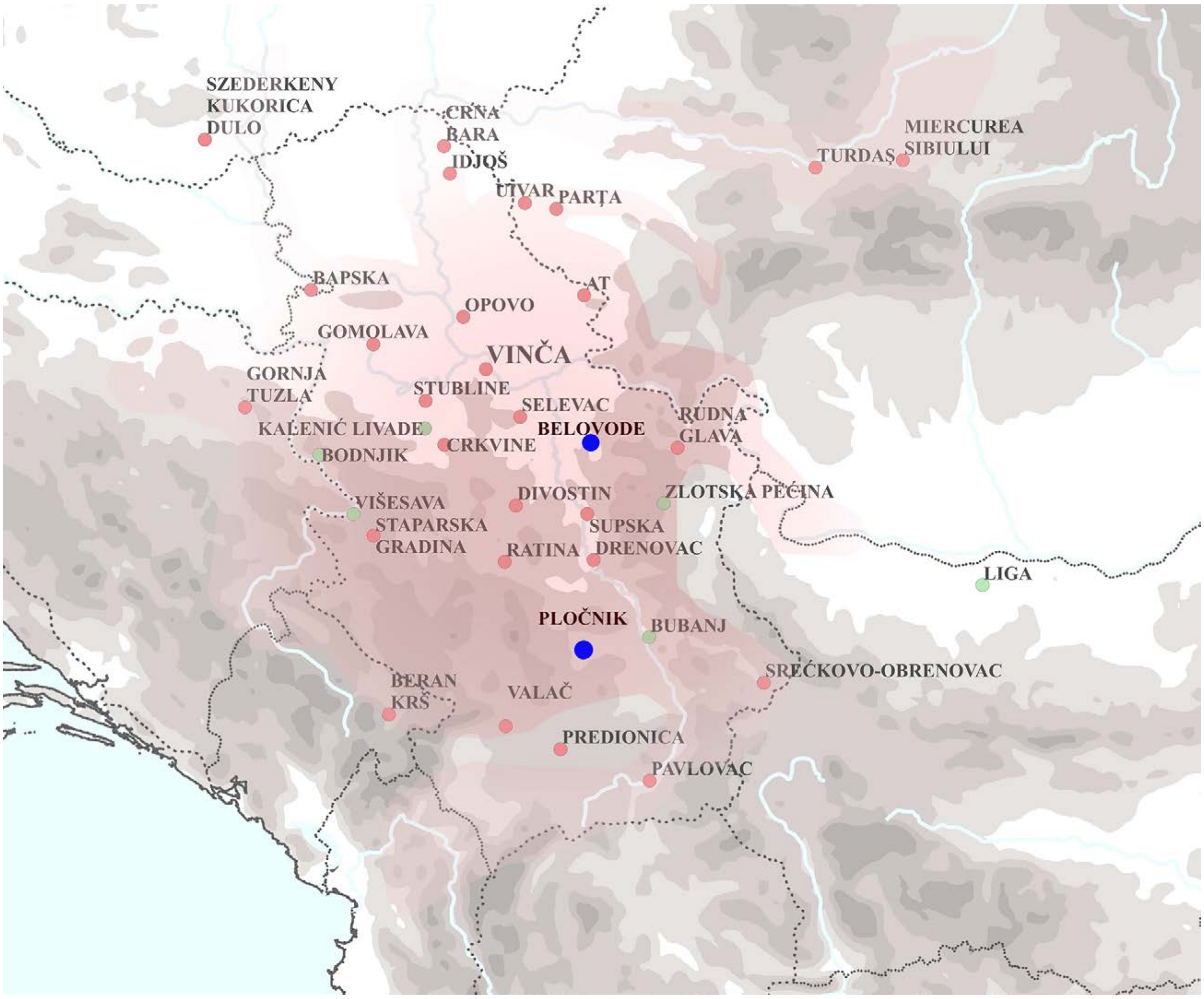


Figure 3.1. The distribution of the Vinča culture (shaded) with Vinča sites (red dots), Belovode and Pločnick (blue dots) and later Middle Chalcolithic settlements (green dots) (from Radivojević *et al.* 2021a: 39; prepared by J. Pendić and M. Marić).

specialist investigations can be found in the project monograph (**Radivojević *et al.* 2021a**).

Belovode

Introduction to the environment and geology

Belovode is situated on a plateau close to Veliko Laole, around 140km southeast of Belgrade (**Figure 3.1**) and 10km southwest of Petrovac na Mlavi. The settlement is strategically placed between two small water courses that emerge as springs about 1km away and join with the larger Busur River near the settlement. Water action has formed a plateau, approximately 600 × 200m in size, with three steep edges that drop abruptly towards the two streams and the Busur River respectively. The plateau consists of podzolised cambisol, whilst the Busur valley is characterised by alluvial-diluvial soil (**Marić 2021a**). The high level of fertility provided by the cambisol soil in combination with alluvial soils to the west of the site ensured excellent yields of grain and other crops at Belovode.

Belovode lies on the western margin of the Serbo-Macedonian composite unit (SMM), a belt stretching north to south along the Great and South Morava valleys into the west of the Republic of North Macedonia and northern Greece (**Robertson *et al.* 2009**). The SMM is one of five geotectonic units into which Serbia can be divided, distinguished from east to west (**Figure 3.2**) as follows: the East Serbian Carphato Balkanides (CBES); the above-mentioned Serbo-Macedonian Massive (SMM); the Vadar Zone Ophiolite Belt (VZOB); the Diniaric Ophiolitic Belt (DOB); and furthest to the west, units of the external Dinarides. The SMM is comprised of a variety of medium to relatively high-grade metamorphic rocks.

Belovode lies within the Kupinovačka Glavica–Busur area, in the upper complex of the SMM (**Dimitrijević

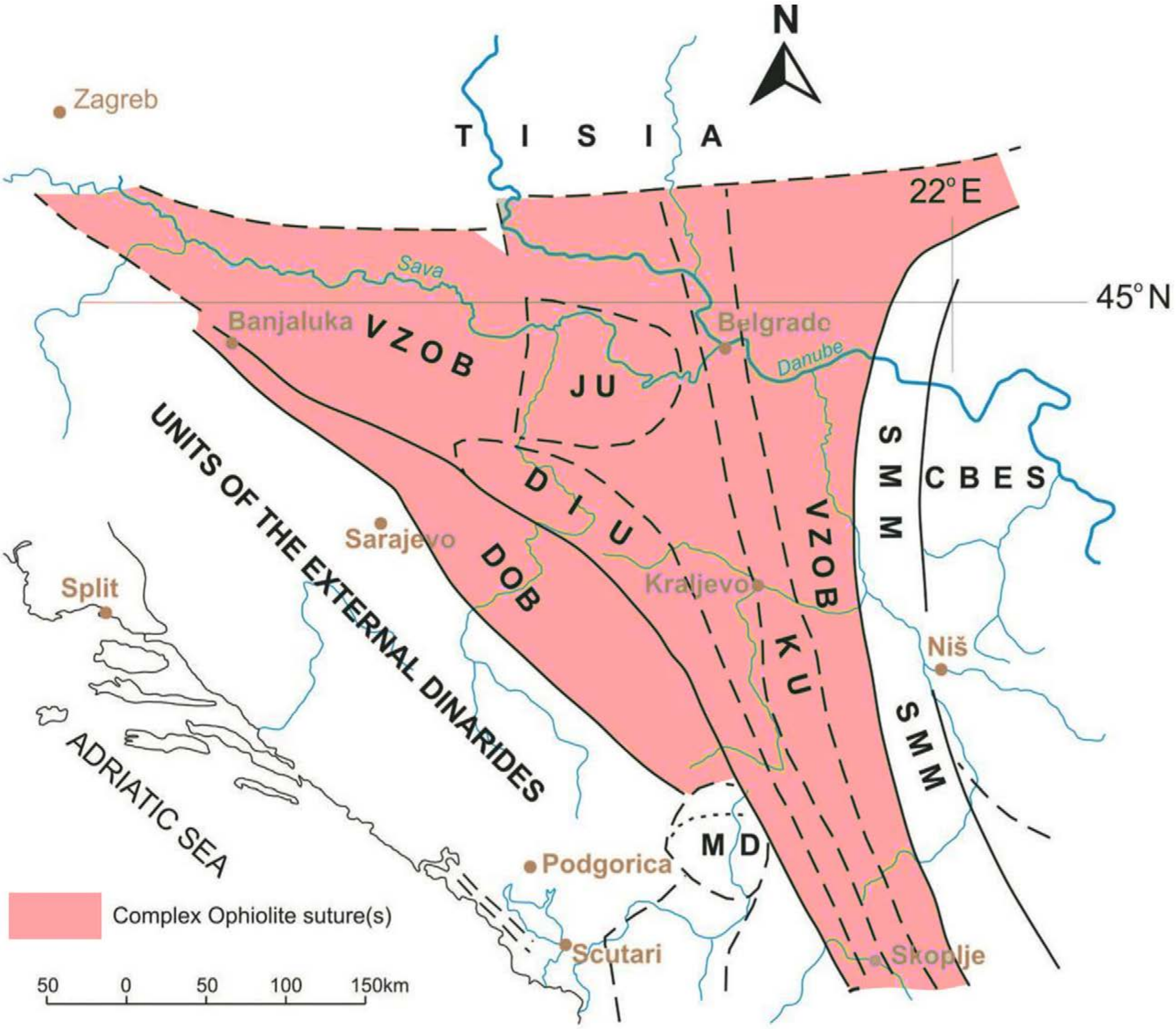


Figure 3.2. Outline of the geotectonic framework of Serbia and adjacent regions (after Vasković and Matović 2010: 4, fig. 2).

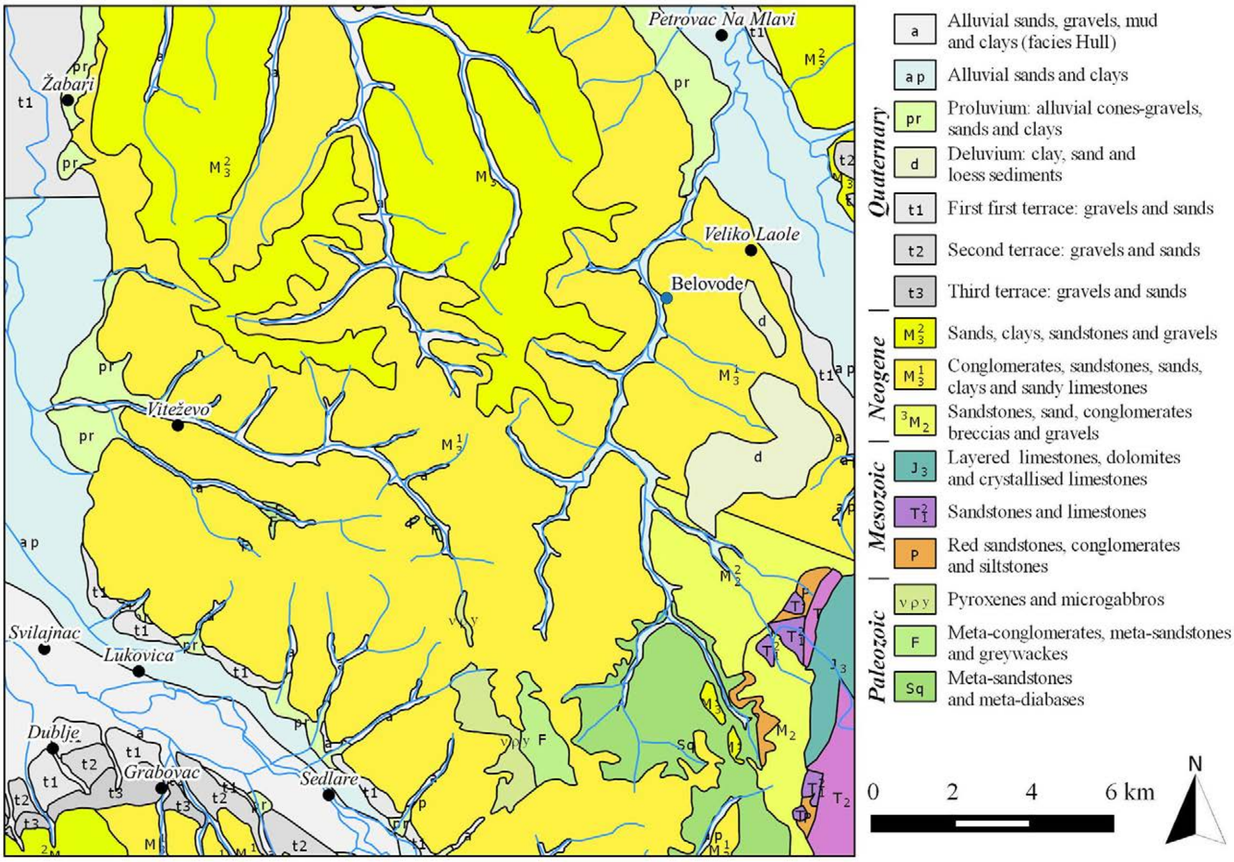


Figure 3.3. Geological map of the area surrounding Belovode (based on Yugoslavia Geological Map issued by the Federal Geological Institute. Sheets L34-127; L34-128; L34-139; L34-140 - 1:100 000, prepared by Enrico Croce).

1997: 115). The region is covered by Neogene deposits and projects outwards over the Triassic area of the Carpatho Balkanides to the east. It is characterised by metapsammites and metadiabases of the greenschist facies group. These rocks form a continuous horizon of quartzite which is underlined with acidic metavolcanics, metapelite and metapsammite. This 800m-thick succession is covered by metaconglomerate and metagreywacke, intruded by gabbro of the Kupinovačka Glavica. The settlement of Belovode is situated on a Neogene formation which overlies the older base of conglomerate, sandstone, mudstone and sandy limestone (**Figure 3.3**). Superficial and recent deposits include alluvial sand and clay from the nearby Busur River.

History of archaeological research at Belovode

Archaeological excavations started in 1993, thanks to cooperation between the National Museum in Belgrade and the Museum in Požarevac (**Jacanović and Šljivar 2003; Šljivar and Jacanović 1996a, 1996b, 1997; Šljivar *et al.* 2006**). The position of Belovode, on a plateau at an altitude of *c.* 200m, is typical for Vinča settlements, and is suitable for agricultural and cattle breeding activities. Initially, the site was estimated to cover 100ha (**Šljivar *et al.* 2006: 8**), but recent geophysical investigation indicates it did not exceed 40ha (**Rassmann *et al.* 2021a**).

The archaeological excavations revealed a cultural layer of up to 4m in the centre of the settlement, comprising the complete sequence of the Vinča phenomenon (**Table 3.1**) from Vinča Tordoš to the Gradac phase (**Jovanović 1994; Šljivar and Jacanović 1996b**). Occasional finds of Starčevo pottery indicate earlier occupation of the site, prior to the Vinča culture. A portion of the site was probably also briefly occupied by people associated with the Chalcolithic culture of Kostolac. A series of nine AMS radiocarbon dates, obtained from animal bones, indicate that permanent occupation began in *c.* 5350 cal. BC and that settlement activities ended around 4650 cal. BC (**Borić 2009: 209**). Recent AMS radiocarbon dating on 20 samples from trench 18, excavated during the RoME project, confirmed this chronological range (**Marić *et al.* 2021d**).

The excavated trenches yielded evidence of a rich material culture, including abundant vessels of various types, as well as other ceramic related materials like

Table 3.1. Relative chronology of Belovode compared to Supska, Selevac and Vinča-Belo Brdo according to Milojčić (1949) and Garašanin (1951) (after Šljivar *et al.* 2006: 251).

Belovode	**Supska**	**Selevac**			**Vinča**	**Garašanin**	**Milojčič**
		Building Horizon 1977-1978		**Strati. Architec. Phase**			
Phase A	9 Stratum 8				8 m	Vinča-Tordoš I	Vinča A
B Phase C	7 Stratum 6	I-IV V-VI	I II	I	6.5 m	Vinča-Tordoš II	Vinča B1 (depth c. 7m)
Phase D	Stratum 5	VII-VIII	III	II	6 m	Gradac Phase	Vinča B2
	Stratum 4	IX	IV	III	4.1 m	Vinča-Pločnik I	Vinča B2-C (depth above 5m)
	3 Stratum 2 1		V	IV	3.45 m	Vinča-Pločnik IIA	Vinča C
						Vinča-Pločnik IIB	Vinča D

figurines, amulets, loom weights, fragments of baking ovens and daub. Finds relating to the lithic industry, including both chipped and ground stones, were also abundant throughout the site. Occasionally, obsidian and spondylus shells were identified, and green copper minerals and objects (beads and pendants) made from malachite were also recorded, with dates ranging from the earliest phases (**Šljivar *et al.* 2011**).

As mentioned in **Chapter 1**, Belovode yielded evidence for the earliest known extractive metallurgical activities so far documented (**Radivojević 2013, 2015, 2021a; Radivojević and Kuzmanović-Cvetković 2014; Radivojević and Rehren 2016; Radivojević *et al.* 2010**). The finds consisted of eight copper slags and slagged ceramics from trench 3, found in the occupational horizon, radiocarbon dated to 5000 BC (**Radivojević *et al.* 2010**), thus corresponding to the beginning of the Gradac phase of the site. Pyrometallurgical activities were also recorded in trench 9, where a metal droplet was found; this context has also been dated to the Gradac phase (for a detailed discussion of copper minerals, archaeometallurgical materials and installations found at Belovode, see **Radivojević and Kuzmanović-Cvetković 2014: 13, tab. 1**).

Excavation of Trench 18

Trench 18 was excavated during the summers of 2012 and 2013 within the framework of the RoME project. During the two campaigns, a total of 31.5m^2 was excavated. The position of the trench was based on previously discovered metallurgical evidence in trenches 3 and 17, to the north and south of the new trench respectively (**Figure 3.4**). The trench was initially 5 × 5m but was extended by 2 × 3m in 2013. The archaeological layer was 2.3m in depth although, as previously mentioned, the cultural layer in the central part of the plateau (corresponding to the centre of the settlement) reached up to about 4m (**Šljivar and Jacanović 1996a: 55**).

The field supervisor of trench 18, Miroslav Marić, excavated using 0.1m spits, with definable contexts (house patterns, pits, ovens, and any kind of definable concentration of material) being numerated and excavated individually to provide secure units which could later be used for processing and dating. The excavation was digitally recorded via GIS software. This trench contained approximately 2.2m of cultural deposits starting just 0.1m below the present surface. A total of 51 features were identified.

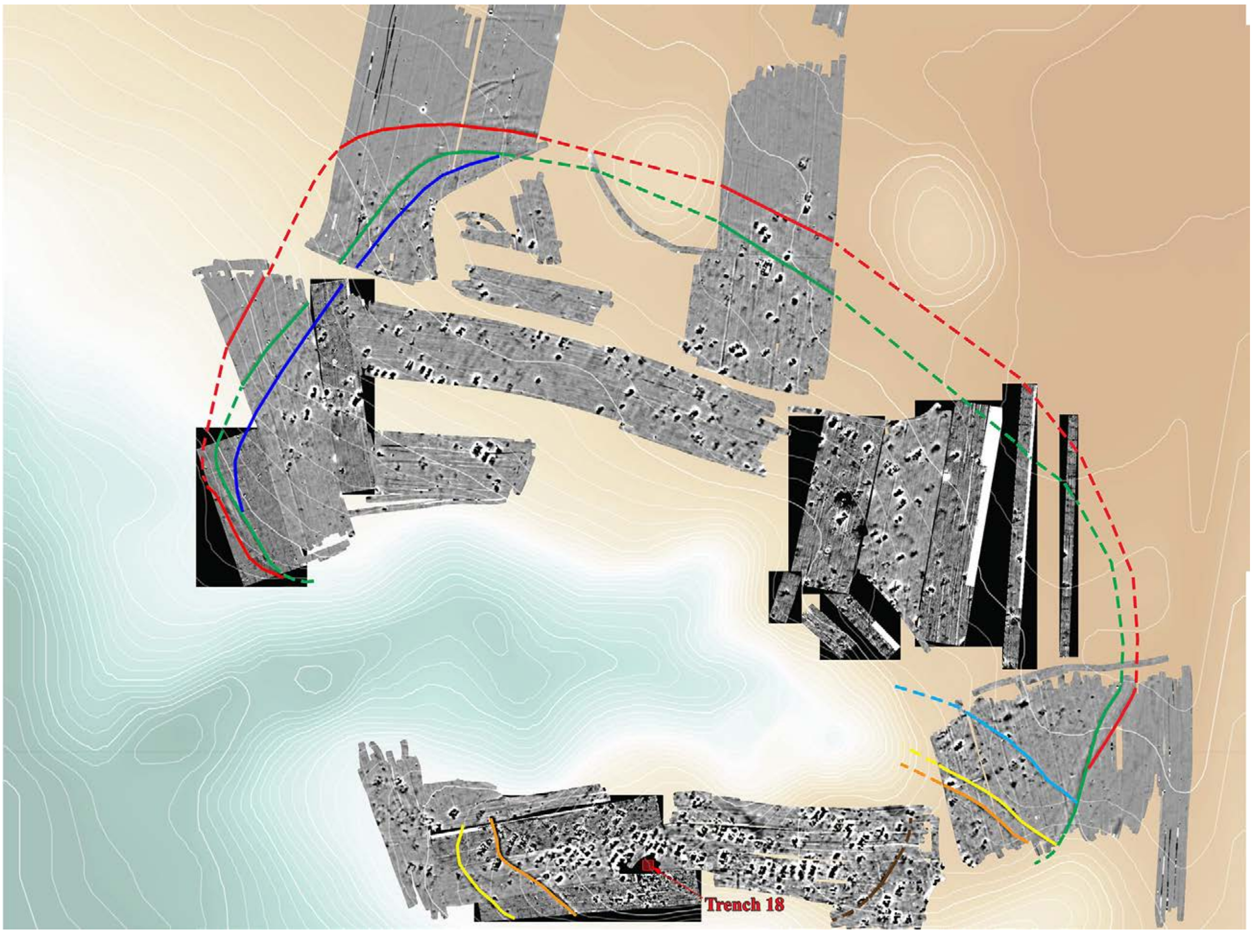


Figure 3.4. Geophysical survey of the Belovode archaeological site with position of trench 18 (Marić *et al.* 2021b: fig. 1, ch. 10).

Based on stratigraphic observations of defined contexts, five building horizons were identified, no. 1 being the latest and no. 5 the earliest (**Figure 3.5**). These horizons represent distinguishable settlement construction phases in this part of Belovode. The overall thickness of each cultural deposit was comparable with those of previously published trenches (**Šljivar and Jacanović 1996a: 55**). The horizons were dated using 20 samples (e.g. grains, animal bones) collected in various features and subjected to AMS radiocarbon analysis (**Marić *et al.* 2021e**).

Some of the most relevant features are discussed below. The focus is on those that are well dated and that yielded most of the sampled pottery and other ceramic material (loom weights, oven fragments, daub) analysed as part of the RoME project.

Vessels of various functions were found in features F1 and F2, each representing pottery concentrations, as well as in feature F9 in horizon 1a (4683–4502 cal. BC 95%). F9 was a larger pit (2.6 × 1.9m) detected within spit 6, next to the southern profile of trench 18 (**Figure 3.6a**). The infill of this pit consisted of dark brown soil with daub, ash, charcoal fragments and, occasionally, yellow clay lumps. Numerous fragments of pottery, animal bones, malachite, figurines, and a miniature cup were also found in the pit. The nature of this material indicates that this could have been a refuse pit, possibly connected to feature F3, a rectangular dwelling structure in horizon 1b (4778–4611 cal. BC 95%) (**Figure 3.6b**), made of wattle and daub and found at the base of spit 3. This structure was located at the northwestern corner of the trench and orientated north-south with a declination of about 18° towards the east. It probably extended further towards the western profile of trench 17. Several fragments of fired daub-covered vessels were found *in situ* on what was probably the floor level; these were burnt in the same event that destroyed the structure. Large ground stones and smaller stones, together with 16 pieces of malachite, were also found on this surface. No cooking or heating installations were detected, indicating that the structure might have been used for storage.

Other relevant features in horizon 1b include F8, F19, F20 and F26. Feature F8 is a concentration of five pots found next to the southeastern corner of trench 18 in spit 6 (**Figure 3.7a**). The vessels have various forms and functions, broadly divided into cooking and

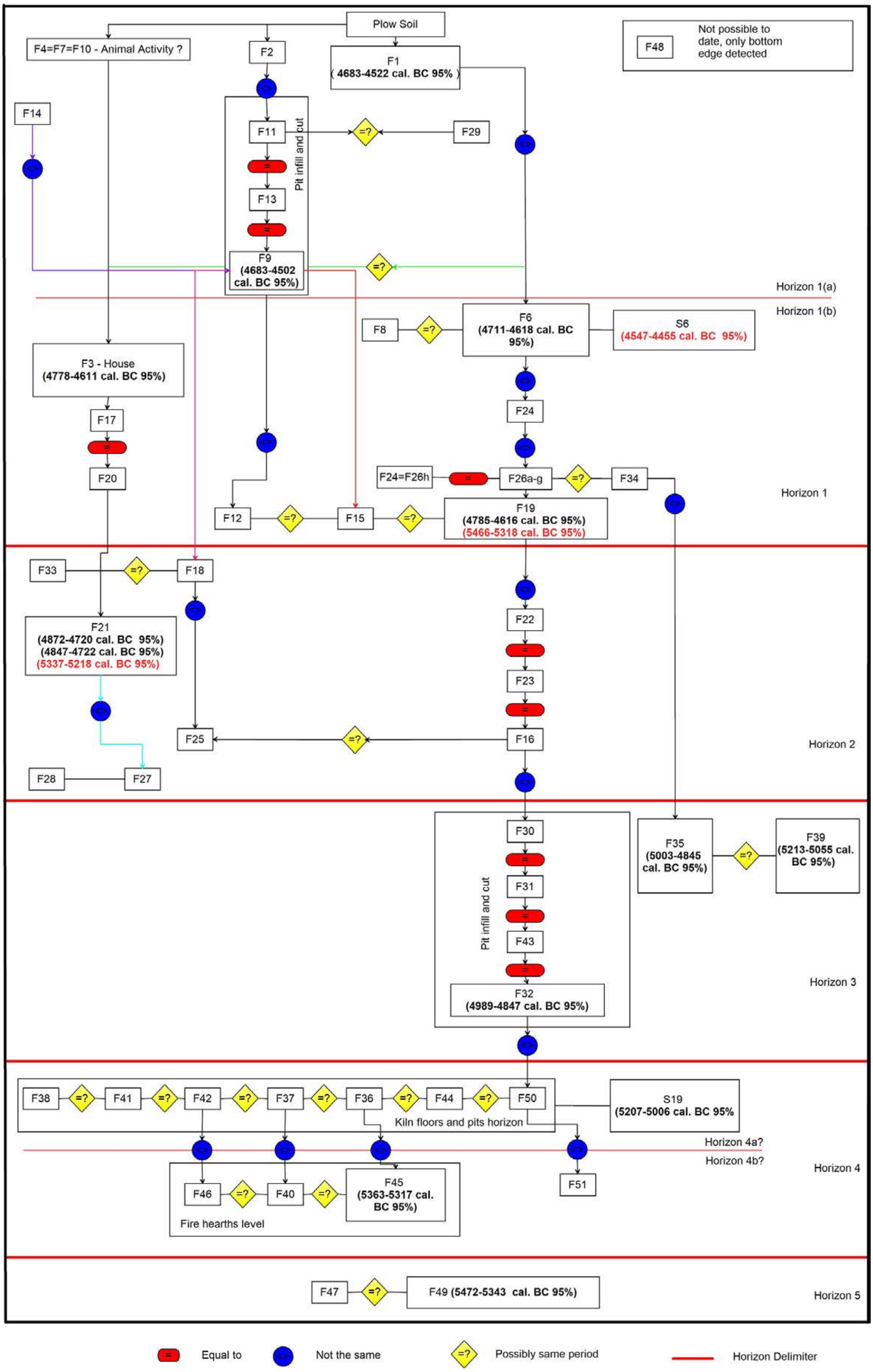


Figure 3.5. Schematic diagram of stratigraphic relations between features in Belovode trench 18 (Marić *et al.* 2021d: fig. 2, ch. 37).

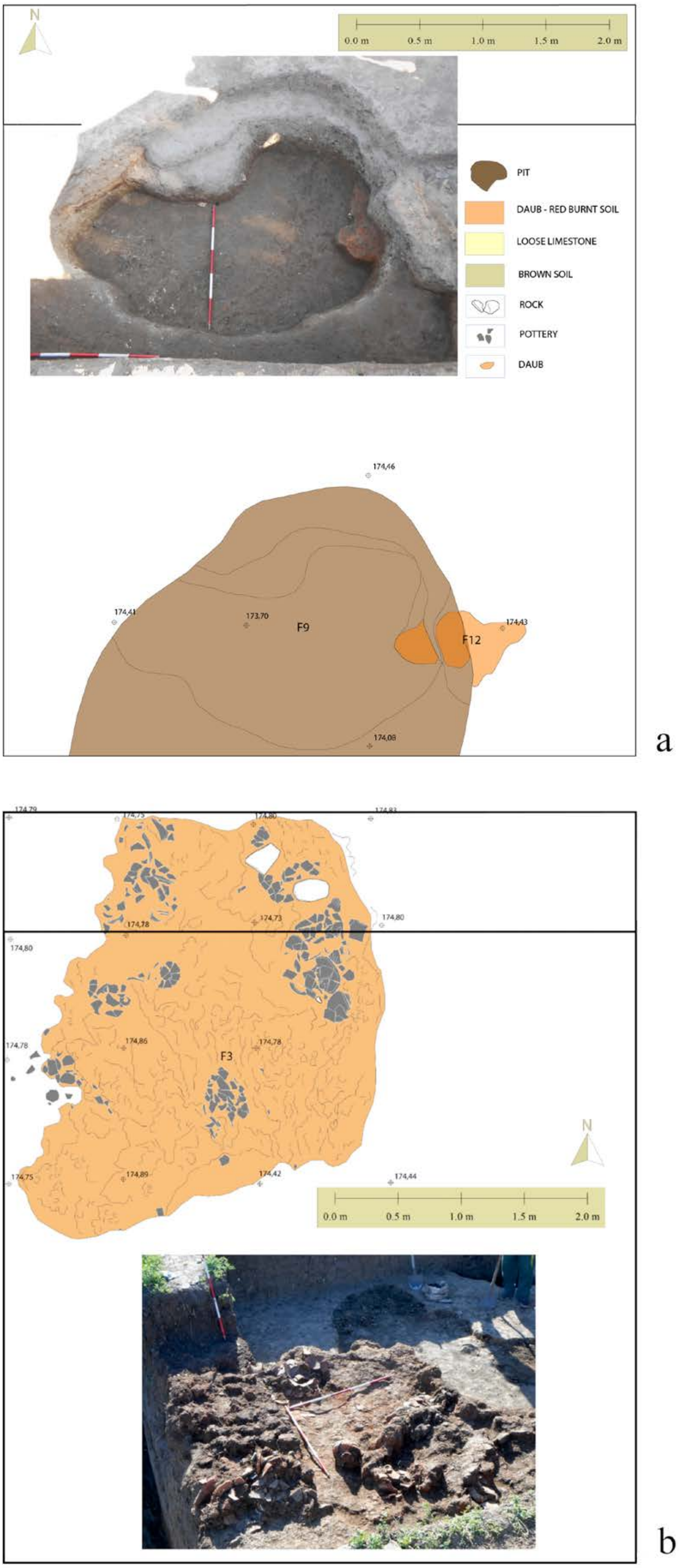


Figure 3.6. a) Feature F9: a large pit with pottery; b) feature F3: a possible dwelling structure (courtesy of the RoME project).

Figure 3.7. a) Feature F8: concentration of five pots; b) feature F19: pit containing abundant pottery; c) feature F26: post-holes (courtesy of the RoME project).

storage pots. Feature F19 (4785–4616 cal. BC 95%) is a large, elliptical, funnel-shaped pit (3.1 × 1.8m) with a maximum depth of 0.70m, located in the eastern part of the trench (**Figure 3.7b**). Most of the finds, consisting of animal bones and potsherds, were concentrated at the very bottom of the pit. Several fragments of thermally altered malachite were also found in this feature.

Finally, feature F20 is sub-oval with evidence of burning, daub, animal bones and pottery fragment, while feature F26 consists of six individual vertical post-holes arranged in a circle (diameter *c.* 0.25–0.26m) that contained several fragments of pottery (**Figure 3.7c**). These post-holes could have been the base of a small wooden structure.

The most relevant features in horizon 2 are F16, F18 and F21. Feature 16 is an irregularly shaped concentration of daub (**Figure 3.8a**) consisting of white ash and charcoal from a destroyed oven. Features F18 and F21 (4872–4720 cal. BC 95%) are pits; the latter has an oval shape measuring 1.6 × 1.4m (**Figure 3.8b**). This yielded several malachite pieces and one obsidian fragment, and was most likely a refuse pit.

In horizon 3, features F30, F31, F32 and F43 (4989–4847 cal. BC 95%) comprise a large pit (3.3 × 1.4m). This was initially detected in spit 12 and the bottom was reached in spit 17 (**Figure 3.9**). The infill included various types of soil, including a burnt layer with many fragments of daub, charcoal and ash. There are several indications that this pit was used over a long period (**Marić *et al.* 2021b**). The infill contained pottery, animal bones and malachite.

Features F36, F41, F42, and F50 (5207–5006 cal. BC 95%) within horizon 4 (**Figure 3.10a**) comprise four oven floors detected at the bases of spits 17 and 18. The ovens were not found *in situ* and the floors do not seem to originate from the same oven. This horizon also includes two smaller pits (features F37 and F38) that might be clay outcrops used for pottery production or another similar activity, as very few objects were found within them. Finally, features F47 and F49 in horizon 5 (5472–5343 cal. BC 95%) are of particular interest (**Figure 3.10b**). Feature F47 is a pit, interpreted as a clay outcrop used for extracting raw materials, for either pottery or construction. Feature F49 consists, instead, of burnt orange soil that becomes black towards the centre and has been interpreted as a hearth. The absolute dating of this feature, to the turn of the 6th millennium, is very close to the beginning of the Vinča culture.

Pločnik

Introduction to the environment and geology

The Neolithic settlement of Pločnik (**Figure 3.11**) lies on a fertile floodplain surrounded by springs and small streams. It is set on the north bank of the Toplica River, which originates from the Kopaonik mountain range about 50km away. This is the major river system in the area and an important communication route (**Marić 2021b**). Immediately to the southwest of the site, the broad Toplica valley, which widens several kilometres west of Prokuplje, begins to narrow again as it enters the mountainous region formed by the northwestern slopes of Mount Radan and the southern margins of the Kopaonik mountain. Pločnik thus overlooks one of the major routes between the Kosovo plain and the Morava valley.

Pločnik lies on the western margin of the Serbo-Macedonian composite unit (SMM), on the lower complex of this unit. The archaeological site is set on an alluvial quaternary deposit related to the Toplica River (**Figure 3.12**). The surrounding area is characterised by Cretaceous deposits of flysch, sandstone, marl, and olistostrome ($^{1}K_{2}^{3}$), which cover Precambrian formations constituted by leptinolite and mica-schist (Sm), fine-grained biotite and gneiss (Gb), as well as amphibolite, which outcrops east of the site around Prokuplje. West of Pločnik, the Kuršumlija area lies in the Eastern Vadar Zone (EVZ) that forms the eastern margin of the Vadar Zone Ophiolite Belt (VZOB). The EVZ is mainly built up of gabbro dolerites, dolerites,

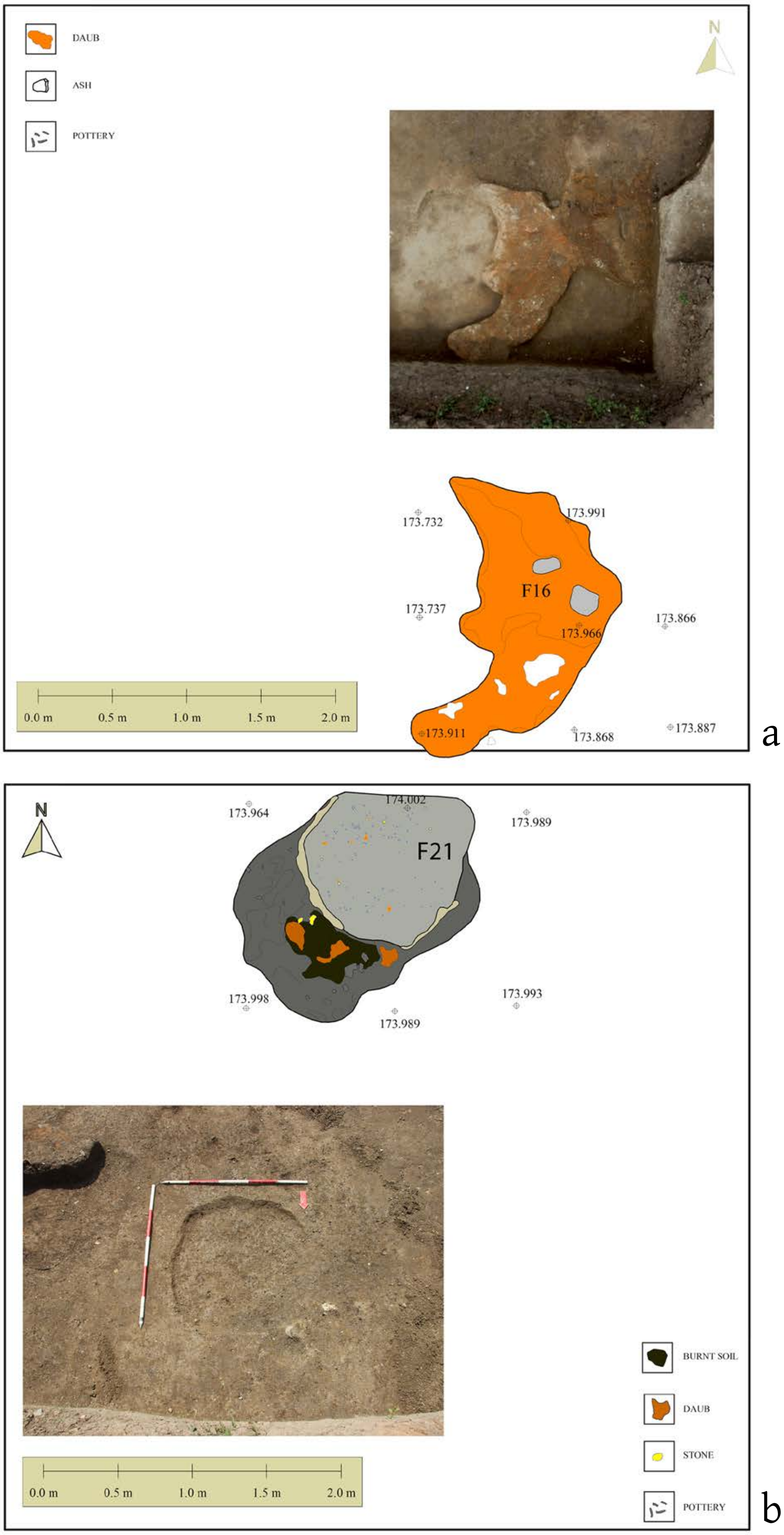


Figure 3.8. a) Feature F16: daub concentration; b) feature F21: oval pit (courtesy of the RoME project).

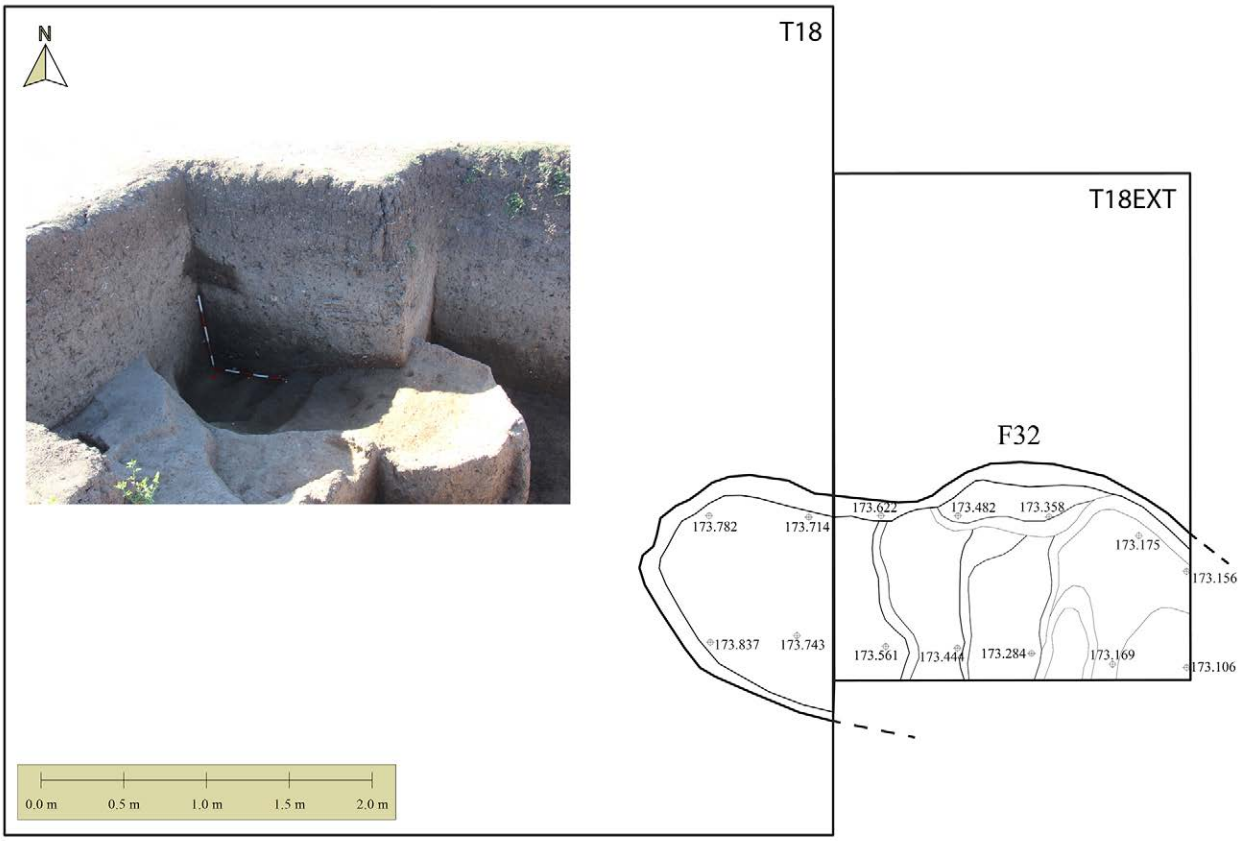


Figure 3.9. Features F30, F31, F32 and F43: large pit with abundant pottery (courtesy of the RoME project).

rare basaltic pillow lavas, and small isolated outcrops of mainly serpentinised hazburgites on the eastern and western margins (**Vasković and Matović 2010: 6**).

History of archaeological research at Pločnik

The prehistoric settlement of Pločnik is situated close to the eponymous modern village, 19km west of the town of Prokuplje in southern Serbia and 300km south of Belgrade (**Figure 3.1**). The site was first identified during the construction of the Yugoslav railway in 1926, when an important group of artefacts was discovered, consisting of two axe-hammers, two chisels, three bracelets (two complete and one fragmented), and two stone axes. The first archaeological campaigns were conducted in 1928, leading to the discovery of 13 copper implements and five stone axes (**Grbić 1929**). The settlement has since been the subject of continuous national and international interest. Between 1960 and 1978, excavations carried out under the scientific supervision of M. Grbić and B. Stalio from the National Museum of Belgrade recovered two other important hoards (**Stalio 1960, 1962, 1964, 1973**). In 1996, research was resumed under the joint guidance of D. Šljivar from the National Museum of Belgrade and J. Kuzmanović-Cvetković from the Museum of Toplica in Prokuplje (**Kuzmanović-Cvetković 1998; Šljivar 1996, 1999, 2006; Šljivar and Kuzmanović-Cvetković 1998a, 1998b; Šljivar *et al.* 2006**). The excavated trenches contained the remains of a rich material culture and indicated three cultural horizons corresponding to Vinča A, B1 and the Gradac phase (**Šljivar 1996; Šljivar and Kuzmanović-Cvetković 1997**). The lower strata, comprising approximately 2.5m of cultural layers, yielded evidence of dwelling structures including post-holes, pits filled with charcoal, ash and bones, and ceramic fragments of phases Vinča A and B1 (**Šljivar 1996**). The uppermost horizon, a cultural layer of around 1m, corresponded solely to the Gradac phase (**Šljivar and Kuzmanović-Cvetković 1998a**).

The first radiocarbon dating of the site was particularly successful (**Borić 2009: 211–215**), confirming that some of the metallurgical evidence from the site belongs to the Vinča culture rather than the Early Chalcolithic Bubanj-Hum culture, as previously thought (**Stalio 1960: 35, 1964: 39–40**). The results also revealed that the Vinča occupation in Pločnik probably started between 5290 and 5140 cal. BC, with the highest probability estimate being 5200 cal. BC. The end of the settlement was dated with the highest probability at *c.* 4650 cal. BC, suggesting that it was inhabited for somewhat less than 600 years.

Between 2012 and 2015, excavations at Pločnik were extended through a co-operation with the RoME

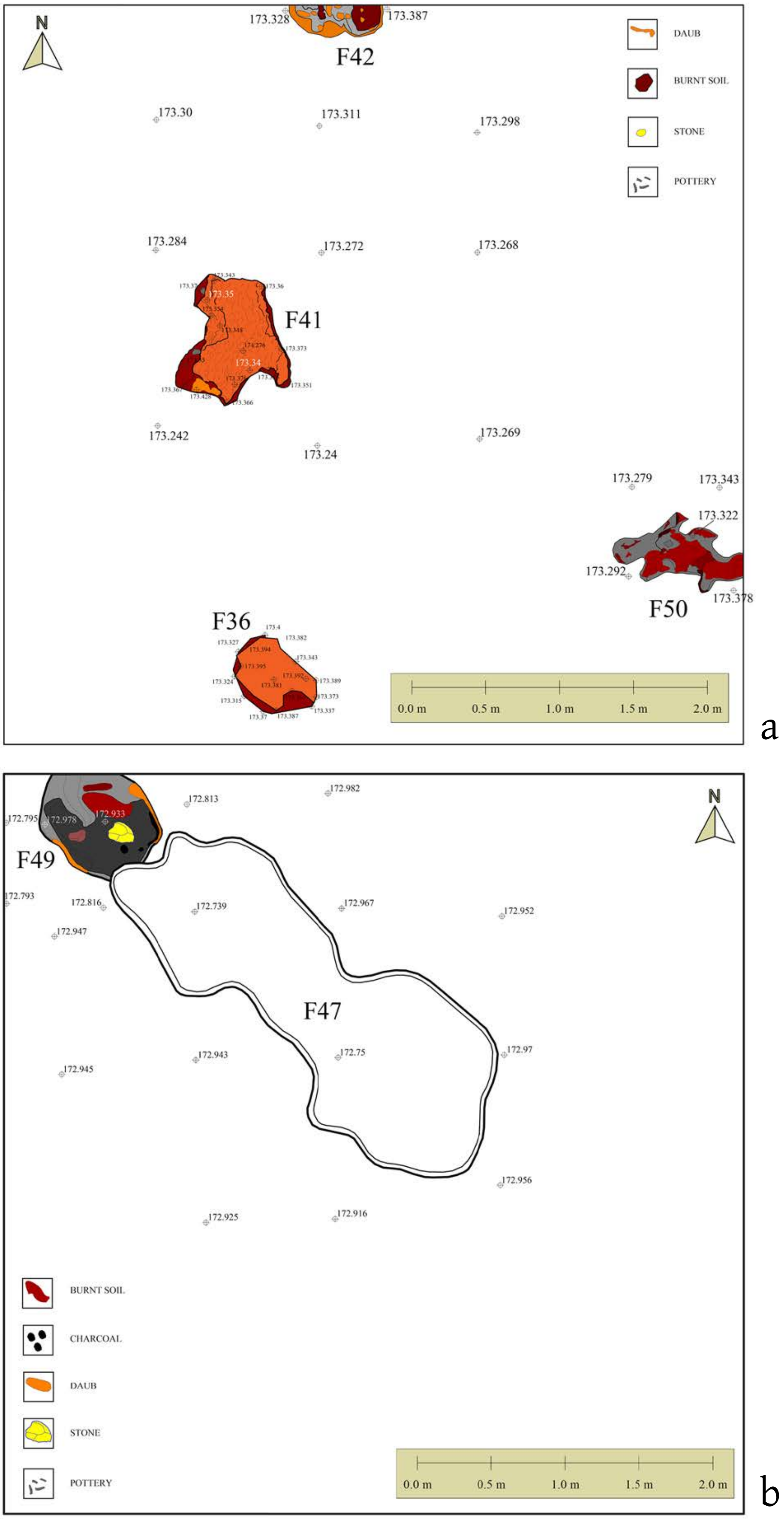


Figure 3.10. a) Features F36, F41, F42 and F50: oven floors; b) feature F49: burnt soil and pottery concentration (courtesy of the RoME project).

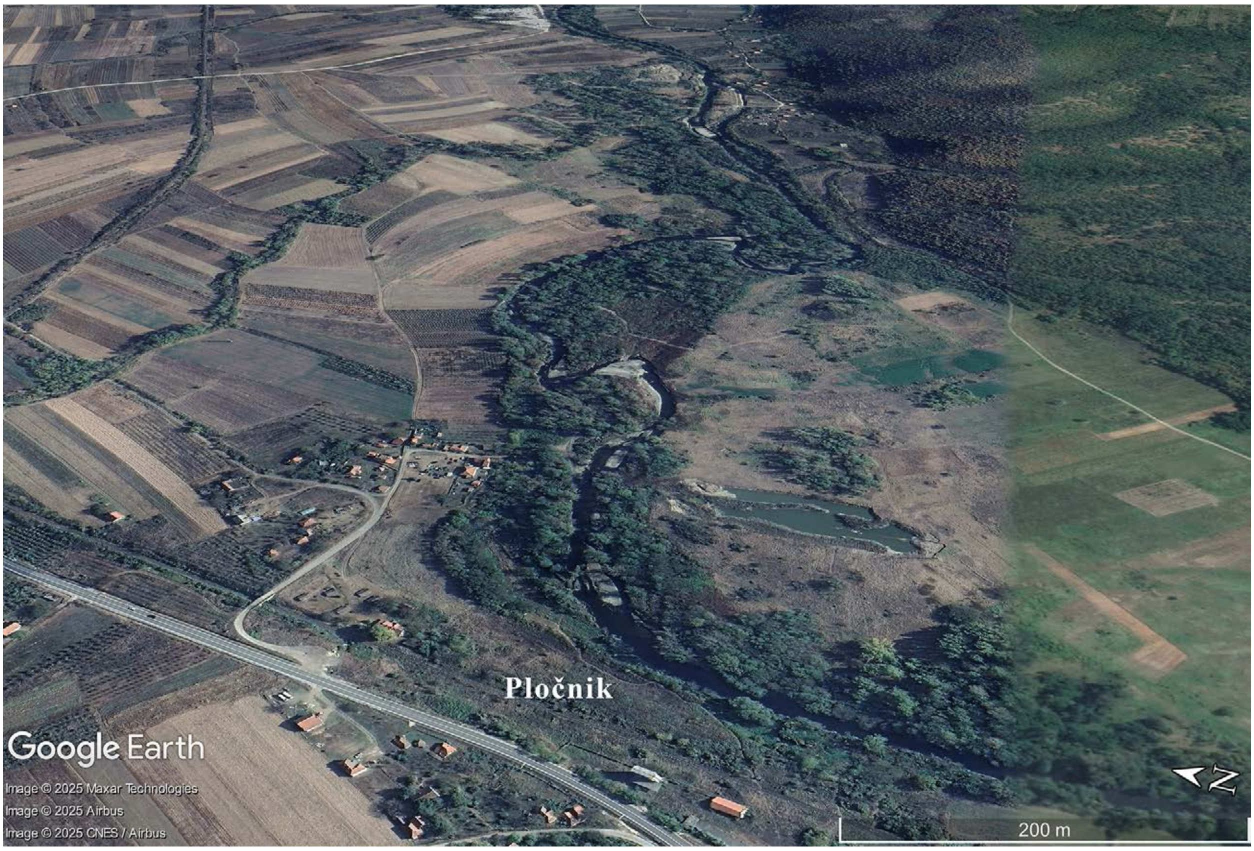


Figure 3.11. Location of the site of Pločnik (from Google Earth).

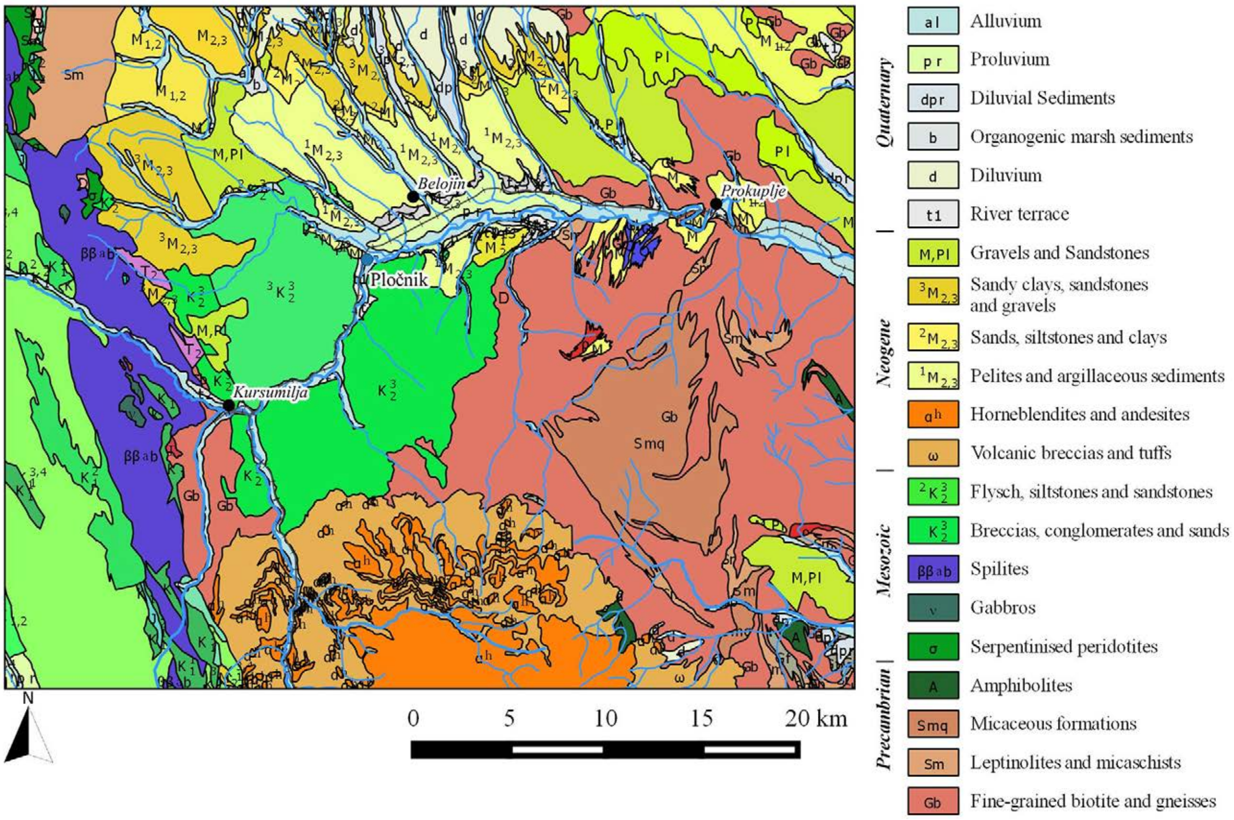


Figure 3.12. Geological map of the area surrounding Pločnik (Based on Yugoslavia Geological Map issued by the Federal Geological Institute. Sheets L34-31; L34-32-1: 100 000, prepared by Enrico Croce).

project. The new investigations indicated that the size of the settlement, previously thought to be around 100ha (calculated from the top of the 3.60m-thick cultural layer), was in fact only about 30ha (**Rassman *et al.* 2021b**). However, a significant portion of the site has unfortunately been destroyed by the meandering of the Toplica River over the last centuries.

As discussed below, radiocarbon dating of 17 samples for the RoME project revealed that the occupation of Pločnik may have started earlier than previously thought (*c.* 5448–5338 cal. BC), and probably extended over a longer period, as indicated by AMS analysis of samples from the final occupation phase (**Marić *et al.* 2021c**). These model the end of the Neolithic occupation at 4446–4231 cal. BC (95.4% prob.) or 4430–4326 cal. BC (68.2% prob.), suggesting that the site was inhabited for around 1000 years.

Excavation of the Trenches 20 and 21

Trenches 20 and 21 were excavated in 2007 and 2008 respectively. The excavations did not reach natural soil, being focused on uncovering the settlement horizon from the Gradac phase. Both trenches provided important archaeological evidence for this phase at Pločnik, especially in terms of metal objects.

In trench 20, at the relative depth of 0.8m, a structure was discovered, the ground level of which was filled with pottery fragments, stone, rubble, metal artefacts and casting debris (**Figure 3.13**). The area was dominated by a rectangular feature measuring 1.4 × 1.4m, with walls preserved up to 0.5m in height. These walls showed indications of repeated repair and were characterised by traces of intense firing. The discovery of this feature, along with a massive copper chisel, a fragmented tool bracelet, a folded metal sheet, a metal tool/ornament and several copper minerals, led the excavators to think that the structure might represent a metallurgical workshop (**Šljivar and Kuzmanović-Cvetković 2009: 61**).

In trench 21 (**Figure 3.14**), at the same relative depth of 0.8m, a dwelling structure was intersected. Here, hundreds of pottery fragments belonging to the final development of the Gradac phase were discovered on the ground level, along with pieces of tin bronze metal (**Radivojević *et al.* 2013**).

Excavation of Trench 24

Trench 24 was excavated during the campaigns of 2012 and 2013 as part of the RoME project (**Figure 3.15**). The field supervisors, M. Marić and J. Pendić, employed the same methodology used at Belovode (**Marić *et al.* 2021a**). The trench initially measured 5 × 5m but, in 2012, was temporarily extended to reveal the full extent of feature 1, a wattle/daub structure. In 2013, the excavation area was again restricted to the original size of 5 × 5m due to limited time and financial constraints. Natural soil was reached at a relative depth of 4m below the surface. A total of 39 features were defined, belonging to five settlement horizons (**Figure 3.16**), with no. 1 being the latest and no. 5 the earliest. As at Belovode, these horizons represent settlement construction phases. AMS radiocarbon analysis of 17 samples collected during the excavation allowed these horizons to be dated with more precision (**Marić *et al.* 2021e)**. The features discussed below held the most relevant pottery assemblages, from which vessels and other ceramic material were sampled for the present study. The full results of the excavation are published in a dedicated chapter (**Marić *et al.* 2021c**) within the monograph of the RoME project (**Radivojević *et al.* 2021a**).

In horizon 1, features F1, F2, F4, F5, F6 and F10 (4448–4330 cal. BC 95%) are of particular interest. These form the above-mentioned wattle and daub structure detected in spit 6, which extended to spit 10. The structure measured 6.3 × 3.5m (**Figure 3.17a**). Large stone blocks found on the sides of the daub and in the central area could have been bases for load-bearing beams. This building technique is also attested in another feature discovered in previous excavations that remain unpublished (personal communication M. Marić). Only a few finds were recovered inside the structure in trench 24: a small number of burnt vessels, a polished axe, a handful of fragments of metal artefacts and a metal droplet. No cooking installations or heating devices were found but in the northwest part of the feature, and a consistent concentration of pottery and stones probably represents the original material removed from below the daub after the collapse of the structure. Beneath the structure was evidence of a floor made of bisected timbers placed in parallel rows with their curved side downwards. Their upper surfaces functioned as a substructure for the actual floor level. Feature F3 (4493–4365 cal. BC 95%) is particularly noteworthy (**Figure 3.17b**). It comprises a small aggregation of stones, and floor and wall fragments of an oven containing a single copper ring. In the same horizon, feature F8 (**Figure 3.18a**) is a concentration of pottery and stones extending between the eastern edge of feature 1 and the eastern profile of the trench; it may represent material intentionally deposited to harden the walking surface between the structures.

In horizon 2, feature F13 (c. 4686–4523 cal. BC 95%) may represent the remains of a rubbish pit, consisting of several layers of depositions covered by a yellow layer of compact soil, and containing small daub fragments and pebbles (**Figure 3.18b**). In the same horizon, feature F11 (**Figure 3.19**) comprises the remains of a horseshoe-type oven. This was rebuilt several times,

Figure 3.13. Workshop in trench 20 (courtesy of Julka Kuzmanović-Cvetković, National Museum, Toplica).

Figure 3.14. Excavations in trench 21 (courtesy of Julka Kuzmanović-Cvetković, National Museum, Toplica).

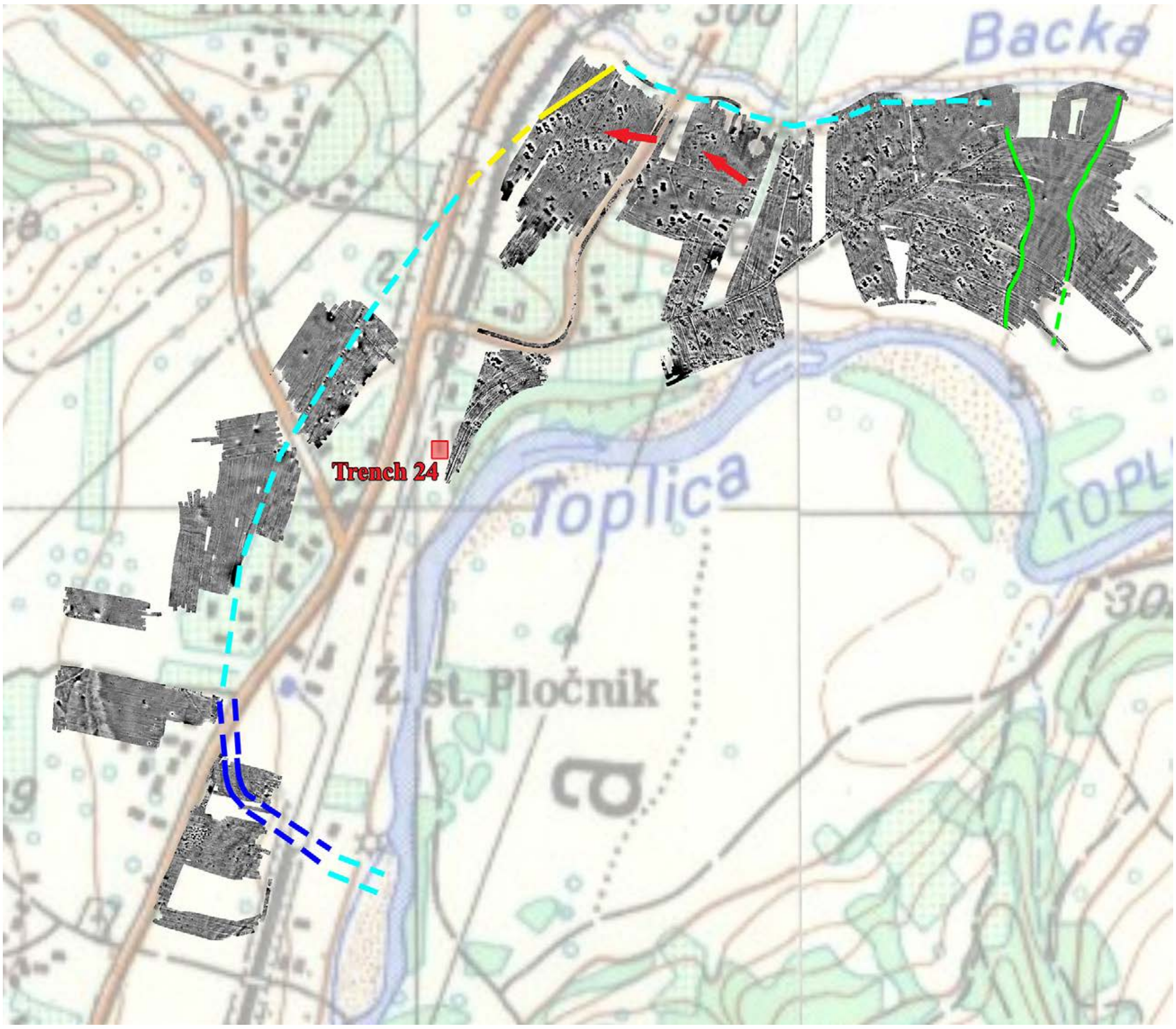


Figure 3.15. Geophysical survey of the Pločnik archaeological site with position of trench 24 (Marić *et al.* 2021b: fig. 1 ch. 25).

testifying to the facility's use over a long period. Four oven floors were excavated. With the exception of the first foundation level, which consisted only of larger stones, the foundation of each oven was made from a mixture of pottery fragments and stones. There was no evidence that the ovens were incorporated into a wattle and daub structure.

In horizon 3, features F16 and F21 (**Figure 3.20a** and **Figure 3.21a**) are large concentrations of pottery and broken grindstones. These could be the filling from a pit whose edges were not detectable. Features F17 (4933–4790 cal. BC 95%), F22 and F23 represent what remains of a daub structure that extended to the southwest profile of the trench (**Figure 3.20a** and **Figure 3.21a**). Feature F19 is a sub-oval pit (diameter 1.2m) containing broken grindstones, unworked stones and abundant pottery fragments (**Figure 3.20a**).

Features F14 and F15 (dated to 5191–4940 cal. BC and 4937–4796 cal. BC 95% respectively), found in spit 14, are what remains of an oven (**Figure 3.20a, b**). The floor is the only part of the structure to be preserved and is surrounded by ash; the oven itself had been renovated at least twice. The foundation of the first floor was made only of pebbles, as in feature F11; the foundation of the second floor was made from pebbles and pottery fragments in a basin of brown compact soil. There is no evidence of any structure surrounding the installation. Finally, features F35, F36 and F37 are post-holes related to a structure of which there were no further remains (**Figure 3.22a, b**).

In horizon 4, feature F30 (*c.* 5188–4987 cal. BC) contains a thick concentration of dark brown soil and pottery (**Figure 3.21b**); feature F34 (5046–4856 cal. BC 95%) is a large rectangular area with irregular boundaries

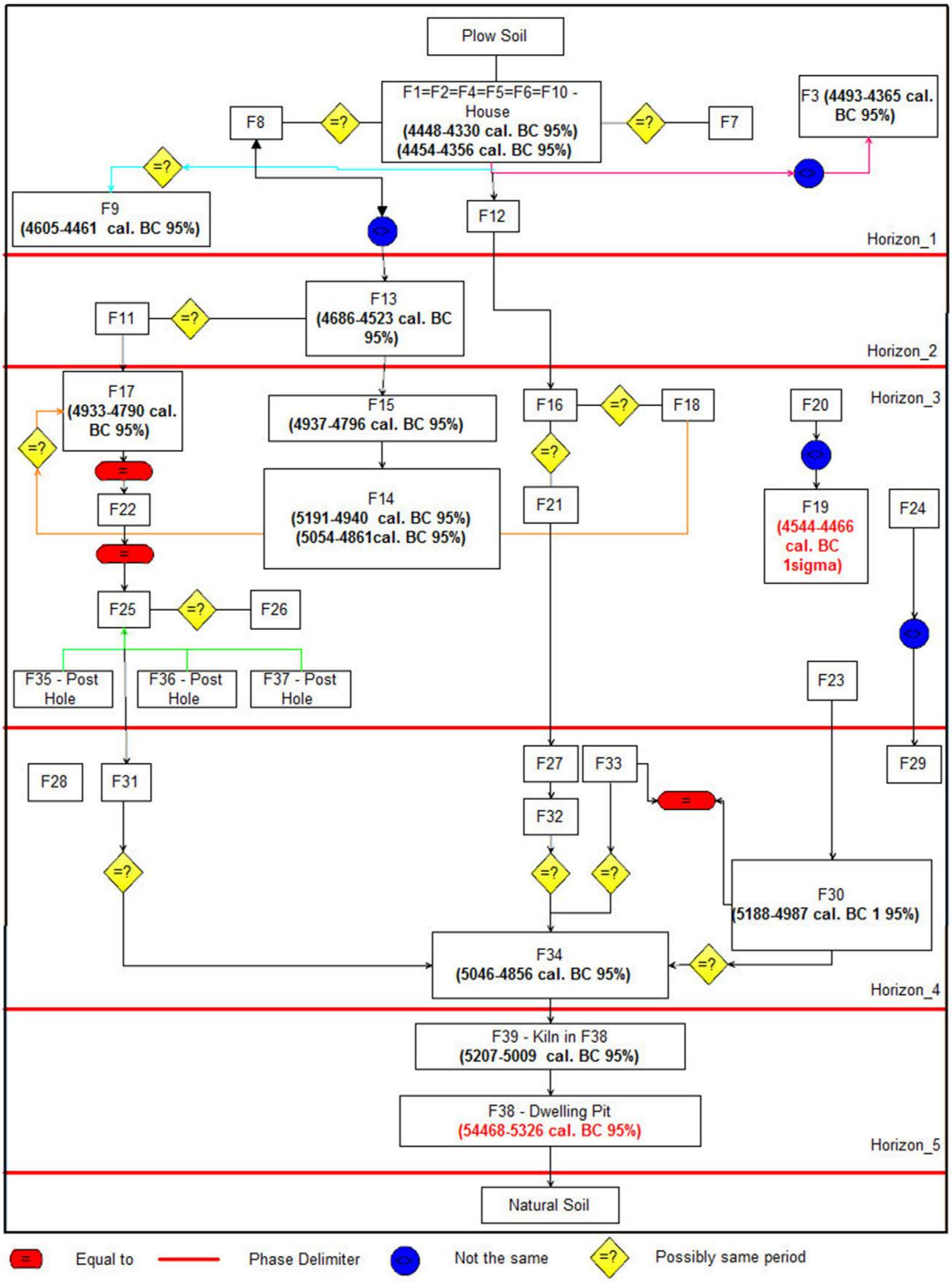


Figure 3.16. Schematic diagram of stratigraphic relations between features in Pločnick Trench 24 (Marić *et al.* 2021d: fig. 3, ch. 37).

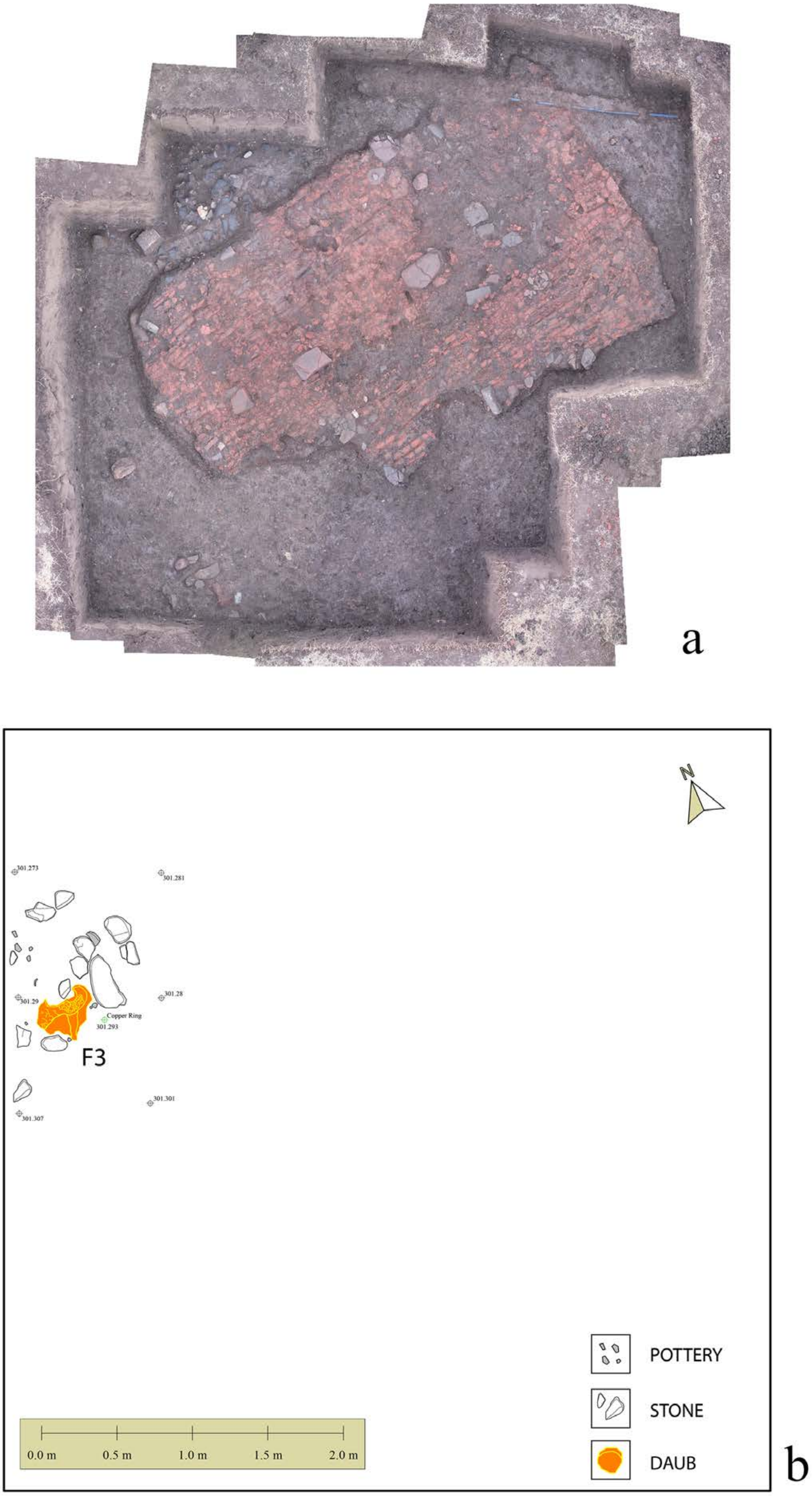


Figure 3.17. a) Dwelling structure; b) feature F3 (courtesy of the RoME project).

Figure 3.18. a) Feature F8: concentration of pottery and stones; b) feature F13: remains of a rubbish pit (courtesy of the RoME project).

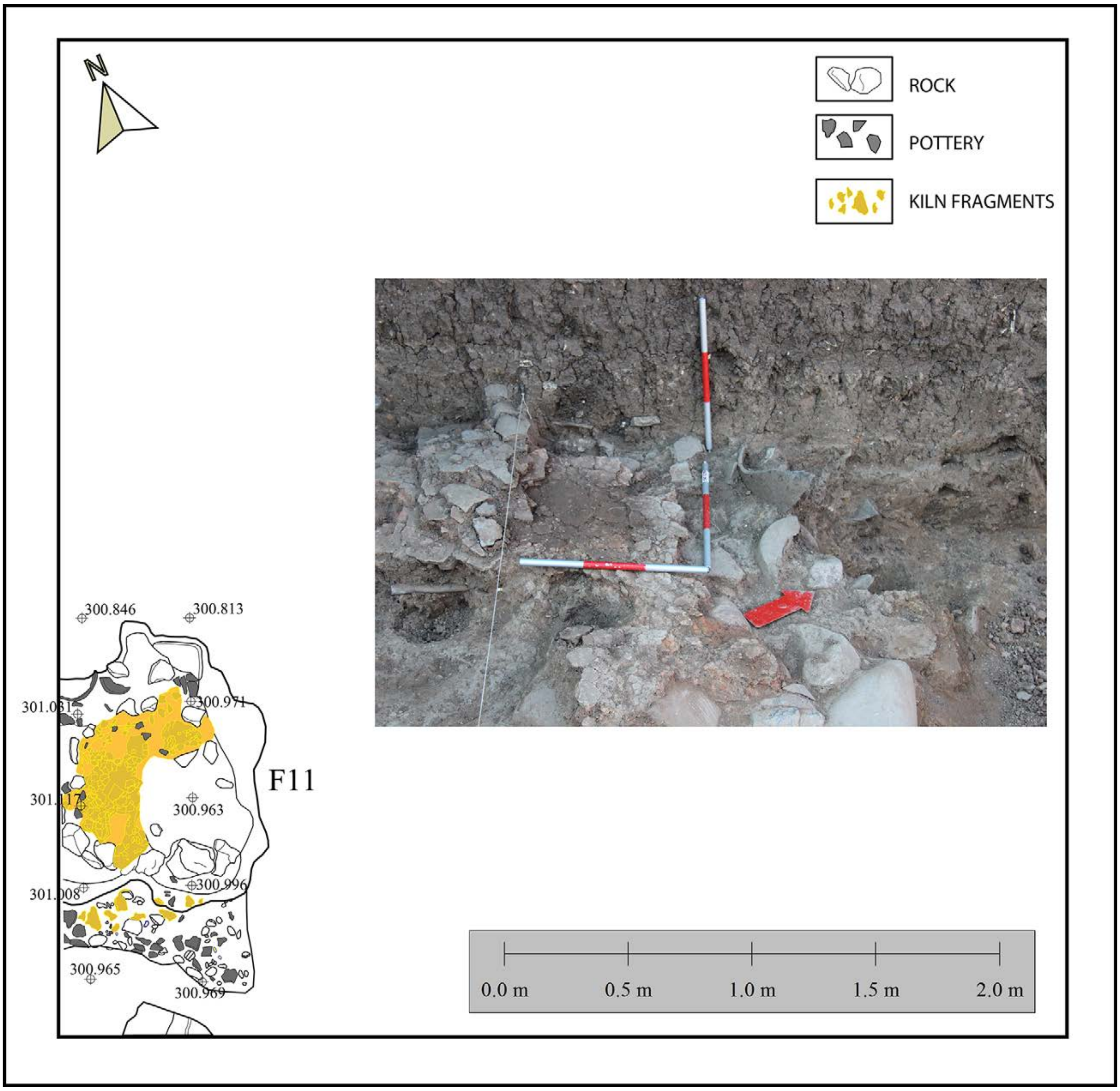


Figure 3.19. Feature F11: remains of a horseshoe-type oven (courtesy of the RoME project).

(**Figure 3.22a, b**). It is several centimetres thick and consists of layers of white ash mixed with charcoal, daub fragments and orange soil. This feature is cut by holes (features F35, F36 and F37) and could be the remains of a burnt structure.

Other relevant features in this horizon include F29, F30, F31, and F32, all of which are concentrations of daub, fired soil and ash.

The most important elements within horizon 5 are features F38 and F39. F38 is a pit of a house with several separate cells; F39 is a daub concentration. Since feature F38 bordered the eastern end of the trench, the excavation was restricted to about one half of its presumed size (**Figure 3.23a, b**). Abundant ceramic material and layers of ash and charcoal were found. The base of the pit was cut into a brown, clayish and very compact soil with no inclusions or further archaeological finds, confirming that the natural soil was reached, as is often the case for this kind of soil in this area of the site.

Relative and absolute chronology of Belovode and Pločnick

As discussed in **Chapter 2**, the reference assemblage used to create the traditional relative typo-chronology of the Vinča culture originated from the eponymous site of Vinča Belo Brdo (**Garašanin 1951, 1979, 1993; Holste 1939; Lazarovici 1981; Lenneis and Stadler 1995; Milojčić 1949; Schier 1996**). It has been observed

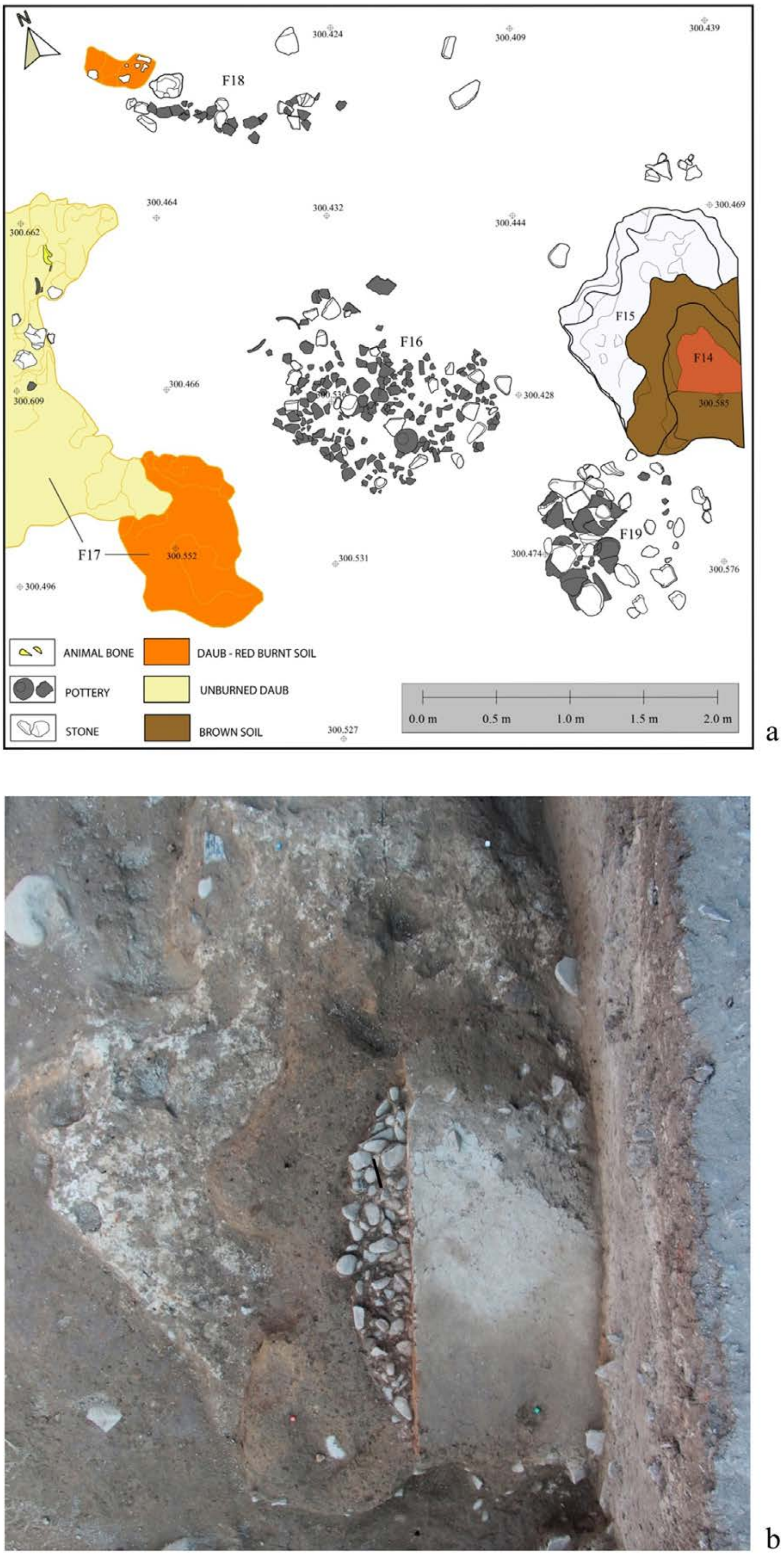


Figure 3.20. a) Feature F16: concentration of pottery; feature F17: daub structure; features F14 and F15: remains of an oven; feature F19: large oval pit; b) features F14 and F15: remains of an oven (courtesy of the RoME project).

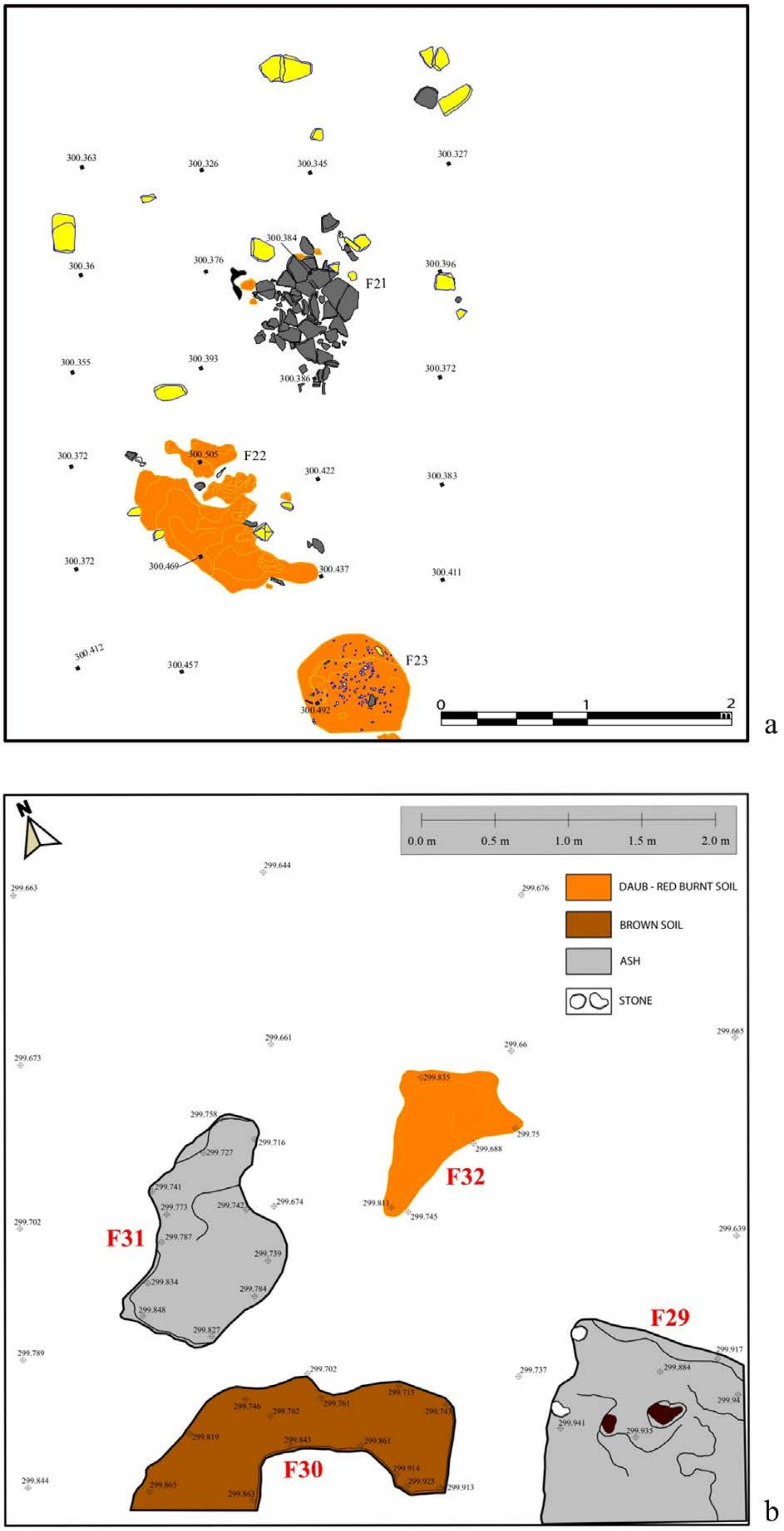


Figure 3.21. a) Feature F21: large concentration of pottery; features F22 and F23: daub structure, b) feature F30: concentration of dark brown soil and pottery (courtesy of the RoME project).

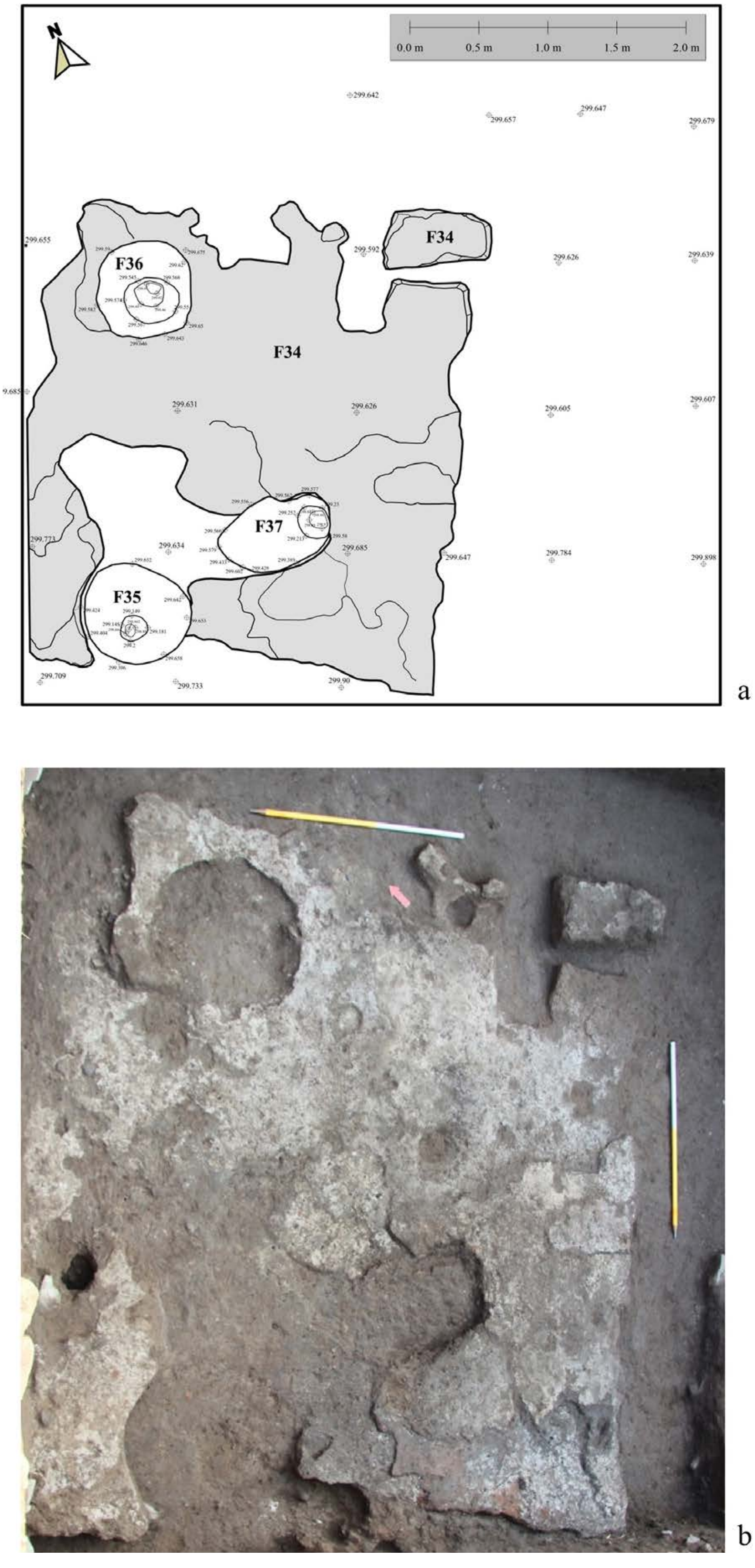


Figure 3.22. a) and b) Feature F34: large rectangular area with irregular boundaries and post-holes (courtesy of the RoME project).

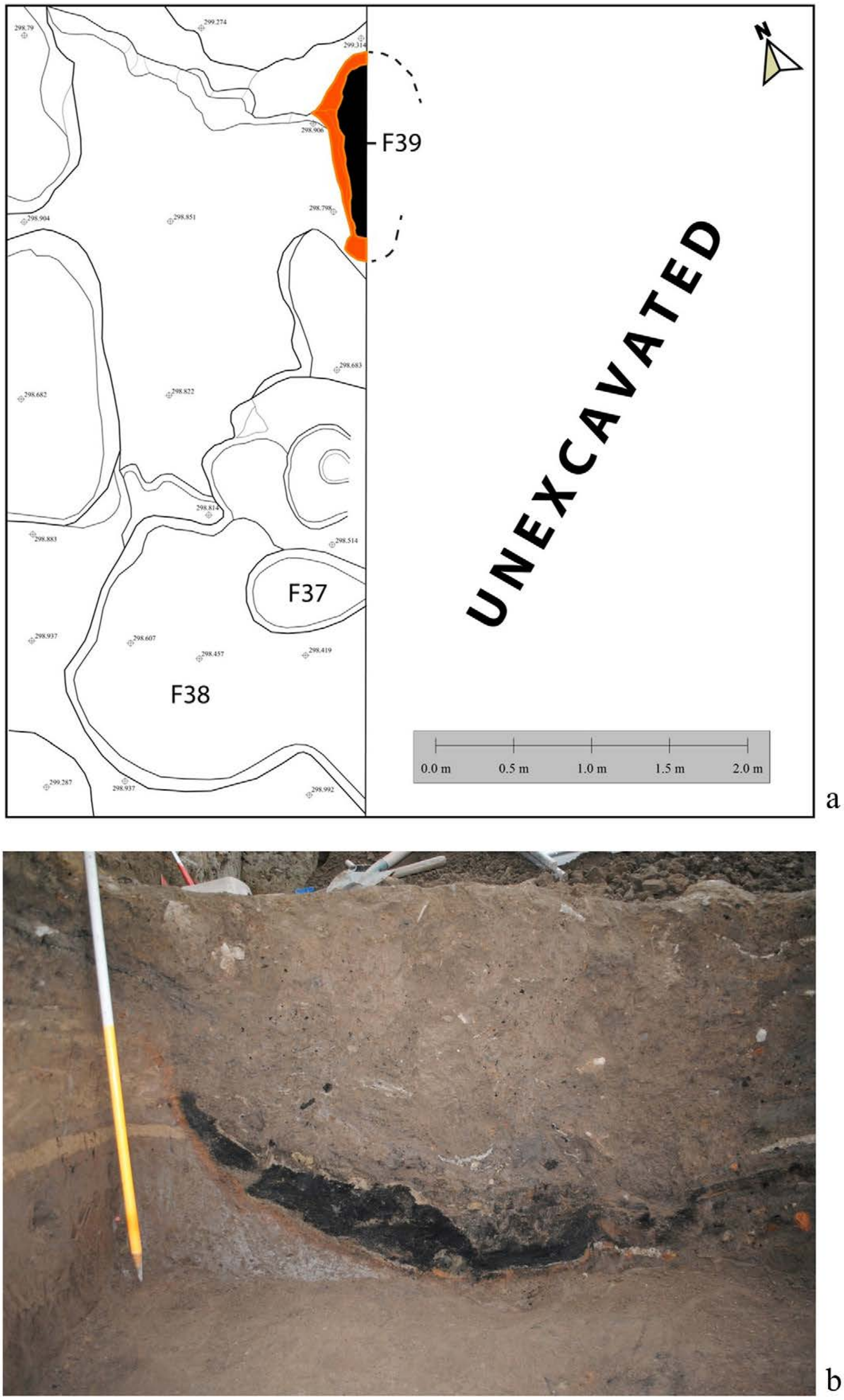


Figure 3.23. a) and b) Feature F38: pit of a house (courtesy of the RoME project).

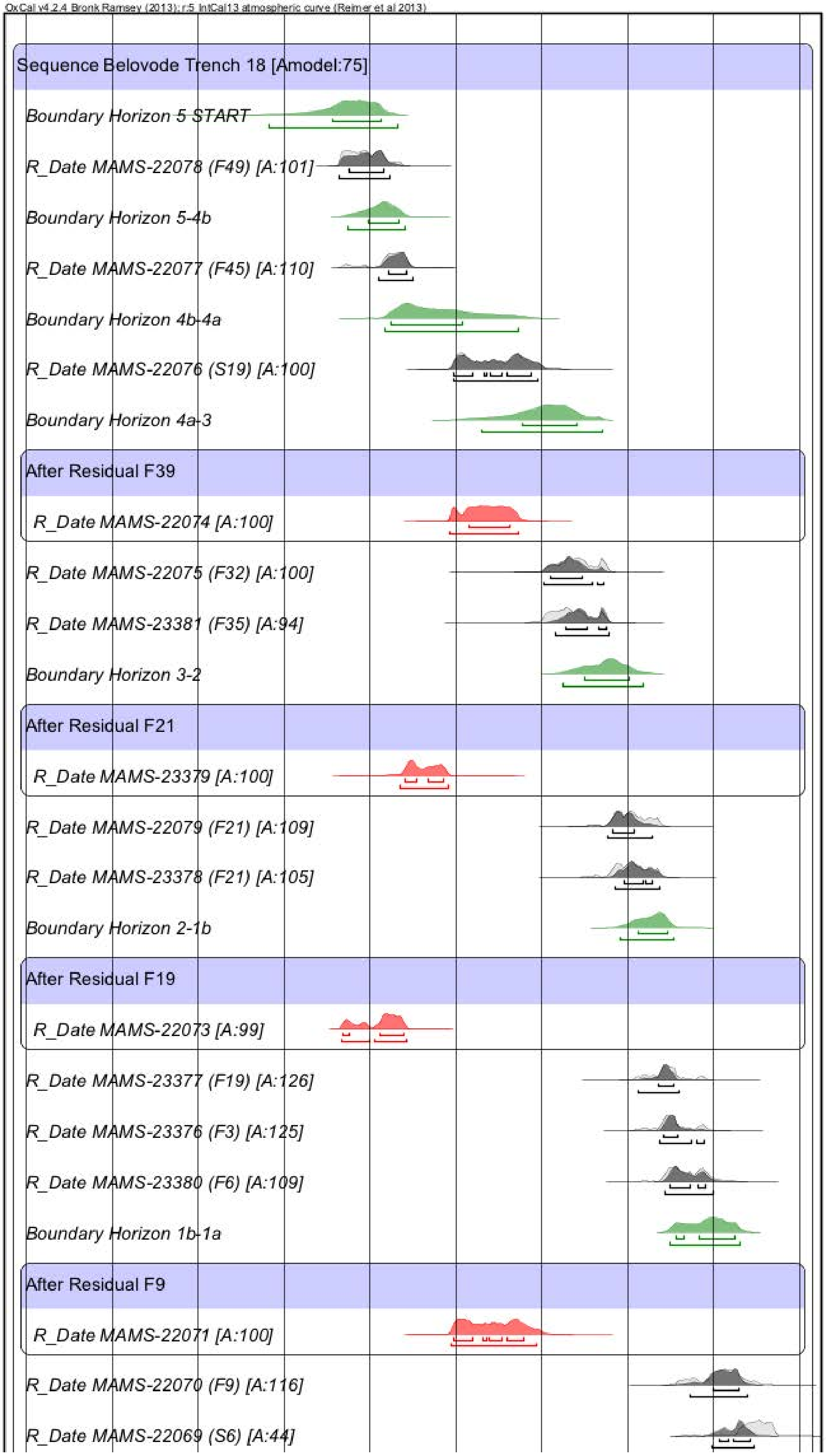


Figure 3.24. Final Bayesian model for Belovode trench 18 (green distributions represent horizon boundaries, Marić *et al.* 2021d: fig. 5, ch. 37).

that regional variations within Vinča material culture tend to increase with distance from this assemblage (**Chapman 1981: 19–31**). It is therefore challenging to connect the relative chronologies of Pločnik and Belovode, which are situated hundreds of kilometres from Vinča Belo Brdo, with the conventional chrono-typological scheme. However, by combining the relative stratigraphic sequence and the typological analysis presented above with the results of radiocarbon dating, it is possible to make some observations about the chronological development of Belovode and Pločnik in relation to Vinča Belo Brdo.

First, typological analysis of the material from trench 18 at Belovode seems to indicate a link with the South Morava Regional Variant (**Garašanin 1979: 188**). Previous typological studies suggested that Belovode had four stages: phases A to D. Phase A equates with Vinča Tordoš I, phases B and C with Vinča Tordoš II, and Phase D with the Gradac phase (**Šljivar and Jacanović 1996a, 1996b; Šljivar *et al.* 2006: 251**). The results of the typological analysis (**Mirković-Marić *et al.* 2021b**) suggest, however, that the complete range of Vinča culture phases present at Vinča Belo Brdo can also be found at Belovode. This is confirmed both by the earlier AMS radiocarbon dating of samples from the site (**Borić 2009: 209**) and by the more recent measurements carried out for the RoME project (**Radivojević *et al.* 2021a**), which suggest that the settlement began in *c.* 5350 cal. BC and ended in *c.* 4710–4520 cal. BC.

A Bayesian (**Marić *et al.* 2021e**) model was constructed by combining the two sets of absolute dates with information about the relative chronology from the excavation of trench 18 (**Figure 3.24**). The very high model agreement (Aoverall= 65:5) implies that the modelled samples support the relative chronology at the site. In addition, the model confirms that the whole spectrum of Late Neolithic Vinča culture is present at Belovode. From this model it is possible to deduce an absolute range of dates for the relative chronology (**Table 3.2**).

By comparing these results with the chronological schemes established by Garašanin and Schier (**Schier 1995, 1996**) respectively, it is possible to propose a relative chronology that can compare the developments of Belovode and Pločnik with Vinča Belo Brdo. In this scheme (**Figure 3.25)**, transitional boundaries were inserted (the blurry white regions in the Belovode/Pločnik column) to annul the slight differences in relative depth in the phasing of the Garašanin and Schier systems.

The start of horizon 5 can be modelled at 5648–5338 cal. BC (95.4%), which corresponds to the date of Starčevo burials at Vinča Belo Brdo (**Tasić *et al.* 2016b: 128, tab. 4**). Late Starčevo pottery is occasionally found at Belovode, suggesting that the location was already visited, if not inhabited, during the Middle Neolithic period (**Šljivar *et al.* 2015**).

The results indicate that the earliest Vinča settlement was established between 5452 and 5318 cal. BC (94.4%), which corresponds to the transition boundary with horizon 4b in trench 18, defined by a series of elliptical hearths and discarded kiln floors. The ceramic sherds from this sub-horizon show analogies with Vinča A pottery. This chronology corresponds to the very early Vinča phase A1 found on the Pannonian plain (**Whittle *et al.* 2016**). At Vinča Belo Brdo, this date correlates to the very end of Starčevo occupation of the site. The subsequent boundary between horizons 4b and 4a is modelled at 5366–5054 cal. BC (95.4%) and corresponds with the start of Vinča occupation at Belo Brdo itself, defined by pits at around 9.3m relative depth (**Tasić *et al.* 2016b: 136–137, tab. 8**).

The beginning of Phase B1 is modelled at around 5139–4860 cal. BC (95.0%) and corresponds to the boundary between horizon 4a and horizon 3 in trench 18. This compares to layers between 7.5m and 6.5m relative depth at Belo Brdo in Vinča (**Tasić *et al.* 2016b: 136–137, tab. 8**), i.e. the Vinča B1–B2 period (**Figure 3.25**). The Vinča B phase shows increasing activity, evidenced by the numerous pottery fragments, a large refuse pit, and a hearth with an ash deposit next to it found in horizon 3.

The transition from horizon 3 to 2, modelled at 4951–4760 cal. BC (95% probability), corresponds to the start of the Gradac phase at Belovode. This correlates to layers between 6.2 and 5.6m at Belo Brdo (**Figure 3.25**), or the Vinča Gradac–Vinča C period (**Tasić *et al.* 2016b: 136–137, tab. 8**). This period witnessed the transition from the non-metallic to the metallic phase at Belovode and equates to the Vinča C period that is represented in horizon 2 in trench 18 by several pits, one of which contains lumps of malachite ores in its infill.

The beginning of the subsequent Vinča D1 phase is modelled at 4818–4692 cal. BC (95.4%) and corresponds to the end of horizon 2 and the start of horizon 1b. The Vinča D1 phase at Vinča Belo Brdo has similar absolute dating values (**Tasić *et al.* 2016b, 136–137, tab. 8**) and corresponds to the layers between 4.9m and 4m, and Vinća C–D1 (**Figure 3.25**). The beginning of this phase at Belovode is marked by a wattle and daub structure surrounded by a pit to the south, and a hearth installation with metallic copper droplets to the east.

The modelled date for the Vinča D2 period at Belovode is 4701–4540 cal BC and corresponds to the boundary between horizons 1b and 1a, equivalent to that for Vinča Belo Brdo (**Tasić *et al.* 2015**) found in layers below 4.0m.

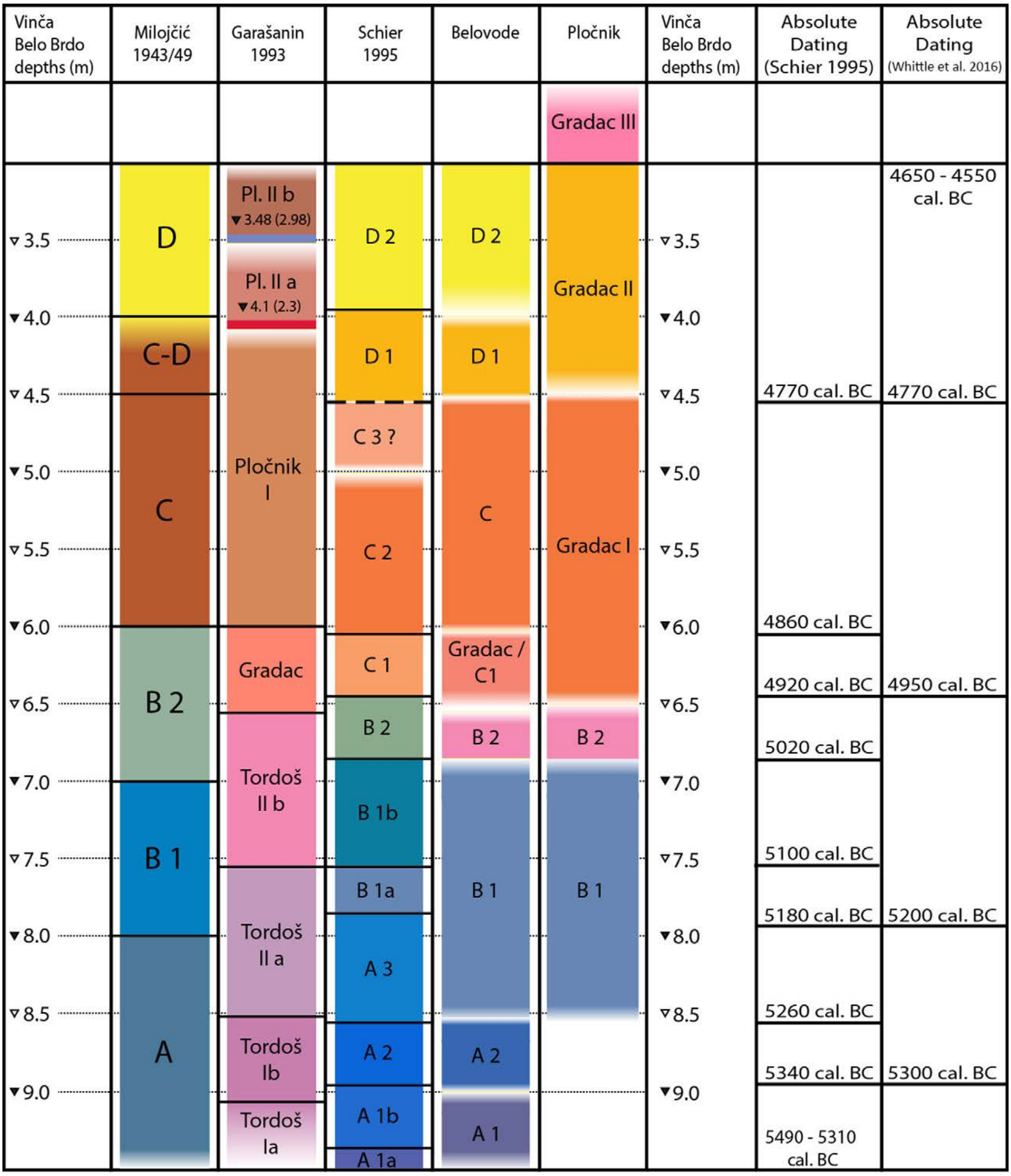


Figure 3.25. Selected chronological schemes for the Vinča culture based on the Vinča Belo Brdo pottery assemblage (modified after Schier 1996: fig. 9).

Table 3.2. Absolute dating and relative chronology phases in Belovode (after Marić *et al.* 2021d).

Posterior density	**Posterior density**	**Horizon**	**Relative Chronology**
interval (2σ)	interval (1σ)		(Belo Brdo)
4600-4400 cal BC	4564-4479 cal BC	Horizon 1a end	End Vinča D2
4702-4540 cal BC	4689-4669 cal BC (10.6%) or 4634-4549 cal BC (57.6%)	Horizon 1a start	Start Vinča D2
4817-4692 cal BC	4776-4709 cal BC	Horizon 1b start	Vinča C-D1
4951-4762 cal BC	4899-4797 cal BC	Horizon 2 start	Gradac-Vinča C
5140-4859 cal BC	5139-4859 cal BC	Horizon 3 start	Vinča B1-B2
5366-5054 cal BC	5351-5185 cal BC	Horizon 4a start	Start Vinča A
5452-5318 cal BC	5404-5335 cal BC	Horizon 4b start	End Starčevo
5648-5338 cal BC	5491-5375 cal BC	Horizon 5 start	Starčevo

Finally, the end of Neolithic life in trench 18 at Belovode is modelled at 4601–4383 cal. BC (95.4% probability) or 4571–4482 cal. BC (68.2%) This corresponds to modelled results from Vinča Belo Brdo of 4570–4460 cal. BC (**Tasić *et al.* 2015: fig. 8; Tasić *et al.* 2016b: 128, tab. 4**), but also, on a wider scale, to most of the Vinča world (**Whittle *et al.* 2016: 38, fig. 35**), especially in the Danube-Sava-Tisza region where the turn of the 46th century saw a complete abandonment of well-established occupied settlements.

It seems that the whole span of Late Neolithic Vinča culture is present at Belovode, and that this settlement began a little earlier than Vinča Belo Brdo (**Schier 1996: 160, fig. 11**).

To conclude, the evidence presented above suggests that the previously hypothesised end of the Belovode settlement during the Gradac phase can now be dismissed. The site was inhabited for about 800 years, from the end of Vinča phase A1 to phase D. Belovode therefore offers the opportunity to observe the technological development of pottery across all phases of this regional variant of the Vinča phenomenon.

Similarly to Belovode, a Bayesian model was constructed for the site of Pločnik (**Marić *et al.* 2021e**) by combining the old sets of radiocarbon dating (**Borić 2009**) and the new measurements with information about relative chronology deriving from the study of the pottery.

The resulting model (Amodel:90), presented in **Figure 3.26** (and see **Table 3.3**), suggests that Neolithic occupation of the southern part of Pločnik settlement began in 5389–5003 cal. BC (95.4% prob.), perhaps in 5180–5028 cal. BC (67.4% prob.) or 5189–5186 cal. BC (0.8% prob.). This correlates to layers between 9.3m and 7.0m relative depth at Vinča, or the Vinča A–Vinča B2 period (**Tasić *et al.* 2016b: 136–137, tab. 8**). The Late Neolithic occupation therefore seems to begin later here than at Belovode and Vinča Belo Brdo, midway through the Vinča A2 Phase. It is important to mention, however, that trench 24 was located towards the southern edge of the settlement, as the central part is covered by the modern village and could not be systematically investigated.

The boundary at the end of horizon 5 and the beginning of horizon 4 is modelled at 5121–4976 cal. BC (95.4%). This corresponds to layers between 7.05m and 6.55m at Vinča, or the Vinča B2 period in relative chronology (**Figure 3.25**). An increase in activity is evident from horizon 4, marked by several features such as the rectangular ash deposit, feature F34.

The end of horizon 4 and the beginning of the subsequent horizon are modelled at 5036–4951 cal. BC (95.4% prob.). This period corresponds to the Vinča B2–C transition, or Gradac phase (Garašanin 1979) at Vinča Belo Brdo (**Tasić *et al.* 2016b: 136–137, tab. 8**). At Pločnick, this phase shows an abundance of activity as evidenced by the edge of a burnt daub structure (feature F17) and a dismantled kiln surrounded by a large ash deposit resulting from its use (features F14/F15).

A single sample (MAMS-22086) dates the span of horizon 2. The end of horizon 3 and the beginning of horizon 2 at Pločnik is modelled at 4927–4621 (95.4% prob.), which would correspond to the layers between relative depths of 6.0m and 4.0m at Vinča Belo Brdo (**Tasić *et al.* 2016b: 136–137, tab. 8**), or the Vinča C–D1 span in relative chronology (**Figure 3.25**). Horizon 2, defined by another dismantled kiln next to the western profile and

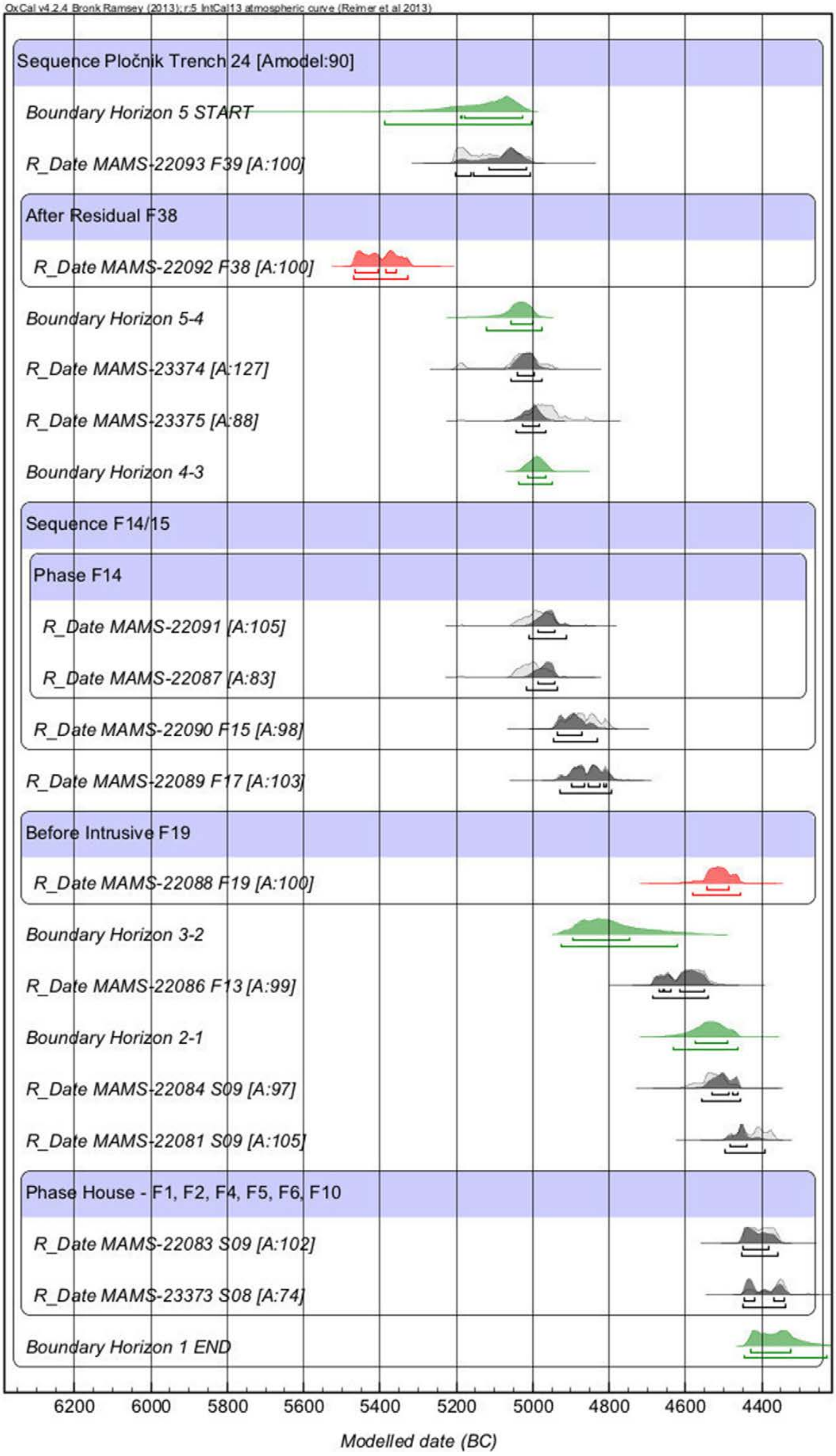


Figure 3.26. Final Bayesian model for Pločnik trench 24 (green distributions represent horizon boundaries, Marić *et al.* 2021d: fig. 8, ch. 37).

Table 3.3. Absolute dating and relative chronology phases in Pločnik (after Marić *et al.* 2021d).

Posterior density interval (2σ)	**Posterior density interval (1σ)**	**Horizon**	**Relative Chronology (Belo Brdo)**	**Relative Chronology (Jovanović 1994)**
4446-4231 cal BC	4431-4324 cal BC	Horizon 1 end	-	Gradac III
4631-4462 cal BC	4576-4491 cal BC	Horizon 1 start	Vinča D2	Gradac II
4927-4621 cal BC	4894-4747 cal BC	Horizon 2 start	Vinča C-D1	Gradac I
5036-4951 cal BC	5013-4968 cal BC	Horizon 3 start	Gradac phase	
5121-4976 cal BC	5057-5001 cal BC	Horizon 4 start	Vinča B2	Vinča B2
5389-5003 cal BC	5199-5190 cal BC (2.5%) or 5182-5028 cal BC (65.7%)	Horizon 5 start	Start Vinča A2-B1	Start Vinča A2-B1

a partially excavated pit in the northeast corner of the trench, seems to mirror the economic activity of the previous horizon. The end of the penultimate horizon at Pločnik, and the beginning of horizon 1 is modelled at 4631–4462 cal. BC (95.4% prob.), corresponding to the layers between 3.4m and 1.3m at Vinča Belo Brdo (**Tasić *et al.* 2016b: 136–137, tab. 8**), or the latter half of Vinča D2 phase and beyond.

Finally, the end of the Neolithic occupation of Pločnik and the end of horizon 1 is modelled at 4446–4231 cal. BC (95.4% prob.) or 4430–4326 cal. BC (68.2% prob.). This posterior density interval was obtained on two dates (MAMS-22083 and MAMS-23373) originating from a large, rectangular, burnt daub structure discovered *in situ* in trench 24 and erected in the final horizon of the Neolithic occupation of Pločnik. This structure was completely burnt at the end of the settlement occupation, well into the second half of the 45th or in the first half of the 44th century BC. This abrupt change in the nature of the space may indicate a new purpose given to the previously predominantly economic area, but could also reflect an increase in the number of households. Regardless of the meaning of this change, it is interesting that there is no direct comparison for this phase at either Belovode or Vinča Belo Brdo. By this period, both these settlements, together with a host of Late Neolithic sites in the wider area of the Danube and its tributaries, were long abandoned after a fiery end that occurred towards the end of the 46th and the beginning of the 45th century BC (**Tasić *et al.* 2015**).

Some authors (e.g. **Srejović *et al.* 1984**) have claimed that Vinča communities of the southern variant disintegrated under the influence of the Bubanj-Salçuta-Krivodol (BSK) complex, merging into the new societies that began occupying the Balkans area from the 45th century BC. Nevertheless, the new dates presented here, extrapolated from a strict and constrained Bayesian statistical framework, corroborate the alternative hypothesis that sees the southern variant of the Late Vinča (the metallic Vinča) culture having a longer duration than the Danubian Vinča (**Jovanović 1994**). This variant might even have had direct contact and overlap with the early BSK communities in the Central and Eastern Balkans (**Tasić 1979, 1995**), as the earliest BSK phase often shows pottery types relatable to those of the Late Vinča culture.

Chapter 4
Theoretical background

The extensive chronological range covered by this research (approximately 1000 years) offered a unique opportunity to trace developments in pottery-making traditions, allowing an exploration of phenomena related to technological continuity and change, as well as cultural transmission, during the emergence of new pyrotechnologies.

The investigative framework integrated various theoretical trajectories, drawing on a body of literature encompassing perspectives from the anthropology of technology and neo-Darwinian evolutionary approaches to cultural diversity and change. A review of the anthropological literature revealed a tension between neo-Darwinian and non-Darwinian approaches with regard to the study of cultural transmission (e.g. **Stark *et al.* 2008: 8–10**). Similar tensions are reflected within archaeology, leading to fragmentation in the discourse. These issues arise not only from the different temporal scales involved but also from genuine theoretical differences within archaeology.

More recent studies (e.g. **Charlton *et al.* 2010; Jennings and Waters 2014; Manem 2020; Radivojević and Rehren 2016; Schillinger *et al.* 2017**) have focused on technological approaches to artefact analysis, demonstrating how micro-level examinations of material evidence can offer valuable insights into long-term processes of cultural evolution, continuity, and change. This work has highlighted the power of detailed technological analysis in uncovering broader patterns of cultural transmission and technological development over time.

Inspired by this body of work, my research builds upon these approaches by incorporating the anthropology of technology, which emphasises that technologies are socially constructed (e.g. **Dobres and Hoffman 1994**; **Forte 2020; Haudricourt 1964**; **Ingold 1988, 1990; Lechtman 1977; Lemonnier 1986, 1992, 1993; Miller 2007; Olivier 1999; Pfaffenberger 1988, 1992; Roux 2019; Sigaut 1994; Van der Leeuw 1993**). This perspective is also informed by Bourdieu's theory of practice (**1977**), particularly his concept of *habitus*, which has been foundational for understanding how technical knowledge and actions are socially and culturally embedded. Taken together, these approaches encourage us to view artefacts not merely as finished products, but as material expressions of social, cultural, and technological choices made throughout the process of production. In addition, concepts drawn from neo-Darwinian evolutionary theory provide the theoretical framework within which to explain technological change and variation. Several studies offer useful models for archaeological interpretation (e.g. **Boyd and Richerson 1985; Charlton 2009; Charlton *et al.* 2010; Eerkens and Lipo 2005, 2007, 2008; Henrich 2009; Henrich and Boyd 1998; Neff 1992; 1993, 1996; O'Brien and Lyman 2000; Radivojević and Rehren 2016; Roux 2003a, 2008; Shennan 2001, 2002, 2008, 2009, 2014, 2015; Ziman 2000**).

The concept of 'recipe', as developed by O'Brien *et al.* (**2010**), is particularly relevant because it bridges both neo-Darwinian theory and non-Darwinian social anthropology perspectives in the study of ancient technology. A 'recipe' is defined as behavioural information about how to perform a task, which is transmitted among individuals or groups. This concept allows us to break down technological processes into distinct components, each representing a unit of cultural transmission. These units can be traced and examined, often with the help of material science analyses, to reveal how knowledge and practices are passed down, modified, or inspire innovation over time.

By using material science to examine artefacts at a micro-level, we can identify specific technological choices embedded in the materials, such as ingredient selection, processing techniques, and craftsmanship. This helps us track the development and transmission of these 'recipes' more precisely. By viewing recipes in this way, we can trace the mechanisms that shape the evolution of technological traditions, whether through direct transmission, innovation, or external influences. In adopting this concept, the present research deepens the connection between micro-level technological analysis and larger cultural dynamics, demonstrating the importance of technological studies in understanding both the continuity and transformation of cultural practices.

Technology and society: a theoretical overview

Technology has long been recognised as crucial to understanding human culture. Early sources, including the Old Testament (Daniel 2: 1–49) and authors like Lucretius (**1799**) and, more recently, Trigger (**2006: 104**), parallel technological changes with significant social advancements. In the 19th century, the anthropologist

Lewis Henry Morgan (**1985[1877]**) identified technological achievements as markers of social development, defining stages of human advancement by technological modes. Archaeologists like Lane Fox Pitt-Rivers (**1906**) and John Lubbock (**1872**) constructed evolutionary sequences based on formal changes in tools. V. Gordon Childe (**1925, 1944**) argued that technology evolved differently across societies due to unique ecological conditions, linking technology with science, social class, and socio-technological change. He shared with cultural ecologist Steward (**1955**) a multi-linear evolutionary perspective, viewing technology as a product of diffusion and ecological adaptation.

From the mid-20th century onwards, scholars developed various approaches to technology. Some focused on its role in driving socio-cultural change (**Wallace 1972**), examining the socio-economic and ideological processes tied to the diffusion of innovation. Others used technological systems to explore problem-solving behaviour and human cognition (e.g. **Keller and Keller 1996; Renfrew and Zubrow 1994**).

In more recent decades, following the emergence of 'New' or 'Processual' Archaeology, two dominant approaches have emerged in pottery technology studies: 'Ceramic Ecology' and the 'Functionalist Approach'. Ceramic Ecology, rooted in processual studies, emphasises the influence of the natural environment and functional context over socio-cultural factors. In other words, this perspective focuses on how the environment shapes the physical features of artefacts and the human behaviour involved in pottery production. Proponents (e.g. **Arnold 1985, 1993; Kolb 1988; Matson 1965, 1995; Rye 1976, 1981**) argue that technological choices made by potters respond primarily to environmental factors, assuming that all humans perceive the environment similarly through shared cognitive processes (**Santacreu 2014: 129**). Conversely, the Functionalist Approach (e.g. **Braun 1983; Rice 1990, 1996; Schiffer 2004; Schiffer and Skibo 1987, 1997**) emphasises the relationship between a vessel's function and the potters' behaviour, viewing vessels as products designed to fulfil specific functions.

A significant shift in the study of technology occurred with the development of perspectives that view technology both as an independent domain and as a reflection of social and cultural values (e.g. **Lechtman 1977; Lemonnier 1986, 1992, 1993; Sackett 1985**). Lechtman's concept of 'technological style' posits that the strategies used by artisans to produce objects are culturally embedded, reflecting the symbolic and structural beliefs of their society. Lechtman's studies of Andean archaeometallurgy, for example, revealed how value systems were connected with the appearance of gold and copper alloys (e.g. **Lechtman 1980, 1984**).

In France, Lemonnier represents a key example of the social constructionist approach. He defined technological systems as combinations of tools, materials, actions, and knowledge that embody both technical skills and cultural representations (**Lemonnier 1986: 154**). His work, rooted in the Francophone tradition known as the 'Anthropology of Techniques', draws heavily on the ideas of Marcel Mauss and Leroi-Gourhan (**1964**), emphasising the complex links between technology and its socio-political context. Mauss, in his 1934 article, 'Les techniques du corps', defines bodily techniques as the culturally learned ways in which people use their bodies, that are essential for understanding how technological knowledge is transmitted across generations (**Mauss 1950: 365; Olivier 1999; Wolff 2010: 338**).

Leroi-Gourhan introduced the concept of *chaîne opératoires* (for a recent history of the concept, see **Delage 2017**). Although this intellectual tradition was not initially well known in Britain and America, it later gained significant influence, with technology being analysed in terms of cultural choices even beyond the discipline of anthropology (e.g. **Ingold 1988, 1990; Pfaffenberger 1988, 1992**). This led to a revitalisation of technological studies within archaeology (e.g. **Dobres and Hoffman 1994, 1999; Schiffer 1992; Schiffer and Skibo 1987, 1997; Van der Leeuw 1993**). Given the impact of the *chaîne opératoire* approach in archaeology, its origins, applications, and its potential for interpreting technological phenomena will be explored here in greater detail.

Chaîne opératoire and technological choices

The study of technological processes in ancient artefact creation has been greatly influenced by the concept of *chaîne opératoire*, first systematised by Leroi-Gourhan. In the 1950s, Leroi-Gourhan, influenced by the work of French anthropologists (**Maget 1953**; **Mauss 1947**) as well as François Bordes' flint knapping experiments, recognised the value of analysing technical processes as sequences of meaningful operations (**Audouze 2002**). He developed the idea that 'Techniques are simultaneously gestures/movements and tools, organised in sequence by a true syntax, which gives the operational series both stability and flexibility. The operational syntax is generated by memory and arises from the dialogue between the brain and the material realm' (**Leroi-Gourhan 1964: 164**). This concept frames production as a physical and cognitive process requiring coordination between body and mind (**Bril 2002**). The notion of *chaîne opératoire* highlights the importance of reconstructing the steps needed to produce an artefact, providing a mnemonic for describing the techno-gestures preserved in the archaeological record. Its introduction marked a shift from focusing solely on morphology, typology, and function (**Dobres 1999: 124**).

Cresswell (**1990: 46**) defines *chaîne opératoire* as 'a series of technological operations which transform a raw material into a usable product.' Lemonnier expands on this, describing operational sequences as actions that transform raw materials from a natural to a manufactured state, linked to knowledge and know-how (**Lemonnier 1986: 8**). While the focus on techno-gestures in *chaîne opératoire* has somewhat waned, Lemonnier, through ethnographic research, argues that these sequences must be understood within the technological knowledge of a group. This implies that artisans' behaviour should not be viewed solely from a functionalist perspective but in relation to the cultural context in which they are operating. He also emphasises the factor of choice among a range of options to achieve the same goal, building on Sackett's work. This broader interpretation of *chaîne opératoire* also entered Anglo-American archaeological discourse (e.g. **Dobres and Hoffman 1994; White 1989, 1997**) and was applied more widely. Dobres (**1999: 124**) highlights this approach, which views techniques as actions within a social context, linking technical acts with socio-political dimensions of production. She also emphasises the relationship between technological practices and agency, arguing that makers shape both objects and themselves, actively moulding traditions rather than passively inheriting them.

Francophone archaeologists and anthropologists like Valentine Roux have maintained a focus on physical techno-gestures and their syntax during production, as seen in studies of lithic production (**Sellet 1993**) and pottery manufacture (**Roux 2010**). This approach is deeply rooted in ethnographic inquiry, where detailed observation of craft practices in contemporary contexts plays a central role in understanding past technologies (e.g. **Gelbert 2003**; **Gosselain 2002; Kramer 1997**). Therefore, in the works of Francophone scholars, there is a strong emphasis on pottery forming and finishing techniques. According to ethnographic studies, this stage of manufacturing is considered one of the most stable aspects of pottery making (**Manem 2020** and literature therein). It is influenced by ecological psychology, which examines how motor skills are transmitted and selected within cultural contexts. (**Bernstein 1967; Bril 2002; Gibson 1979**). This culturally driven selection of motor skills recalls Mauss's concept of bodily techniques, acquired during apprenticeship and resistant to change (**Mauss 1950: 365**).

This perspective explains why forming techniques seem to be more stable within certain social groups (**Arnold 1985; Bril 2002; Roux 2007**). As a result, many French archaeologists (e.g. **Gomart 2014; Manem 2012**) studying ancient pottery focus on the manufacturing stage, identifying macro-traces left by potters that reflect their techniques and integration into particular social groups. Thus, the apprenticeship process and transmission of tradition are both key to understanding cultural identity and the interaction between people and technology.

Another significant development in relation to *chaîne opératoire* is Lemonnier's concept of 'technological choices' (**1992**), which views artefacts as the result of culturally embedded choices at different production stages. These choices, including the selection of materials and techniques, reflect cultural aspects like identity, beliefs and social status, offering insights into the organisation of past societies. To understand pottery production, it is argued, archaeologists should investigate why certain techniques were preferred over others (**Van der Leeuw 1993**). This approach has been well-received in Anglo-American literature, especially in archaeological science, with the term 'technological choices' appearing in over 70 papers published in *Archaeometry* and the *Journal of Archaeological Science* between 2000 and 2010 (**Martinón-Torres and Killick 2015**).

Sillar and Tite (**2000**) integrate *chaîne opératoire* and 'technological choices' with a behavioural approach developed by Schiffer (**1975, 1976, 1996, 1999, 2000, 2002, 2004, 2005a, 2005b**) and his colleague Skibo (e.g. **Schiffer and Skibo 1987, 1997; Schiffer *et al.* 2001**). These authors explain variability and changes in production technology in terms of constraints imposed by performance characteristics. These characteristics, necessary for each activity within an artefact's life cycle, are influenced by the situational context (environment, technology, economy, society, politics, ideology). According to Sillar and Tite, each 'technological choice is dependent on other technological choices which go together to form a particular *chaîne opératoire* that produces a pottery vessel with specific properties and performance characteristics' (**Sillar and Tite 2000: 5**). They also incorporate the concept of 'technological style' (**Lechtman 1977**), which reflects both conscious and unconscious factors influencing technological choices.

Despite the success of *chaîne opératoire* and 'technological choices', this approach has faced criticism. Neff (**Cumberpatch *et al.* 2000**) argues that such concepts address only proximate causes and fail to explain why specific choices become manifest or why technology varies over time and space. Neff suggests that proponents of 'technological choice' need to 'think about how long-run effects emerge out of technological decisions made in the short run', as these long-term evolutionary effects determine the archaeological record, which is what we must ultimately seek to understand (**Cumberpatch *et al.* 2000: 280**). Thus, Neff concludes that archaeology needs a framework that encourages questions about historical processes and how they shaped technological diversity and change.

Technological change

The study of technological change has long been central to various scientific disciplines, each developing explanatory models that link technical systems with social contexts (e.g. **Akrich 1994; Dobres and Hoffman 1994, 1999; Lechtman 1977; Lemonnier 1986, 1992, 1993; Leroi-Gourhan 1973; Pfaffenberger 1992**). These models often depend on the duality that exists between technology and society, which can be seen either as an explanatory paradigm or a method of investigation (**Akrich 1994; Roux 2003a: 3**).

As an explanatory paradigm, this duality suggests that external needs drive technological evolution, while internal rules regulate the specifics of change (e.g. **Gille 1978**). Some scholars focus on the technical system's internal dynamics, with social, economic, and political factors acting as triggers, while others highlight mutually reinforcing interactions between technology and society as the primary drivers of change (e.g. **Leroi-Gourhan 1973; Marx 1967**).

When viewed as a heuristic method, research into technological change seeks to understand the specific rules governing this process, often through the analysis of artefacts' *chaîne opératoire* (**Roux 2003a: 4**). Behavioural archaeologists (**Schiffer 2002, 2004, 2011; Schiffer and Skibo 1987, 1997; Skibo and Schiffer 2001**) advocate a 'life history' approach, which considers the behavioural chain of an artefact as shaped by technological choices influenced by behavioural, social, and environmental factors. Variability in artefact design is seen as a compromise between performance characteristics and formal properties, influenced by the producer's apprenticeship (**Schiffer and Skibo 1997: 33–34**). This approach seeks to explain variability and change in human behaviour by studying the relationships between people, their artefacts, and their environment (**Schiffer 1996: 645**), using tools like performance matrices to compare technological solutions (**Schiffer 1995**).

Some scholars, however, reject the dualism between technology and society, arguing that they form an inseparable whole, with technological change rooted in the socio-cultural matrix (e.g. **Latour and Lemonnier 1994; Lemonnier 1993; Pfaffenberger 1992**). This view emphasises that cultural forms of representation shape technological practices (**Miller 1987**), though it struggles to explain why similar tools and techniques arise from different cultural logics.

Another approach, derived from 'ecological' and 'perception-action' perspectives (e.g. **Bril *et al.* 1998, 2000; Ingold 2001; Roux and Corbetta 1989**), views technological practices and skill acquisition as outcomes of interactions between tasks, the environment, and the subject, without relying on pre-existing cultural representations. This aligns with Roux's 'dynamic system' theory, in which change results from interactions among various components, rather than from cultural construction (**Roux 2003a**). Roux's concept of the 'technological fact' describes a system where technological change is the result of interactions between non-hierarchically ordered components such as technical tasks, the environment, and the subject across social and technological domains (**Roux 2003a**).

A breakthrough in the study of technological change in archaeology came with the development of 'dual-inheritance theory' within the evolutionary neo-Darwinian framework (**Boyd and Richerson 1985; Cavalli-Sforza and Feldman 1981; Prentis 2019; Shennan 2002**). Neo-Darwinian theorists argue that cultural evolution, like biological evolution, is governed by processes of variation, adaptation, and natural selection (**Jablonka and Ziman 2000: 13–14**). This approach has been applied to issues of technological knowledge transmission and change (e.g. **Manem 2020** and literature therein), offering clear mechanisms for explaining technological change, which are often lacking in other models.

In archaeological discourse, common approaches include 'human behavioural ecology' (HBE), which focuses on the relationship between behaviour and environmental context (e.g. **Fitzhugh 2001; Smith and Winterhalder 1992; Ugan *et al.* 2003**), and 'selection archaeology' which, along with 'dual-inheritance theory', dominates the debate. Selectionists view cultural behaviour as part of the human phenotype, explained by drift, mutation, and selection. In contrast, dual-inheritance archaeologists incorporate both anthropological and evolutionary theories, emphasising that cultural transmission through social learning is influenced by cultural biases, which can lead to maladaptive behaviours in terms of survival and reproduction.

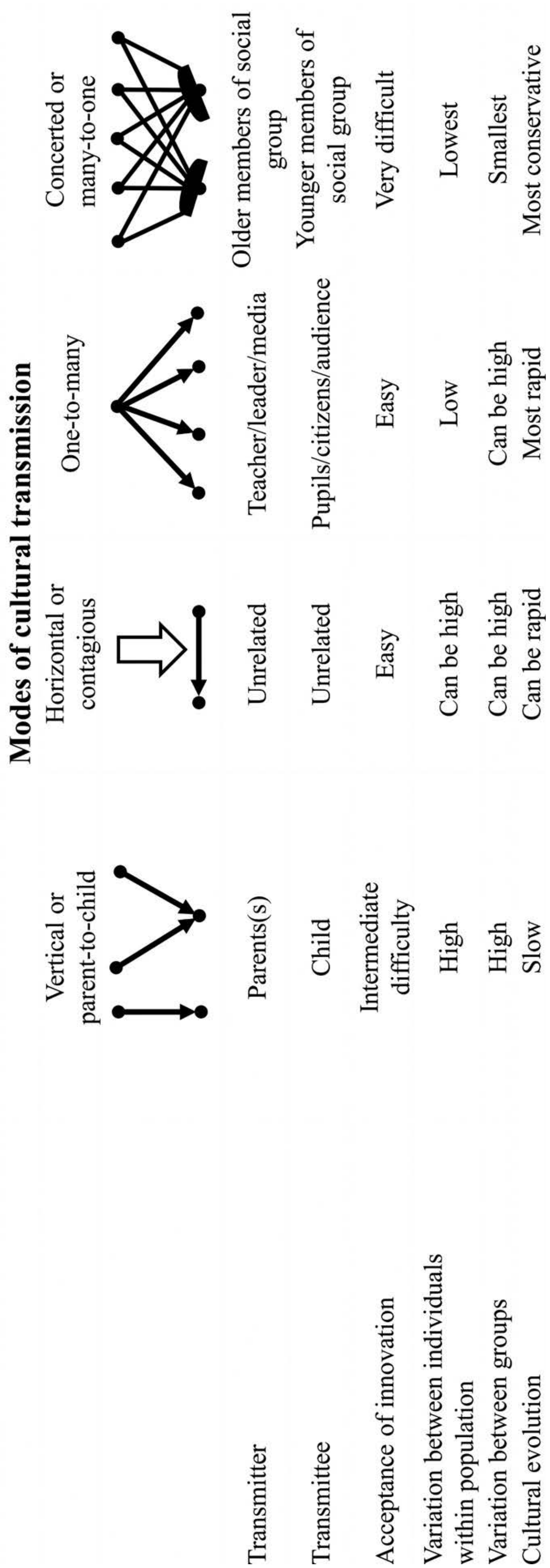
The dual-inheritance approach is particularly valuable because it provides a clear set of mechanisms to explain technological change – something other approaches often lack. The next sections discuss this theory in detail, including its application to the study of technological change within the research presented in subsequent chapters.

Cultural transmission theories and social learning

Cultural transmission theory, or cultural learning, posits that behaviours are learned from the surrounding society or culture. It addresses how and why beliefs, ideas, and behaviours are transmitted across generations, a central concern for understanding cultural persistence and change (**Stark *et al.* 2008: 2**). Archaeology scholars have long been interested in these processes, using the material remains left by people to trace cultural trajectories, social systems, and group boundaries over time.

In archaeology, two key concepts are used to explore ideas of learning and cultural transmission. The first relates to communities of practice and is rooted in situated learning theory. This concept refers to groups sharing common enterprises, such as crafts, and the related learning networks (**Lave and Wenger 1991; Wenger 1998**). Within these communities, members learn from each other through shared experiences, with knowledge deriving from daily participation in social life. Specifically, the concept of 'legitimate peripheral participation' is introduced as a means of learning within communities of practice. Learning occurs gradually, beginning at the periphery of the community when an apprenticeship starts and progresses toward full participation as mastery of the practice is achieved. Legitimate peripheral participation is a key concept in communities of practice, closely tied to the apprenticeship experience. Additionally, knowledge transmission happens both vertically, as masters pass down expertise to apprentices, and horizontally, as apprentices learn from one another within the group. This approach has been applied by archaeologists interested in socialisation, identity, and social reproduction, with an emphasis on microscale patterns in cultural transmission (e.g. **Eckert 2008, 2012; Huntley 2008; Sassman and Rudolphi 2001**).

The second major direction in archaeology is the dual-inheritance theory of the neo-Darwinian approach, where cultural transmission is seen as the primary mechanism for the evolution of cultural features (e.g. **Boyd and Richerson 1985, 2005; Cavalli-Sforza and Feldman 1981; Mesoudi and O'Brien 2008; Shennan 2008**). Cultural transmission in this context is defined as 'the process of acquisition of behaviours, attitudes, or technologies through imprinting,


Modes of cultural transmission

	Vertical or parent-to-child	Horizontal or contagious	One-to-many	Concerted or many-to-one
Transmitter	Parents(s)	Unrelated	Teacher/leader/media	Older members of social group
Transmittee	Child	Unrelated	Pupils/citizens/audience	Younger members of social group
Acceptance of innovation	Intermediate difficulty	Easy	Easy	Very difficult
Variation between individuals within population	High	Can be high	Low	Lowest
Variation between groups	High	Can be high	Can be high	Smallest
Cultural evolution	Slow	Can be rapid	Most rapid	Most conservative

Figure 4.1. Modes of cultural transmission and their biases on the production of variation (modified after Cavalli-Sforza *et al.* 1982: 21, fig. 1 and Hewlett and Cavalli-Sforza 1985: 923, fig. 1).

conditioning, imitation, active teaching and learning, or a combination of these' (**Cavalli-Sforza *et al.* 1982**). Here, social learning, where individuals learn from one another, is the most important mechanism driving cultural transmission (**Shennan 2014**).

Cavalli-Sforza and Feldman (**1981**) propose a model of cultural transmission, outlining different modes that help predict within-group variability and stability of cultural traits over time (**Figure 4.1**). Vertical transmission, from parent to child, is conservative and maintains the status quo, making innovation slow to spread unless other modes are involved. Horizontal transmission, occurring between individuals regardless of their relationship, can lead to rapid cultural evolution, especially with frequent contact. One-to-many transmission is efficient, enabling swift cultural change, while many-to-one transmission, where a single recipient is influenced by many transmitters, generates high uniformity (**Cavalli-Sforza and Feldman 1981**).

Mechanisms of cultural transmission in dual inheritance theory

A range of sorting mechanisms and constraints (biases) play a significant role in patterning cultural change over time and form the basis of cultural evolutionary approaches. One such sorting mechanism, analogous to genetic drift, is stochastic sampling error without selective or path-dependent bias. This means that the frequencies of certain cultural attributes change randomly, leading some traits to be transmitted more often than others, while some may not be transmitted at all.

Selection is another crucial mechanism, affecting both humans and other animals. Individuals whose genes or cultural attributes better fit the environment are more likely to survive and reproduce, making these traits more prevalent in future generations. Selection also operates through cultural traits that are advantageous and more likely to be imitated.

In addition to selection, biases collectively known as constraints affect cultural transmission. These include immanent and configurational constraints (**O'Brien and Lyman 2000: 336; Smith *et al.* 1985**). Immanent constraints are physical laws that limit the possible range of technological configurations. For example, engineering-design constraints restrict the range of possible technological variants. Another immanent constraint is pleiotropy, where the transmission of one attribute affects related traits. This is particularly relevant in technological contexts. For instance, selecting a specific paste recipe in pottery manufacturing may constrain the choice of forming technique and *vice versa* (**Sillar and Tite 2000: 5**). Resource-based constraints, linked to environmental factors, also influence the success or failure of a technology.

At the behavioural level, configurational constraints impact what people try to imitate, affecting patterns of variation. 'Results bias' occurs when people change their behaviour because they observe more successful methods. 'Content biases' refer to features that are more easily transmitted and remembered due to cognitive factors, such as fairy tales (**Washburn 2001**). 'Context bias' involves copying behaviour based on the social context, such as imitating prestigious individuals ('prestige bias') or conforming to the majority ('conformist bias').

Units of cultural transmission

The processes described above consider both the agent involved and the factors influencing their decisions. While important, this is not the only perspective. Archaeologists typically focus on cultural attributes such as artefacts, which are the primary data available to them. This leads to a crucial debate within dual-inheritance theory regarding the units of cultural transmission. In evolutionary analysis, three theoretical units are typically considered: the individual (equivalent to the gene in genetics), the lineage, and the environment. Cultural selectionism, paralleling dual-inheritance theory, hypothesises the existence of transmission units analogous to genetic replicators, often referred to as memes, culture genes, or cultural viruses (e.g. **Cullen 1993; Dawkins 1989; Rindos 1985**).

Evolutionary archaeologists have explored the use of different units to track cultural transmission, focusing on the concept of the 'cultural trait'—the unit that enables the diffusion and establishment of traditions, defined as 'patterned ways of doing things that exist in identifiable form over extended periods of time' (**O'Brien *et al.* 2010: 3797**). Cultural traits, transmitted through behaviour, are typical of the human phenotype and act as units of replication subject to recombination and copying errors, potentially leading to new traits (**Eerkens and Lipo 2005**). Although these units are not directly observable, artefacts and other components of the archaeological record serve as proxies for studying cultural transmission (**O'Brien *et al.* 2010: 3797**).

Evolutionary archaeologists have developed methods like seriation (e.g. **Allen 1996**) and cladistics (e.g. **O'Brien *et al.* 2010**) to build and explain artefact lineages, enabling analysis of the evolution of artefact shapes and structures, as well as the direction of change. Other research (**Fitzhugh 2001; Eerkens and Lipo 2005**) highlights the role of invention and manufacturing techniques in constraining artefact

Table 4.1. Summary of key aspects of the concept of recipe.

Key Aspect	**Summary**
Flexibility and Detail	Recipes can be broken into steps for detailed analysis and tracking of technological transmission.
Cultural Transmission	Focus on how knowledge is inherited, modified, or innovated over time.
Behavioural Focus	Highlights the social and behavioural aspects of knowledge transfer.
Evolutionary Framework	Integrates Darwinian and non-Darwinian perspectives to explain technological change.
Integration with Material Science	Uses material science to trace artefact composition and technological choices.

evolution. For instance, Eerkens and Lipo (**2005, 2008**) studied morphological variability in projectile points and ceramics produced over 1500 years, simulating the effects of different transmission biases—unbiased, conformist-biased, and prestige-biased. They found that variation increased under unbiased conditions but was suppressed under conformist and prestige biases. In ceramics, low variation over 400 years suggested conformist or prestige-biased transmission, while increased copy-error in another period indicated intentional design innovation (**Eerkens and Lipo 2005: 329, 2008: 80**).

Recipes as units of transmission

Evolutionary concepts can be applied to technological and compositional data to investigate technological traditions (**Charlton 2010; Manem 2020** and literature therein). Tool construction involves a sequence of actions that transform raw materials into finished products. Cognitive psychologists Mesoudi and Whiten (**2004**) suggest that tools can be understood as interlinked, hierarchical knowledge structures, much like recipes. In this way, artefacts can be seen as the result of transmitted recipes.

The concept of a recipe as a unit of cultural transmission is particularly valuable. Firstly, recipes represent behavioural information exchanged among people, encapsulating cultural traits. They link ingredients and procedures that can be recombined to create different products (**Eerkens and Lipo 2007)**. Secondly, recipes are ideational, meaning each product is an imperfect expression of the original recipe, with variation arising from factors like raw materials and skills (**O'Brien *et al.* 2010**). This ideational nature allows recipes to be studied at various scales and broken down into subroutines, such as the stages in pottery production—selection, processing, forming, decoration, and firing. This flexibility enables a more nuanced analysis of technological processes, from simple actions to complex traditions (**O'Brien *et al.* 2010**).

Moreover, the recipe concept effectively bridges different theoretical approaches (**Table 4.1**). It serves as a robust unit of transmission within an evolutionary framework while also connecting to the *chaîne opératoire* and technological choices approaches. While both concepts examine sequences of operations, the recipe model emphasises behavioural information and enables technological processes to be broken down into smaller, transmissible units. This makes it particularly useful for studying cultural transmission and technological change over time.

Finally, it better reflects the nature of the technological analysis carried out in the study presented here, which places a strong emphasis on the elements of recipes related to the selection and processing of raw materials and pyrotechnology, rather than on reconstructing the techno-gestures related to forming and finishing techniques typical of the Francophone approach to the *chaîne opératoire*.

The role of material science in reconstructing recipes

As discussed, every artefact can be seen as the empirical realisation of a technological recipe, which can be divided into subroutines. This concept is particularly applicable to pottery making, which includes sub-practices like raw material selection, paste preparation, forming techniques, decoration, and firing. Although there are limitations in reconstructing the detailed processes followed by artisans, studying artefacts as technological recipes helps us to trace human behaviour and understand how it is transmitted over time.

To reconstruct these artefact-making recipes, archaeologists use macro-observations alongside various archaeometric analyses. These methods offer a level of resolution that simpler macroscopic analyses cannot achieve. A materials science-based approach has proven invaluable in understanding ancient technologies, revealing patterns in raw material selection, provenance, and manufacturing processes (e.g. **López Varela 2019; Martinón-Torres and Killick 2015; Quinn 2013; Pollard *et al.* 2023; Rice 2015; Tite 1995, 1999; Tite *et al.* 2001; Torrence *at al.* 2015**). For these reasons it is a very important tool for reconstructing technological recipes.

Charlton (**2007, 2009**), for example, developed a model for identifying smelting lineages through the chemical characterisation of iron slags from different periods. This research indicated that while selection shapes iron-making recipes, physical and social biases play crucial roles in determining technological solutions and learning. Specifically, the results show that Welsh smelters experimented with or adjusted recipes in response to a competitive market.

In pottery studies, a materials science approach is particularly useful for reconstructing subroutines related to raw material selection and processing. Clay selection and preparation are commonly addressed topics, often through functionalist approaches that view ceramics as adaptations to environmental and functional constraints. However, ethnographic studies highlight the cultural factors influencing these practices, which are transmitted and acquired during apprenticeship (**Arnold 1993; Gosselain and Livingstone Smith 2005; Livingstone Smith 2015**).

Quinn (**2013**) suggests considering petrographic fabrics as representative of paste recipes, defined by their constituents and preparation methods. This perspective allows a focus on culturally significant compositional patterns and their relation to technological traditions. Neff (**1993, 1996**) further proposes applying evolutionary concepts to technological and compositional data, such as chemical and petrographic pottery groups. Pottery with similar compositions most likely originates from regions where people shared technological traditions regarding clay collection and raw material processing. The persistence of a paste recipe indicates the transmission of this knowledge (**Neff 1996: 269**).

Application to the present study

This chapter provided an overview of key approaches to studying technology and technological change, with a focus on the concepts of *chaîne opératoire* and 'technological choices', both central to the research presented here: artefacts are understood as the result of the deliberate decisions of the artisans, made from a range of possibilities within the technological process. In addition, the study foregrounds the social context of learning, aligning with the concept of communities of practice. However, while these models focus on artefacts and production communities in a synchronic context, this research adopted a diachronic and dynamic approach to technology. To achieve this broader perspective, it incorporated the neo-Darwinian dual inheritance theory, particularly the idea of technological recipes (**O'Brien *et al.* 2010**), which integrates both Darwinian and non-Darwinian frameworks, making it especially suited for exploring continuity and change in material culture.

Our characterisation of cultural lineage, while drawing on evolutionary frameworks, remains fundamentally qualitative. It is not based on phylogenetic reconstruction or cladistics, but rather on identifying continuities and shifts in technological practices as indicators of shared traditions and social learning. Although the available analytical tools limited the complete reconstruction of the pottery recipes used at the study sites, and the high degree of material fragmentation hindered a detailed understanding of vessel-forming techniques, the ideational nature of recipes allowed for their investigation at various scales. This research primarily focussed on subroutines related to raw material procurement and processing, as examining paste recipes and their transmission provides key insights into cultural transmission and social learning. Additionally, the research addressed pottery firing techniques, with the goal of reconstructing firing routines and investigating potential technological links between pottery and metallurgy. In doing so, this study offers a qualitative reconstruction of how specific aspects of pottery recipes might have evolved at the two sites during the emergence of metallurgy, highlighting the value of integrating anthropological and evolutionary perspectives in understanding technological change.

Chapter 5
Materials and methods

A variety of methods were employed to conduct a comprehensive technological characterisation of the pottery assemblages under study. These included both macroscopic and archaeometric methods. The latter were conducted using thin section petrography, wavelength dispersive X-ray fluorescence (WD-XRF), and X-ray powder diffraction X-ray powder diffraction (XRPD), and scanning electron microscopy (SEM). The sampling strategy and the methods applied are discussed in more detail below but first a brief overview of previous research on Vinča ceramic technology is presented.

Interdisciplinary approaches to Vinča ceramics

The first extensive and published technological study on Vinča ceramic technology was conducted almost 30 years ago by Kaiser (**1984, 1989, 1990, Kaiser *et al.* 1986; Tringham *et al.* 1992**). He focused on three sites, Gomolova, Selevac and Opovo, and reconstructed different aspects of pottery technology and the organisation of production, using macroscopic and archaeometric analyses (thin section petrography, scanning electron microscopy, thermal expansion analysis). He found no clear evidence that Vinča pottery was produced by specialists, and all the analysis supported the hypothesis of a model of domestic pottery production within the Vinča culture. In addition, Kaiser focused his research to shed new light on the conventional theory that sees a connection between pottery and metal pyrotechnology in the Balkans **(Gimbutas 1976; Renfrew 1969**).

The last few years have seen a growing interest in different issues related to pottery technology and society (e.g. **Gajić-Kvaščev *et al.* 2012a, 2012b; Lewis and Chatzimpaloglogou 2025; Spataro 2014; Vuković 2010, 2011**). For example, Spataro (**2014**) carried out a technological study on samples from the Romanian Neolithic sites of Miercurea (Harghita County) and Parța (Timiș County) in which she compared Starčevo-Criş and Neolithic Vinča pottery. Using archaeometric methods, she analysed aspects relating to the selection and processing of raw materials, revealing elements of continuity and change in pottery traditions during the transition from the Middle to the Late Neolithic period. She also analysed ceramics from the eponymous site of Vinča Belo Brdo (**2018**) to address the topic of specialisation by looking at the production process.

Conversely, Gajić-Kvascev developed non-destructive methods for provenance analysis using p-XRF (**Gajić-Kvaščev *et al.* 2012a**) and also studied the pigments used for pottery decoration. For example, for the Vinča culture site of Pločnik, she investigated the red pigment used for vessel decorations through an integrated approach utilising archaeometric analyses. This revealed that the pigment was cinnabar (**Gajić-Kvaščev *et al.* 2012b**). This was a very important and unexpected result since there are no known sources of this mineral in the vicinity of Pločnik and it was suggested that cinnabar was brought from the Mount Avala region, more than 300km away.

Vinča pottery technology has also recently begun to be studied in Hungary by Kreiter at the site of Maroslele (**Kreiter *et al.* 2011**). This Late Neolithic site is characterised by the co-existence of Alföld Linear and Vinča material culture. In his study, Kreiter investigated the technology of both productions, concluding that the local production of Vinča ceramics at Maroslele was based on a ceramic tradition entirely distinct from the Alföld Linear pottery. This could indicate the presence at the same site of potters with different ceramic technological traditions.

In addition to these studies, my own PhD research (**Amicone 2017, 2021a, 2021b; Amicone *et al.* 2020a, 2020b, 2021a),** now published in full here, made a significant contribution to the technological understanding of Vinča pottery. Focusing on pottery from the Vinča culture sites of Belovode and Pločnik in Serbia, this research applied a comprehensive range of archaeometric methods. It examined not only the technological choices in raw material selection and processing but also the firing conditions and the organisation of production. The analyses provided key evidence that contributed to the broader discussion on the relationship between ceramic and metallurgical technologies. As mentioned above, my PhD research was not the first to address this topic with a number of studies prior to my own research also seeking to establish pyrotechnological links not only within Vinča material culture, but also in the wider Balkan region;

new studies continue to clarify the processes and social dynamics at play.

Pyrotechnological connections: pottery and metallurgy

The earliest investigation of the pyrotechnological link between pottery and metallurgy in the Balkans was carried out by Frierman (**1969**), who analysed a late 5th millennium BC dark-burnished sherd decorated with graphite from the site of Karanovo in Bulgaria (Karanovo VI) via thermal analysis. He estimated that the sample had been fired to a temperature of around 1050°C in a strongly reducing atmosphere which was beneficial for graphite application, since under oxidising conditions graphite burns off above *c.* 725°C. Frierman (**1969**) therefore suggested that firing took place in a kiln, given the high temperature and prolonged period of reduction required to produce this type of pottery. This finding was taken forward by Renfrew (**1969: 38**) who suggested that 'refractory technology in the south-east European Chalcolithic had evolved sufficiently in the firing of pottery to provide the conditions required for smelting and casting of copper'. However, a few years later, Kingery and Frierman (**1974**) re-fired the same sherd at 700, 800, 900 and 1000°C in reducing conditions and concluded that it had in fact been subjected to a maximum temperature of <800°C, and possibly as low as 700°C.

Kaiser *et al.* (**1986**) studied the firing temperature of dark-burnished pottery and other ceramic types from the Vinča culture sites of Selevac and Gomolava in Serbia via thermal expansion (see also **Kaiser and Lucius 1989**) and SEM to document the vitrification microstructure. This indicated that the ceramics they studied had been variously fired at between 850 and 1000°C under oxygen-poor conditions. Despite this variability, the authors concluded that potters of the western Balkans were routinely capable of achieving temperatures of 1000°C under reducing atmospheres, and that this pointed to a sophisticated knowledge of the firing process, including managing the required resources of labour, fuel and time. Since the pottery came from different contexts at these two relatively distant sites (around 100km apart), it may be inferred that this knowledge was widely shared between Vinča culture communities at the time and could have been transferred to craftspeople who specialised in other pyrotechnologies, such as the smelting of copper metal.

Other studies on the firing of dark-burnished and graphite-painted pottery from the Balkans and Greece include those by Gardner (**1978, 1979, 2003**), Goleanu *et al.* (**2005**), Maniatis and Tite (**1981**), Perišić *et al.* (**2016**), Spataro (**2014, 2017, 2018**) and Yiouni (**1995, 2000, 2001**). Among these, Perišić *et al.* and Spataro focused especially on Vinča pottery. Perišić and co-workers (**2016**) analysed ten samples from Pločnik, but only a few were dark-burnished, and their typology and chronology were not contextually secure. Spataro (**2018**) researched materials from Vinča Belo Brdo, originating from contexts excavated between 1930 and 1936 by Miloje Vasić, which have no direct association with metal artefacts from this site. All these studies applied a wide range of techniques including thin section petrography, SEM, re-firing tests, Fourier Transform Infrared (FTIR) spectroscopy, XRPD and thermo-analytical studies. These investigations revealed that firing temperatures were highly variable and, contrary to the findings of Frierman (**1969**) and Kaiser *et al.* (**1986**), did not appear to have exceeded 900°C. Gardner (**1978, 2003: 289**) observed that graphite-painted vessels from Phase III at the site of Sitagroi in Greece had a red core, suggesting that the firing process involved two steps. This may have included an initial firing step under oxidising conditions below 700°C, followed by a second, smoky, reduction phase.

From this overview it is quite clear that prior to the work reported in this volume, considerable uncertainty surrounded the topic of Late Neolithic/Chalcolithic ceramic pyrotechnology in the Balkans, particularly regarding the conditions required to achieve dark-burnished and graphite-painted decorations and their role in the inception of early metallurgy. Too much emphasis was placed on firing temperature with little attention given to other pyrotechnological parameters such as the redox conditions and length of firing. Firing conditions are crucial to the process of smelting copper (**Gardner 1979: 20–21; Rehren 1997**). A reducing environment is required for the formation of metallic copper, with the chemical transformation beginning at temperatures as low as 700°C. In contrast, an oxidising environment and a further increase in temperature, reaching the melting point of pure copper at 1083°C, are necessary to initiate the physical change from solid to liquid metal (**Pollard et al. 1991; Radivojević et al. 2010**).

Building on this extensive body of research, the technological study presented here re-examined the relationship between pottery firing technology and early metallurgy in the Vinča Culture at the sites of Belovode and Pločnik, Serbia, with a more nuanced perspective that drew on a deep understanding of the pyrotechnologies involved in both crafts.

Macroscopic classification and sampling strategy

Pottery assemblages recovered from trench 18 at Belovode and trench 24 at Pločnik were classified macroscopically based on various parameters. As noted in **Chapter 3**, approximately 50,000 sherds were recovered

Table 5.1. Summary of ceramic samples analysed through archaeometric methods.

	Petrography	WD-XRF	XRPD	SEM	Horizon	Absolute Chronology
Belovode T18	82	37	14	9	1	4817-4400 cal. BC
	36	16	7	1	2	4951-4762 cal. BC
	10	5	3	2	3	5140-4859 cal. BC
	16	6	3	1	4	5452-5054 cal. BC
	7	3	1	1	5	5648-5338 cal. BC
	151	**67**	**28**	**14**		
Pločnik T24	34	20	11	2	1	4631-4231 cal. BC
	22	16	8	4	2	4927-4621 cal. BC
	45	32	7	2	3	5036-4951 cal. BC
	29	15	9	2	4	5121-4976 cal. BC
	17	15	13	1	5	5389-5003 cal. BC
	147	**98**	**48**	**11**		
Pločnik T20-T21	69	34	9	4	1	
	2	1	0		2	
	12	4	2	1	3	
	83	**39**	**11**	**5**		
	Total					
	381	**204**	**87**	**30**		

from each trench. Of these, 14,288 from Belovode and 15,235 diagnostic sherds from Pločnik were classified by a team of experts led by N. Mirković-Marić, following the typological system developed by Šljivar and his collaborators over previous decades (**Arsenijević and Živković 1998**). In addition to typological classification, a technological study was conducted, considering macroscopic fabric characteristics such as forming technique, surface finishing, decoration, and colour. Fabrics were primarily classified by their coarseness, with additional information recorded regarding their composition. Detailed results of this study are published in dedicated chapters of the RoMe project monograph (**Radivojević *et al.* 2021a**). Based on this macroscopic characterisation, samples were selected for various archaeometric analyses, as described below (**Table 5.1**).

Compositional characterisation

Compositional analysis was conducted using ceramic thin section petrography and chemical analysis. Thin section petrography was performed on all 381 selected pottery samples (230 from Pločnik and 151 from Belovode), while chemical analysis via WD-XRF was carried out on a subset of 204 samples (137 from Pločnik and 67 from Belovode). In addition to the detailed analysis presented here, **Appendix E** includes the results of an analysis of 27 samples from various Neolithic sites around Pločnik. This was undertaken to address the issue of microregional circulation of pottery in a region that, due to its significant geological variability, offers great potential for understanding patterns of pottery production and exchange.

The petrography of archaeological ceramics involves the description, classification, and interpretation of ceramic pastes or fabrics using techniques derived from geology and soil micromorphology. The primary tool used is the petrographic or polarising microscope, which features two light filters: the polariser and the analyser. The polariser restricts light to one plane of vibration, while the analyser, positioned at 90° to the polariser, can be moved in and out to switch between plain polarised light (PPL) and cross-polarised light (XP). In thin sections (approximately 30μm thick), minerals in the ceramic sample become translucent under the polarising microscope and can be identified based on their optical properties visible in PPL and XP. This technique provides insights into various technological aspects (e.g. forming techniques, tempering) and aids in identifying the raw materials used in pottery production, thus offering important information about the provenance of the artefacts (e.g. **Freestone 1995; Quinn 2013; Whitbread 1995**).

All thin sections analysed in this study were prepared by the author at the Wolfson Archaeological Science Laboratories (UCL). A slice was cut from the vertical cross-section of each sherd, which was then consolidated with epoxy resin, lapped with silica powder (600 grain size), and affixed to a glass slide. The samples were subsequently ground to approximately 40μm using a Buehler PetroThin Thin Sectioning System and further reduced to 20–30μm using finer silica powder (600 to 900 grain size). The sections were then covered with a removable transparent varnish, then analysed and described using an adapted version of the protocol developed by Whitbread (**1989, 1995**), with a focus on three main features: matrix, voids, and inclusions.

Appendices B1, **B2** and **B3** contain tables with detailed descriptions of groundmass, pores, and inclusions (excluding identification) for each sample. Based on the aplastic inclusions, matrix, and voids observed through thin section petrography, the samples from Belovode and Pločnik were divided into distinct fabric groups, summarised in **Chapters 7** and **8**. These summaries include the nature and frequency of inclusions along with details about texture and matrix (homogeneity, optical state, and colour). **Appendix B4** also includes a full description of the main petrographic groups identified at both sites.

In order to conduct compositional characterisation, petrographic results were integrated with chemical data. As mentioned, due to research funding limitations, chemical analyses were performed on a selection of samples representing the variability observed in thin section analysis. The integration of elemental and mineralogical techniques provides more detailed results, as these methods, though traditionally developed and applied separately, complement each other in archaeological studies (e.g. **Day *et al.* 1999**). The chemical profile of a ceramic sherd reflects both its provenance and technology; integrating chemical and petrographic data aids in understanding whether different chemical groups identified through statistical analysis correspond to provenance, technological groups, or both. Furthermore, chemical analysis can verify and clarify petrographic findings.

X-ray fluorescence spectroscopy is widely used for elemental analysis and determines a broad range of major, minor, and trace elements (**Artioli 2010**). The chemical analyses in this study were conducted at the Fitch Laboratory of the British School at Athens using a WD-XRF BRUKER S8-TIGER wave-length dispersive spectrometer with a Rh excitation source. A custom calibration was employed, based on 42 certified reference materials and developed for the analysis of soils and ceramics prepared as glass beads with a 1:6 dilution (**Georgakopoulou *et al.* 2017**). Samples received as sherds were cleaned with a tungsten carbide drill, crushed in an agate mortar, and homogenised in an automatic mill. Loss on ignition was determined by placing approximately 1.5g of pulverised sample in a porcelain crucible and heating it to 950°C for four hours in a muffle furnace. Glass beads were prepared on an automatic fluxer using 1 g of the ignited sample and 6 g of a mixture of lithium metaborate/lithium tetraborate. Two certified reference materials (NCS DC73301 (GSR-1) and PM-S) were analysed alongside the samples to monitor instrument performance (**Appendix C3**). The instrument's precision is approximately 0.5% for major elements and about 5% for trace elements, with an accuracy of around 0.5% for major elements and less than 11% for trace elements. The quantitative analysis for each sample involved calculating the concentration of major and minor elements, expressed as wt% of their oxide (Na2O, MgO, Al2O3, SiO2, K2O, CaO, TiO2, Fe2O3, P2O5, MnO), and trace elements, expressed in ppm (V, Cr, Co, Ni, Cu, Zn, Rb, Sr, Y, Zr, Ba, La, Ce, Nd, Pb, Th).

Statistical treatments of the WD-XRF data

The datasets from Belovode and Pločnik were treated separately using the following statistical procedures (see **Baxter 2003; Quinn 2022; Shennan 1997**). Initially, a descriptive statistical approach was applied to the WD-XRF dataset for each site. The mean, standard deviation, variance, coefficient of variation, minimum, first quartile (Q1), median, third quartile (Q3), and maximum were calculated to describe the central tendency and dispersion of the data distributions (Sheldon 2003). The normal probability test was performed via the Shapiro-Wilk test to assess whether the observations followed a normal distribution.

Subsequently, the variation matrix of the two WD-XRF datasets was calculated: one comprising 26 measured chemical elements, and the other 21, after the removal of those affected by post-depositional processes. The concept of a variation matrix (VM) was introduced by Aitchison (**1986, 1990**). Within the VM, the total variation (vt) is crucial as it represents the sum of all variations in a VM divided by twice the number of elements considered. The vt quantifies the variability within the dataset, providing information about its monogenic or polygenic nature, and helps to estimate the likelihood of different groups related to various provenances. Moreover, the VM and vt calculations identify elements with the highest variance in the dataset, typically those such as P_2O_5, CaO, Cu, Ba, Pb, Co, affected by post-depositional effects (**Freestone *et al.* 1985; Gascón and Buxeda i Garrigós 2013: 81; Maritan 2020**).

After the elements to be considered were determined, various statistical analyses were applied to process the chemical data. Principal component analysis (PCA), designed to investigate multivariate datasets, was employed first (**Baxter 2003; Shennan 1997**). PCA is a mathematical procedure that applies orthogonal transformation, compressing information from a large number of variables into a smaller number of new variables, or principal components, which are uncorrelated. By plotting the variables that account for the highest variance (usually the first two components), a score plot of the data is produced, enabling visual appreciation of a large amount of information. The position of any sample in the score plot is based on the combined weightings of the two plotted principal components. The contribution of each element to this score plot is displayed in a variable plot, where the weighting of each element is represented by its position on the graph axes. R, a computer-based statistical package, was used to perform the PCA on the chemical analysis results from Belovode and Pločnik. This programme calculates the correlation coefficients between variables, transforming them into principal components, and allows the visual representation of data through the creation of graphs.

Initially, PCA was conducted on the log-transformed (log10) datasets. The need for logarithmic transformation has been widely discussed, and a useful review is provided by Baxter and Freestone (**2006**). Log-transformation offers two main benefits: it enhances the graphical representation of analysis results by making the log-transformed variable more symmetrical and standardises variables to a similar order of magnitude. PCA was next applied to the datasets transformed via log ratio transformation. The use of ratios to a single element or a sum of elements in conjunction with log-transformation was noted, in the 1970s, to provide better differentiation between pottery of known provenance compared to raw concentration (**Wilson 1978**). Aitchison and colleagues developed statistical theories for compositional data analysis in the 1980s, introducing the centred log-ratio transformation (CLR) (**Aitchison 1986**). Aitchison's approach treats compositions as relative values characterised by ratios and logarithms of ratios, which are more easily handled and interpreted statistically (**Aitchison and Greenacre 2002**). Buxeda i Garrigós (**1999**) further advanced this field by developing a model for pottery composition analysis that incorporated log-ratios for statistical analysis. Buxeda also created an asymmetric log-ratio transformation (ALR), using the element with the lowest variation in the dataset as the divisor, distinguishing his approach from Aitchison's CLR, which uses the geometric mean of each compositional vector as the divisor.

The application of different log-ratio transformations has been debated in recent years. The results of these transformations may be overly influenced by the high relative variance of minor oxides, which are not 'structure-carrying' (**Baxter and Freestone 2006**). Moreover, non-log-ratio transformed data sometimes yields results that are more archaeologically interpretable. For example, the diluting effect of non-plastic inclusions, such as the addition of quartz (Si) to ceramic bodies made from similar clay, has technological relevance. Different ratios of quartz to clay could reflect varying tempering practices over time and space. Baxter and Freestone (**2006**) suggest that these concentrations are more likely to be captured when applying PCA to non-log-ratio transformed data. However, log-ratio transformation can be valuable when comparing the geochemical characteristics of clay, as it suppresses the diluting effect of tempering. Therefore, different statistical tools should be applied depending on the aspect being investigated (e.g. provenance versus technology). For these reasons, multiple statistical procedures were applied to the dataset to explore their impact on the results.

Additionally, hierarchical cluster analysis (HCA) was applied to the datasets as a supplementary statistical method to evaluate the presence of archaeologically relevant patterns (**Baxter 2003; Shennan 1997**). HCA creates clusters by linking variables with comparable levels of similarity, presented as a dendrogram. These clusters exhibit internal cohesion and external isolation. R was again used to process the data, which was clustered using the average linkage method after log-transformation (log 10, CLR, ALR). HCA was also combined with PCA, which can serve as a pre-processing step for clustering, to de-noise the data (**Husson *et al.* 2010**). The graphs most significant for understanding the compositional variability of the datasets considered in this research are included in **Chapters 7** and **8**.

Estimation of firing temperatures and pyrotechnology

The estimation of maximum firing temperature in archaeological ceramics has been widely debated (e.g. **Amicone *et al.* 2021a, 2023**; **Gosselain 1992; Livingstone Smith 2001; Tite 1995, 2008**). It has been noted that using maximum firing estimation to distinguish between 'open firing' and 'kiln firing' is overly simplistic and neglects other equally important aspects of the firing process. Nevertheless, the maximum firing temperature to which a vessel is subjected is an important piece of archaeological information that helps clarify the technological processes used by ancient potters (**Rice 2015; Rye 1981**). Maximum firing temperatures may also be relevant in identifying the firing technology used by particular societies, distinguishing between such technologies across time and space.

Methods for reconstructing firing temperatures involve establishing a relationship between firing temperatures and changes in pottery microstructure (e.g. porosity, clay matrix sintering, vitrification), colour, as well as mineralogy (e.g. **Heimann and Franklin 1979; Kazakou *et al.* 2019; Tite 1995, 2008**).

Firing temperature can be estimated using various methods, including thermal expansion, coercive force and saturation magnetisation measurements (**Coey *et al.* 1976**), monitoring the intensity of Mössbauer lines (**Shimada *et al.* 2003a, 2003b, 2003c, 2003d**), and colour coordinate analysis **(Mirti 1998**). Mineralogical analysis through XRPD, as well as FTIR (**Gliozzo 2020; Maggetti and Rossmanith 1981; Shoval and Beck 2005**), and microstructural analysis via SEM (**Maniatis and Tite 1981**), are particularly well-known and widely applied methods in pyrotechnological studies of ancient pottery.

XRPD allows for the characterisation of minerals that cannot be identified through thin section petrography due to their small size (e.g. clay minerals or new phases formed during firing). The identified mineral assemblages can provide insights into production technology, such as raw materials used, firing temperatures, and post-depositional phenomena (**Maggetti 1994**). X-ray diffraction measurements of minerals present in ceramics can help to identify the temperature ranges at which they were fired, as certain minerals serve as indicators of mineralogical changes during firing (**Duminuco *et al.* 1998; Gliozzo 2020; Maggetti 1982; Maritan 2004; Maritan *et al.* 2007; Nodari *et al.* 2007**). Key minerals include haematite, magnetite, cristobalite, mullite, calcite, montmorillonite, illite, and feldspars. Through SEM analysis, it is possible to observe sintering and vitrification of the clay matrix **(Faber *et al.* 2009; Maniatis and Tite 1981; Mentesana *et al.* 2019**). In the present research, an integrated approach was employed, incorporating XRPD and SEM.

It is important to stress that there are some limitations to these methods, including restricted accuracy and applicability within a limited temperature range. Additionally, the uncertainty introduced by the firing history—such as the maximum temperature, heating rate, duration of firing, cooling rate, and potential secondary firing events (e.g. destruction fires)—needs to be carefully considered to ensure accurate results. However, despite these challenges, these methods can provide valuable insights into ancient pottery production processes (**Amicone *et al.* 2021b** and literature therein). Observations of surface and fabric colour made during the macroscopic assessment, combined with XRPD results concerning the presence of iron oxides of red or dark colour (e.g. haematite or magnetite), provided further information about the atmospheric conditions used in firing dark-burnished ware and graphite-decorated pottery.

A total of 87 samples (28 from Belovode and 59 from Pločnik) were analysed through XRPD. The surface of each sherd was removed with a tungsten carbide drill and discarded, and a fragment from the body, weighing approximately 1g, was ground to a fine powder and dried for 12h at 110°C. Initial characterisation of all samples was performed using a Rigaku MiniFlex 600 Xray diffractometer equipped with a Cu-X-ray tube running at 40kV/30mA and a graphite primary monochromator. This was used to select specific samples for more detailed analysis (**Chapters 7** and **8**) using a Bruker D8Advance powder diffractometer with a Cu-X-ray tube running at 40kV/20mA, with a Goebel mirror optic, a 0.2mm divergence slit, a fixed knife edge to suppress air scatter, sample rotation and a VÅNTEC-1 detector. Mineral identification was performed by matching the diffractograms against the 2006 International Centre for Diffraction Data-Joint Committee of Power Diffraction Standards (ICDD-JCPDS) database.

A total of 30 samples (14 from Belovode and 16 from Pločnik) were analysed through SEM to assess their degree of vitrification. Subsamples of five dark-burnished pottery sherds from each site were re-fired in a furnace (Nabertherm N 60 E) at 700, 750, 800, 850, 900, 950, 1000, 1050 and 1100°C, respectively, for one hour under reducing conditions, then studied in the SEM and their vitrification compared to the original specimens (see **Chapters 7** and **8**). Reducing conditions were produced by re-firing the ceramic fragments inside crucibles filled with charcoal. The degree of vitrification of the glass phase increases with higher firing temperatures. By comparing the vitrification of the original samples with that observed after re-firing them at known temperatures for a standard duration, it was possible to infer precise information about the original firing temperatures (**Wolf 2002).** The samples were all gold coated (approximately 2–20nm) and the analysis was carried out on a HITACHI S-3400N SEM using an accelerating voltage of 5kV and an operating current of 110μA with a variable working distance. The images presented in this volume were taken at 2000x magnification.

Geological prospection and raw material analysis

The selection of clay sources is a fundamental aspect of pottery making and involves both spatial and temporal interactions between potters and their surrounding landscape. To understand how technological practices and knowledge were transmitted over time within a particular landscape, a systematic raw material prospection was conducted in the areas surrounding both study sites. Pottery making should always be considered in the context of its broader landscape (**Broodbank and Kiriatzi 2014; Gauss and Kiriatzi 2011**), with the aim of recognising how ancient people oriented themselves within this landscape and how they managed various other daily activities. Thus, raw material sources have significant potential to reveal histories of interactions between people, materials, and the landscape (**Michelaki *et al.* 2014**).

A total of 80 samples were collected during this study, 32 from Belovode and 48 from Pločnik. The collection points were recorded using a GPS, and geological maps were produced using Quantum GIS software, with the assistance of a GIS specialist (Enrico Croce, Università degli Studi di Milano). The geo-referenced polygons were developed based on pre-existing cartographic documentation, into which the GPS points of the sampling locations were later added (see **Appendices D1.1 and D1.2**).

Of the 80 collected samples, 59 (22 from Belovode and 37 from Pločnik), including clays, sands, and rock fragments, were examined via petrographic analysis. Before thin section preparation, the clay samples were formed into briquettes and fired in a furnace (Nabertherm N 60 E) at 700°C for one hour under oxidising conditions. Additionally, ten sandy-clay samples (five from Belovode and five from Pločnik) were analysed via WD-XRF. Only those samples relevant to the research objectives are discussed in detail, however a list of all collected geological samples, along with brief descriptions, can be found in **Appendix D1.3.**

The results of these analyses are presented in **Chapters 6–8**. **Chapter 6** reports the results of the macroscopic studies, while **Chapters 7** and **8** present the results of the archaeometric analyses for Pločnik and Belovode, respectively.

Chapter 6

Results of pottery macroscopic analysis – Belovode and Pločnik

During the two excavation campaigns conducted in 2012 and 2013 as part of the RoME project, approximately 50,000 pottery fragments were recovered and examined from the Late Neolithic sites of Belovode and Pločnik. Detailed analyses of these materials are presented in dedicated chapters of the RoME project monograph (**Mirković-Marić *et al.* 2021a, 2021b**; **Marić and Mirković-Marić 2021**), which also include comparative studies with other Vinča culture sites. Together, these investigations offer valuable insights into the relative chronology of the five occupation horizons identified at each site, with the data organised stratigraphically to trace typological developments across time. This chapter presents a summary of these studies enriched by macro technological observations carried out by the author. The macroscopic analysis of pottery from Belovode is presented first, followed by that of Pločnik, allowing a clearer understanding of site-specific developments within the broader Vinča cultural framework.

Belovode - pottery types by horizon

Among the pottery fragments found in Belovode, 14,288 diagnostic fragments were processed by a team of pottery experts supervised by N. Mirković-Marić. They were analysed using a typological classification system based on findings from earlier excavations (**Figures 6.1** and **6.2** and **Table 6.1**), developed over the past decades by various researchers (e.g. **Arsenijević and Živković 1998**).

This section provides an overview of the main pottery types found in the five horizons at Belovode (**Figures 6.3** and **6.4**), with the relative chronology of each horizon considered in terms of the presence and relative frequency of these types. The data is presented starting from the earliest horizon so that typological developments can be traced through the subsequent periods.

Horizon 5

The most relevant features in horizon 5 are pits F47 and F49, although the amount of diagnostically significant pottery they produced is quite limited. Bowls dominate the pottery assemblage, comprising 72% of the total number of vessels from the entire horizon. Among the bowls, biconical forms with a short upper part (type 109) and those with upper and lower parts of equal length (type 110) are well attested (25% of all bowls). Biconical forms with a short cylindrical neck and angular shoulder (type 111) also account for 25% of the bowls in this horizon. Other types of regularly occurring bowls include types 104b, 112, 113 and 116. Pedestal beakers are also relatively numerous (9%) in horizon 5, most being of type 201, with a hollow conical foot. Other shapes present include storage vessels such as pithoi and cooking vessels (type 422).

The ceramic inventory from this horizon could relate to Vinča A1/A2 (Vinča Tordoš I), the oldest phase of Vinča culture (**Mirković-Marić *et al.* 2021a: 166** and literature therein). Starčevo-style pottery, tempered with organic material and decorated with barbotine, is also present, if only sporadically.

Horizon 4

The most significant features of horizon 4 are pits F37 and F38. This horizon includes predominantly of conical bowls with straight and rounded walls of types 100 and 101 respectively, each accounting for 18% of the assemblage. Rounded forms (types 106, 107 and 108) are also frequently attested. Among the biconical forms, those with a short cylindrical neck and rounded shoulder (type 112) comprise 10% of all bowls. Other forms include types 104a, 104b, 109, 110, 111, 113, 115, 116 and 160. Additional shapes present are pedestal beakers (type 201), amphorettae (types 323, 324 and 325) and storage vessels such as amphorae (types 304, 305, 306 and 307) and pithoi. Also attested are cooking pots (types 421, 422, 424 and 425), plates (types 604 and 605), and a few fragments of lids (type 703). This ceramic repertoire aligns well with the final part of A2 and B2 (Vinča Tordoš II) phase of the Vinča cultural development (**Mirković-Marić *et al.* 2021a: 166** and literature therein)

Horizon 3

The most important features of horizon 3 are F30, F31, F32 and F43, which together comprise a large pit. Almost half (49%) of the vessel fragments identified in horizon 3 belong to bowls. Biconical bowls with a turned-in rim (type 117) start to appear and instantly become the most common bowl shape (15%) but many of the types present in earlier horizons still frequently occur. These include conical bowls with straight walls (type 100; 10%), bowls with rounded walls (type 101; 12%), with a short (type 112) or long (type 114) cylindrical neck and rounded shoulders (14%) and with

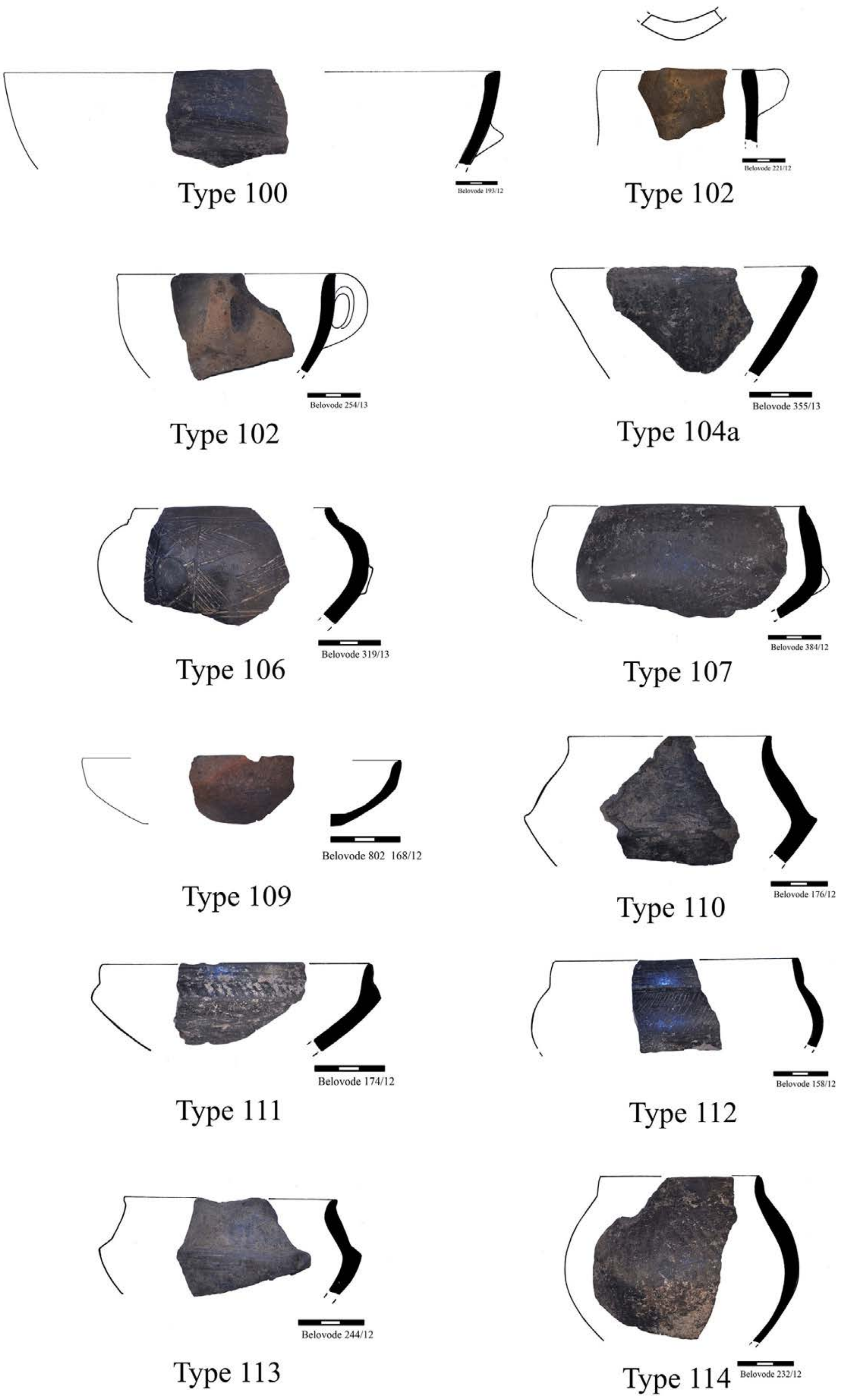


Figure 6.1. Some of the main vessel types found at Belovode (courtesy of the RoME project).

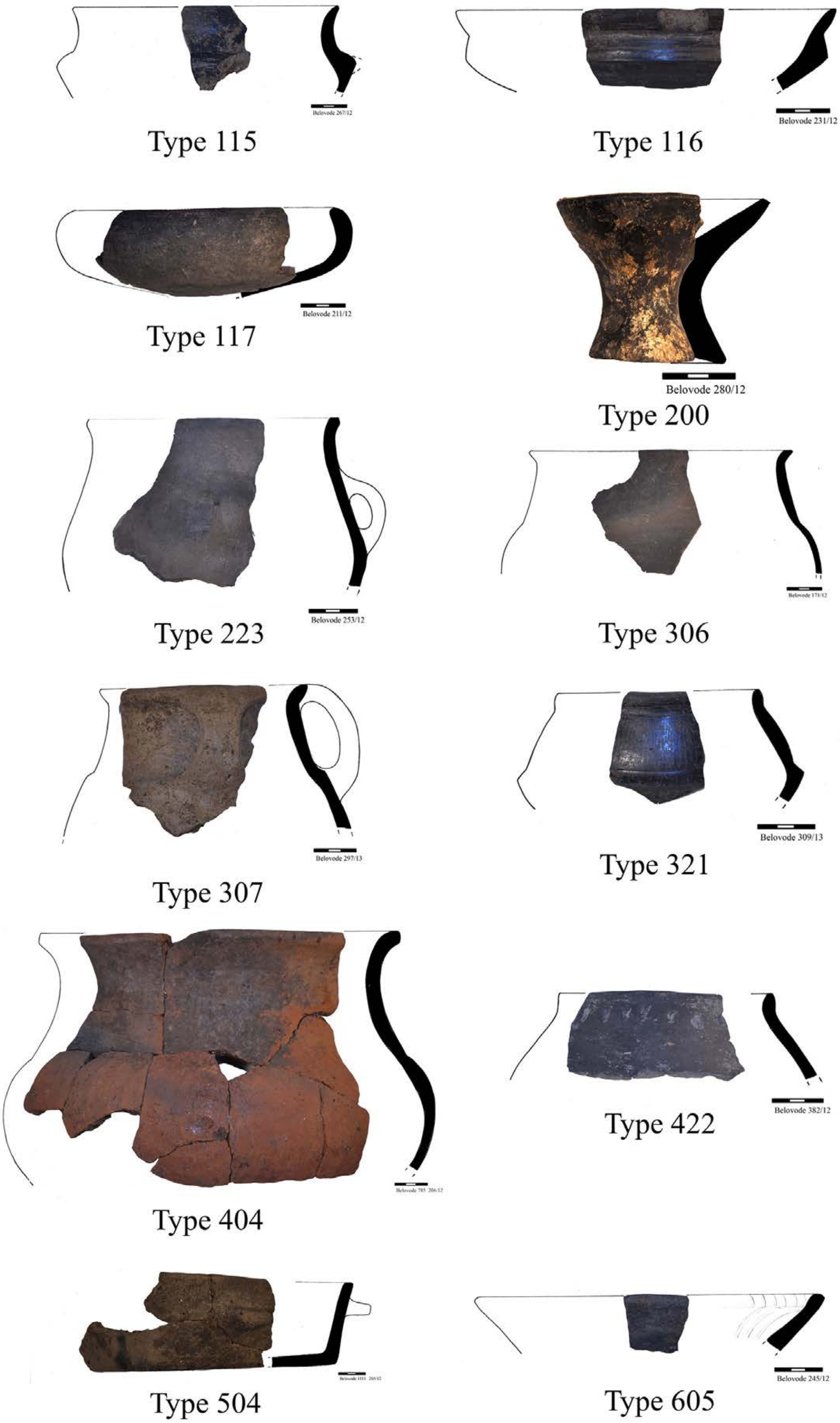


Figure 6.2. Some of the main vessel types found at Belovode (courtesy of the RoME project).

Table 6.1. List of the most represented vessel types at Belovode.

ID	Type
100	Conical bowl with straight wall
101	Conical bowl with rounded wall
102	Conical bowl with handles on the rim
104a	Conical bowl with thickened rim
104b	Conical bowln with profiled rim
104c	Conical bowln with massive profiled rim
104d	Conical bowl with thickened rim on the outside
106	Spherical bowl with short cylindrical neck
107	Spherical bowl
108	Hemispherical bowl
109	Biconical bowl with short upper part
110	Biconical bowl with equally high upper and lower part
111	Biconical bowl with short cylindrical neck and angular shoulder
112	Biconical bowl with short cylindrical neck and rounded shoulder
113	Biconical bowl with long cylindrical neck and angular shoulder
114	Biconical bowl with long vertical neck and rounded shoulder
115	Biconical bowl with concave upper part
116	Biconical bowl with funnel-shaped upper part
117	Biconical bowl with turned-in rim
118	Biconical bowl with massive angular shoulder
160	Spouted bowl
170	Pedestal bowl
200	Pedestal beaker
201	Pedestal beaker with a hollow conical foot
221	Biconical beaker with conical neck and handles on the rim
222	Biconical beaker with cylindrical neck and ribbon-shaped handles
223	Biconical beaker with conical neck and ribbon-shaped handles
300	Amphorae
304	Pear shaped amphora with elongated conical neck
305	Biconical amphora with cylindrical neck
306	Biconical amphora with conical neck
307	Biconical amphora with funnel-shaped neck
320	Amphorettae
321	Biconical amphoretta with high shoulder
322	Biconical amphoretta with high shoulder and horned handle
323	Pear shaped amphoretta
324	Biconical amphoretta with conical neck and funnel-shaped rim
325	Amphoretta with concave upper part and conical lower part
340	Jugs
341	Biconical jug with long cylindrical neck and strap handles
343	Jug with sharp biconical profile, massive conical neck and strap handle
344	Jug with sharp biconical profile, massive conical neck and strap handle on the rim
400	Pithoi
401	Pitos with handles on belly
403	Pithos Myres
404	Biconical pithos with conical neck
420	Pots
421	Conical pot with rounded profile
422	Biconical pot
423	Cylindrical pot
424	Biconical pot with rounded profile
425	Conical pot
450	Cylindrical pots (chimneys)
500	Casserole
502	Conical shallow casserole with massive walss
504	Deep conical casserole
600	Plates
602	Plate with profiled thickened rim
604	Conical plate with thickened rim
605	Conical plates with profiled thickened rrim
700	Lids
703	Flat lids without a handle
704	Flat lids with a handle
720	Prosopomorphic lids
800	Miniature vessels
900	Plastic vessles
904	Other forms

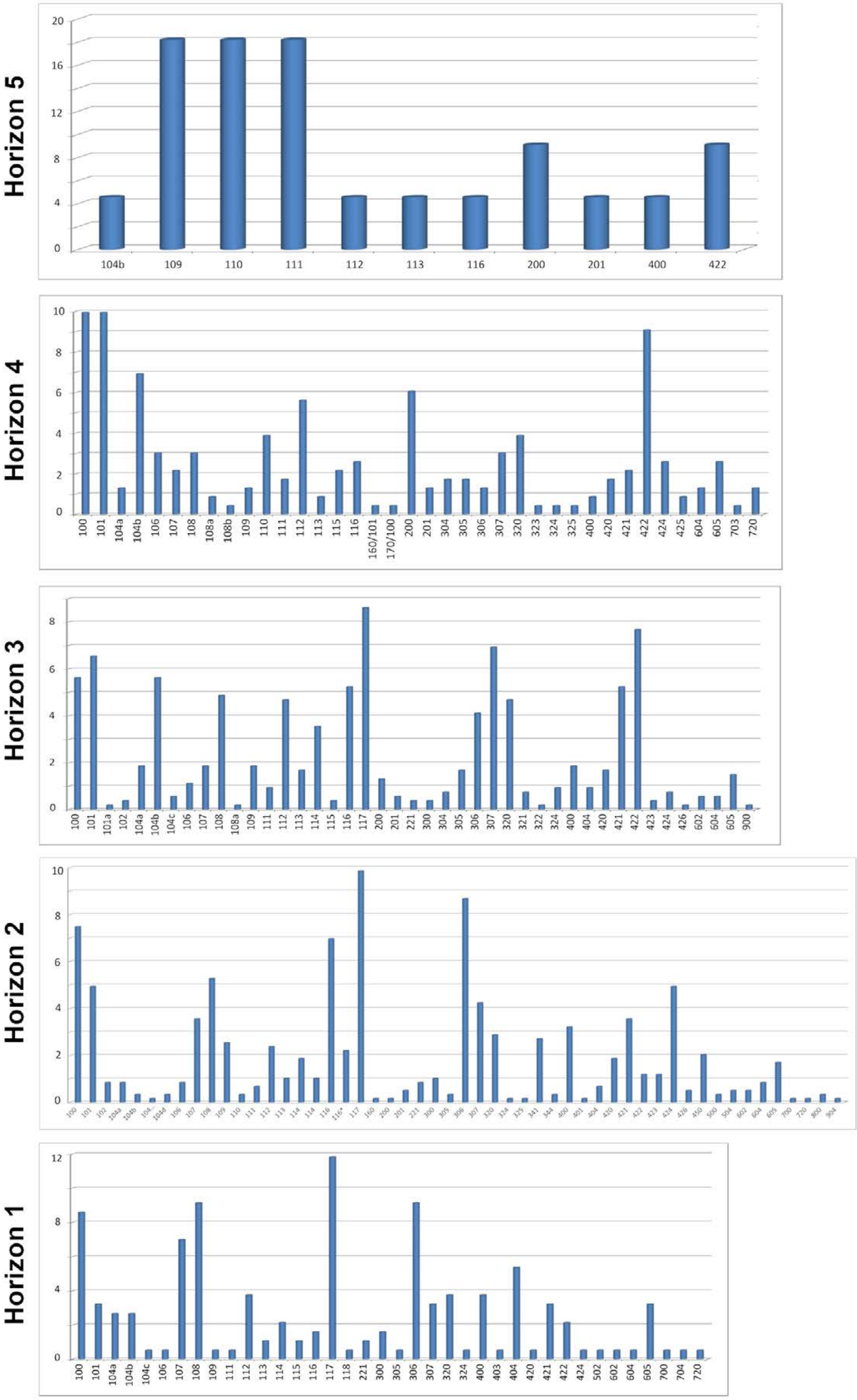


Figure 6.3. Representation of vessel types according to the five horizons from the trenches studied at Belovode (after Mirković-Marić *et al.* 2021a).

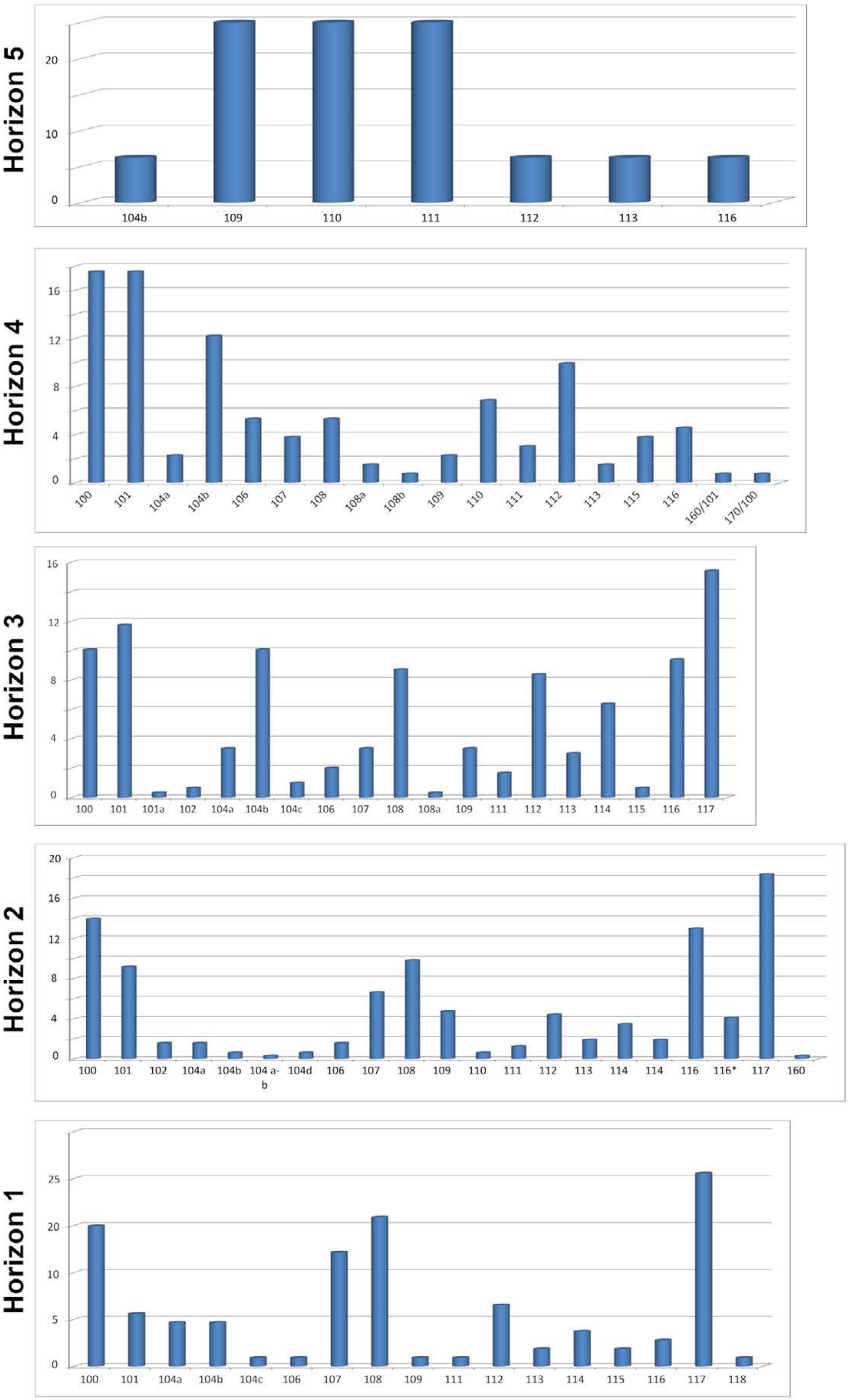


Figure 6.4. Representation of bowl types according to the five horizons from the trenches studied at Belovode (after Mirković-Marić *et al.* 2021a).

a profiled rim (type 104b; 10 %). Other forms of bowls include types 102, 104a, 106, 107, 108, 109, 111, 113, 115 and 116. Also present are beakers (types 201 and 221), amphorettae (types 321, 322 and 324), amphorae (types 304, 305, 306 and 307), pithoi (type 404), cooking pots (types 421, 422, 423, 423, 424 and 426), plates (types 602, 604 and 605) and plastic vessels (type 900). The ceramic inventory from this horizon seems to represent a period extending from the Gradac phase to Vinča Pločnik I or Vinča Pločnik I/II (**Mirković-Marić *et al.* 2021a: 162, 166** and literature therein).

Horizon 2

The most relevant features of horizon 2 are pits F18 and F21. This horizon is again dominated by the presence of bowls, which form 54% of the entire assemblage. Bowls with a turned-in rim (type 117; 18%) and conical bowls with either straight walls (type 100; 14%) or rounded walls (type 101; 9%) are most common but there is also a significant number of biconical bowls with a funnel-shaped upper part (type 116; 17%). Hemispherical bowls (type 108) also occur frequently (10%). Several additional bowl forms are also attested (types 102, 104, 106, 107, 109, 110, 111, 112, 113, 114 and 115), most having occurred in all previous horizons.

Cooking vessels in this horizon account for 13% of the entire assemblage and include cooking pots (types 421, 422, 423 and 424) and casserole pots (type 504). Also present are pedestal beakers (types 201, 221, 222 and 223), amphorettae (types 324 and 325), jugs (types 341 and 344), amphorae (types 305, 306 and 307), pithoi (types 401 and 404), plates (types 602, 604 and 605), lids (type 720), miniature vessels (800) and plastic vessels (904). Fragments of so-called 'chimneys' (type 450) are also documented. These are elongated cylindrical ceramic forms open at both ends that have been tentatively associated with the smelting process (**Radivojević 2013: 16; Radivojević *et al.* 2010: 2779**). The repertoire of pottery in horizon 2 matches the expected composition of Vinča C and D1 (Vinča Pločnik I to IIa) assemblages (**Mirković-Marić *et al.* 2021a: 162** and literature therein).

Horizon 1

The most important features of horizon 1 are F1, F2 and F8, each representing pottery concentrations. Other relevant features include F3, a rectangular structure of wattle and daub as well as pits F9, F19 and F20. This horizon is even more dominated by bowls than horizons 2–4. They now form 67% of the entire pottery assemblage, occurring in a variety of shapes. The most common are biconical forms with a turned-in rim (type 117; 22% of all bowls) and conical forms with straight walls (type 100; 15%). Sherds from rounded forms are also numerous: 16% are from hemispherical bowls (type 108) and 12% from spherical bowls (type 107). Forms of bowls that occur less frequently include types 101, 104, 106, 109, 111, 112, 113, 114, 115, 116 and 118.

Other frequently occurring types of vessels include beakers (types 221 and 223), biconical jugs (types 341, 343 and 344), conical plates (type 605), and small amphorae (type 324). Storage vessels, such as amphorae (types 305, 306 and 307) and pithoi (types 403 and 404), and cooking vessels, such as cooking pots (types 420, 421 and 424) and cooking pans (type 502), are also attested. Sherds from plates (types 602 and 604), flat lids with a handle (type 704) and 'chimneys' (type 450) are also present.

The ceramic inventory from this horizon corresponds largely to Vinča D2 phase assemblages, i.e. the final phase of Vinča culture development at many sites (**Mirković-Marić *et al.* 2021a: 162** and literature therein).

Belovode - macroscopic technological characterisation of pottery

An overall assessment of the technological variability of the pottery assemblage from trench 18 revealed macro-traces left by potters during manufacturing, providing information about forming techniques, surface finishing and decoration. The macro-traces indicated the use of the coiling technique (**Figure 6.5**) in forming bottoms, bellies and rims of different types of vessels throughout all horizons. The analysis revealed diagnostic points of connection between adjacent coils and the presence of preferential fractures that follow these areas between coils.

The fragmented nature of the assemblage prevented a detailed reconstruction of the specific types of coiling methods employed at Belovode. It appears that the potters used one coil per level rather than a long spiral coil, but the type of overlap (internal, external or U-shaped base), its orientation (straight or oblique), together with the type of pressure employed (continuous and discontinuous) were difficult to determine (**Roux 2019**). It is interesting to observe that, in the entire pottery assemblage, there is little evidence of any other forming techniques. The only exception is in the production of the bases of bowls, where clay may have been pinched to form either a shallow or deep hemisphere, but the upper parts of these vessels were certainly built with coiling.

The surface finishing techniques of smoothing, burnishing and, more rarely, polishing, are all evident in the assemblage (**Figure 6.6**). Polished vessels tend to have a more reflective appearance than those finished by burnishing. Tool traces are not clearly visible on the surface. It is argued by Martineau (**2010: 17**) that

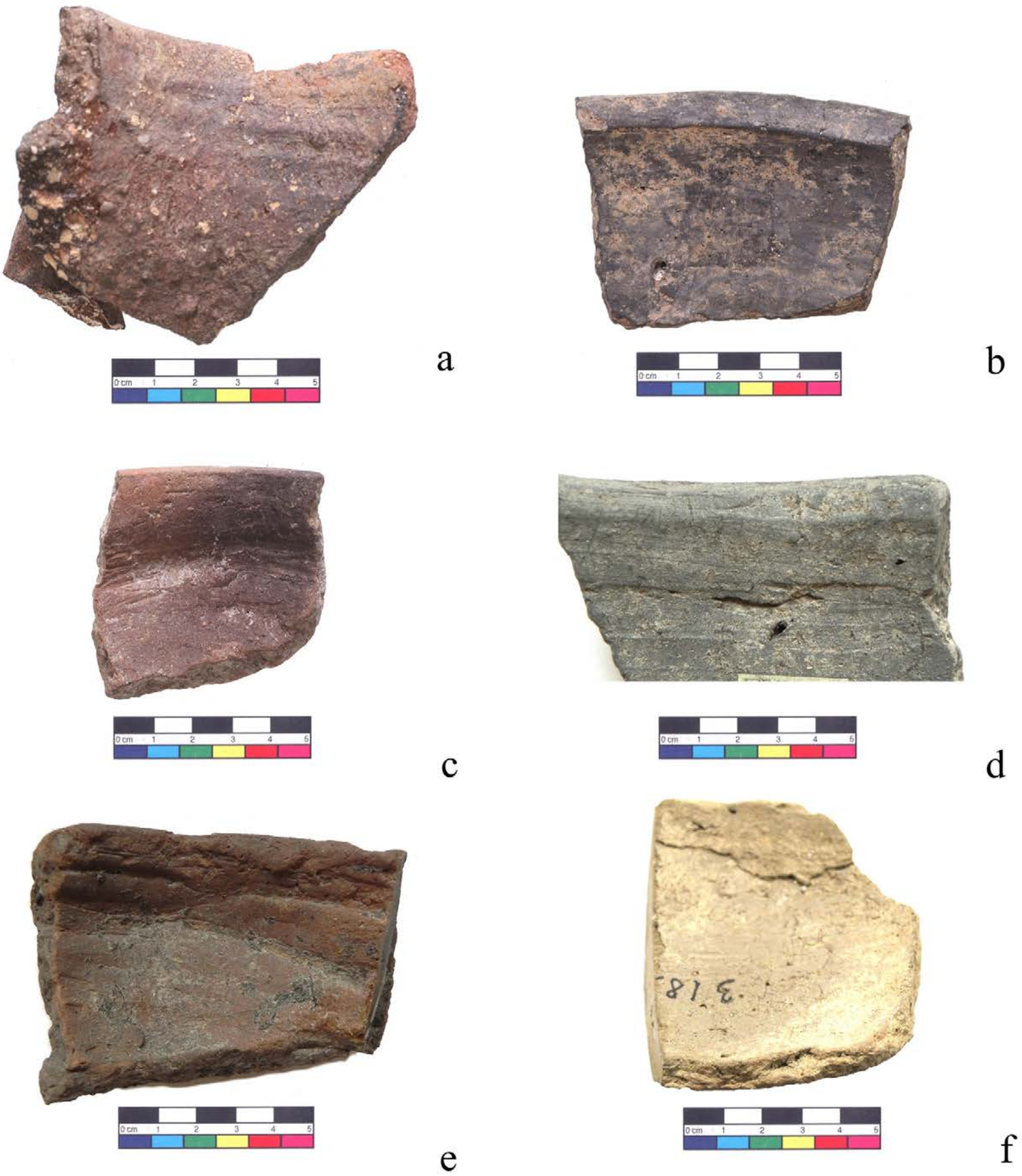


Figure 6.5. Selected sherds from Belovode which show evidence of coiling as the primary forming technique: a) BEL 18-82; b) BEL 18-99; c) BEL 18-286; d) BEL 18-67; e) BEL 18-136; f) BEL 18-184.

the tools and the movements employed to produce smoothing, burnishing and polishing are not critical in producing these different surface effects, which could instead be related to the particular drying stage during which the vessel is treated: when the surface of a pot is wet, the treatment will result in smoothing; when it is leather-hard or is dry, the same treatment will produce burnishing and polishing effects respectively. Both techniques may be combined on the same vessel (**Figure 6.6e**).

At Belovode, potters also applied *polished decoration* (usually polished lines) over the top of burnished surfaces (**Figure 6.6f**). This is particularly common in horizon 1 (Vinča D2), occurring on about 8% of the sherds. Although this combination of surface

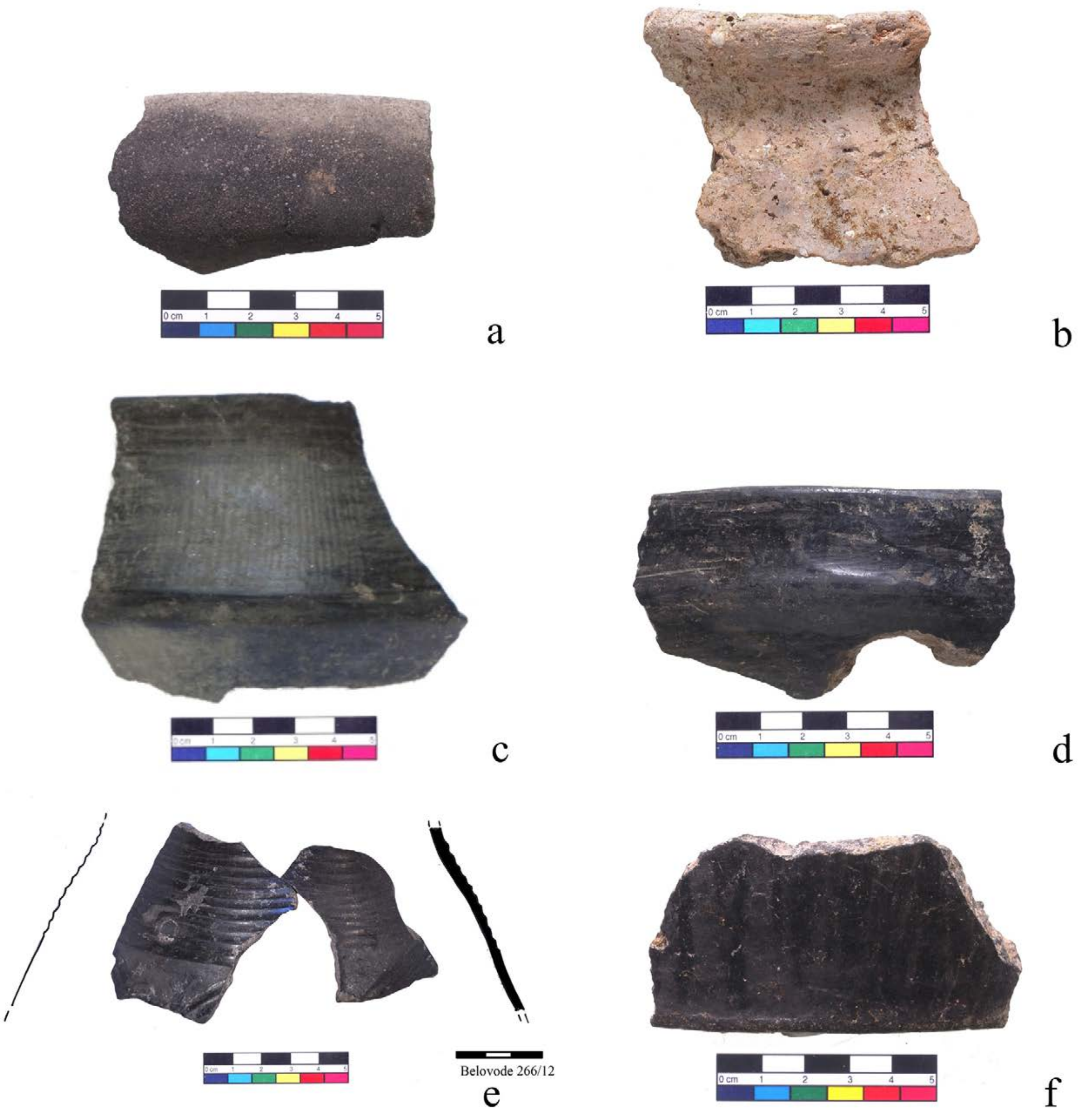


Figure 6.6. Selected sherds from Belovode which show the employment of different surface treatments: a) BEL 18-21 rough surface; b) BEL 18-116 smoothed surface; c) BEL 18-219 burnished surface; d) BEL 18-162 polished surface; e) BEL 18-204 burnished and polished surface; f) BEL 18-287 burnished surface with polished vertical lines.

modification techniques is employed from the earliest phase of the settlement, polishing and burnishing become more frequent from horizon 4 onwards (Vinča A2–B2), when 50% of the sherds are burnished or polished. It is especially common in association with bowls but also employed in the production of amphorae and pithoi.

Another surface decorating technique, the application of *barbotine*—a mixture of clay and water (**Cuomo di Caprio 2007: 153**)—is very common in horizon 5 (Vinča A1–A2), being present on about 50% of sherds (**Figure 6.7a**). It remains common (33% of sherds) in horizon 4 (Vinča A2–B2). *Incised decoration* (**Figure 6.7b, c**) is also present, produced by applying a narrow-ended tool to the wet surface with sufficient pressure to cut various geometric motifs. Sometimes the incised decoration is filled with white material: calcium carbonate and bone white (**Perišić *et al.* 2016**), or with a red pigment: cinnabar (**Gajić-Kvaščev *et al.* 2012b**). *Impression decoration* (**Figure 6.7d**) is also present but is less common. It is created by pressing an object, such as

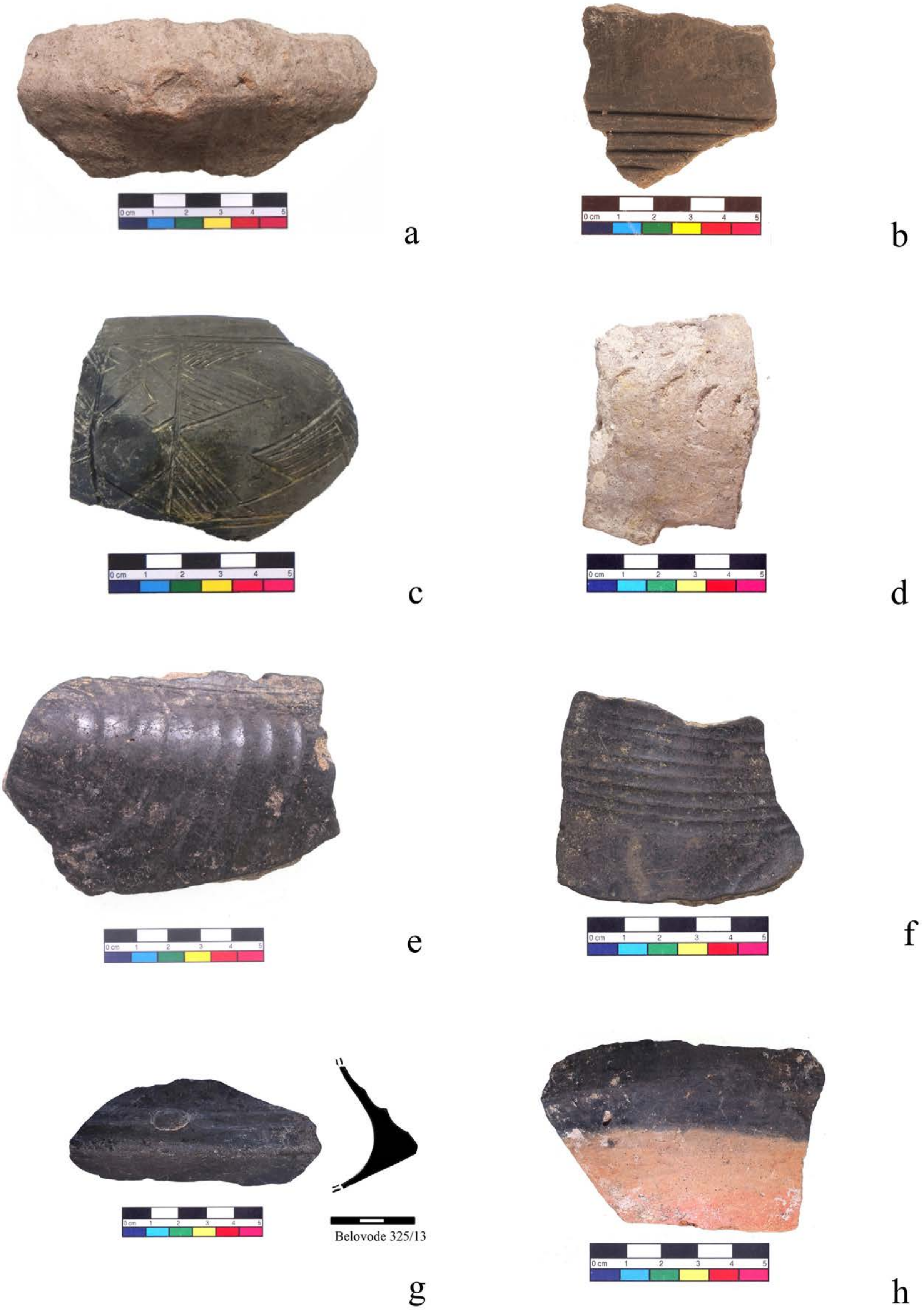


Figure 6.7. Selected sherds from Belovode which show different decorative and surface modifications: a) BEL 18-295 with barbotine decoration; b) BEL 18-249 with geometric incised decoration; c) BEL 18-226 with incised geometric motifs; d) BEL 18-320 with impressed (nails?) decoration; e) BEL 18-118 with vertical channelling decoration; f) BEL 18-176 with horizontal channelling decoration; g) BEL inv.no. 325/13 with applied decoration; h) BEL 18-302 with black topped decoration.

a fingernail, into the wet surface to produce negative reliefs. Both these techniques become less frequent from horizon 3 (Gradac phase) onwards, when they are gradually replaced by *channelling decoration*. This is produced by the gentle impression of a tool to produce shallow inclined, horizontal, or spiral channels (**Figure 6.7e, f**). Although much less common, found on just 3% of the sherds in the entire analysed assemblage, *applied decoration* is also recorded in all the settlement horizons (**Figure 6.7g**). This ornamentation is produced with the application of separate pieces of clay to produce different types of protrusions (buttons, tongues or lunate shapes), mostly with a solely decorative purpose.

The surface colour of sherds was examined macroscopically, primarily to assess the atmospheric conditions during firing. In the earliest horizon at Belovode (horizon 5, Vinča A1–A2), pottery was very often fired in oxidising conditions, indicated by the lighter yellow and reddish yellow colour of the sherds. Black-topped sherds are also recorded in the assemblage (**Figure 6.7h**)**.** At Belovode, the employment of reducing conditions for at least part of the firing process, resulting in darker (grey to black) surfaces, is mostly associated with vessels having burnished or polished surfaces, producing a metallic sheen effect. For this reason, this pottery type has traditionally been termed black-burnished ware. However, only a few sherds from the analysed assemblage display a homogeneous black colour across their surfaces, with the majority varying between light and medium grey. This is why the term dark-burnished ware (as mentioned in **Chapter 2**), introduced by Chapman (**2006**), is preferred in this work. Notably, cooking pots appear to have been fired in an oxidising atmosphere.

Finally, a macroscopic fabric assessment was carried out on the sherds from trench 18. The fabric colour of the samples varies from light reddish brown (M 5YR 6/4) to red (M 2.5 YR 5/6) and from grey (M 5YR 6/1) to very dark grey (M 10 YR 3/1). While some sherds have a homogeneous reddish or dark grey colour, most are not homogeneous throughout, some having a reddish core and becoming darker towards the surface. This is the result of different atmospheric conditions created during the firing process (**Rice 2015: 276–290**). The sherds also differ in the nature, abundance, size, and sorting of the inclusions present. It was possible to divide the assemblage into three principal macroscopic fabrics (**Figure 6.8**).

The first (**Figure 6.8a, b**) is dominated by white (probably quartz) and grey inclusions, iron-rich red inclusions, and muscovite flakes, and has been labelled 'sand fabric'. This fine-to-coarse fabric is found in all horizons. Compositional and textural variation was noted, but it was not possible to divide it into well-defined smaller sub-fabrics. Sand is found in most samples but is poorly sorted; few specimens show a degree of sorting compatible with the intentional addition of aplastic inclusions during paste preparation. The second fabric (**Figure 6.8c, d**) , named 'shelly fabric', shows the presence of calcareous-rich inclusions like shell and limestone fragments, reactive when tested with HCl. This fabric is usually associated with cooking pots and appears within horizon 3 (Gradac phase). The final macroscopic fabric (**Figure 6.8e, f**) contains elongated voids, possibly indicative of vegetal tempering, and has been labelled 'chaff fabric' as this seems the most likely addition to the paste. It is associated only with Middle Neolithic Starčevo sherds and is found in horizon 5 (Vinča A1–A2).

Pločnik - pottery types by horizon

Among the pottery fragments recovered at Pločnik, 15,235 diagnostic sherds underwent detailed typological analysis by a team of pottery experts led by N. Mirković-Marić. The classification system used, developed by Duško Šljivar (**Figures 6.9** and **6.10**; **Table 6.2**), is the same as that applied to the Belovode assemblage.

This section provides an overview of the main pottery types found in the five horizons at Pločnik (**Figures 6.11** and **6.12**), with the relative chronology of each horizon considered in terms of the presence and relative frequency of these types. As for Belovode, the data is presented starting from the earliest horizon so that typological developments can be traced through the subsequent periods.

Horizon 5

The most important features of horizon 5 are pits (F38) and a daub concentration (F39). A significant number of the pots in this horizon (87%) are serving vessels. Most common are conical bowls with profile rim of type 104b (33% of all bowls), but other types of conical bowls with straight and rounded walls (types 100 and 101 respectively), spherical and hemispherical bowls (types 106, 107 and 108) and biconical bowls (types 109, 110, 112, 113, 114, 115 and 116) are also present. Other frequently occurring shapes include beakers (types 200 and 223), amphorettae (types 304, 305 and 307) and storage vessels such as amphorae (type 323), pithoi (type 404) and pots (types 422, 423 and 431). Less frequently occurring are pans (type 500), plates (type 605), various types of lids (types 703, 704 and 720), and miniature and plastic vessels.

The composition of the ceramic material of this horizon can be related to the Vinča A2/B1 phase (Vinča Tordoš II/I, **Mirković-Marić *et al.* 2021b: 333** and literature therein).

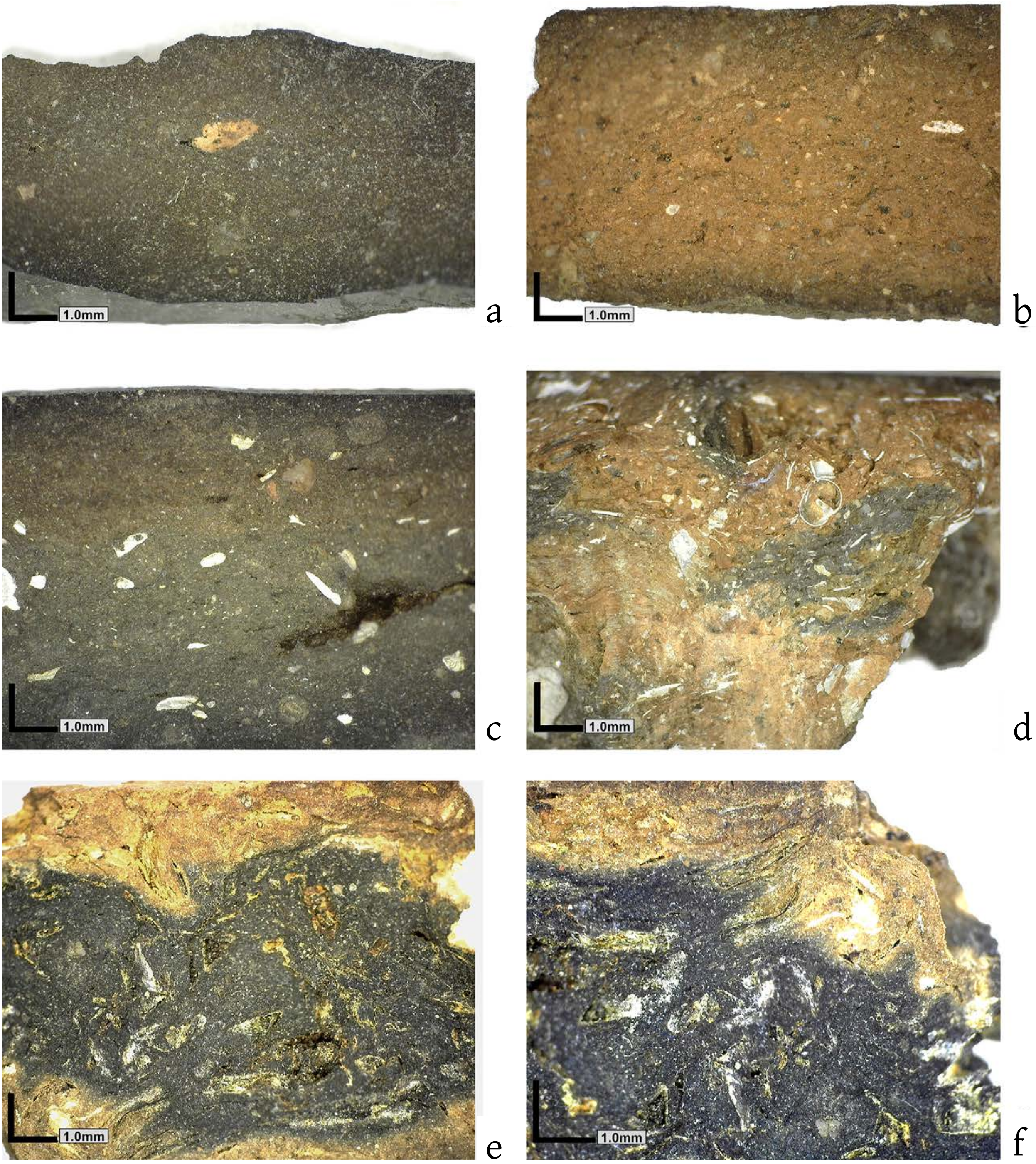
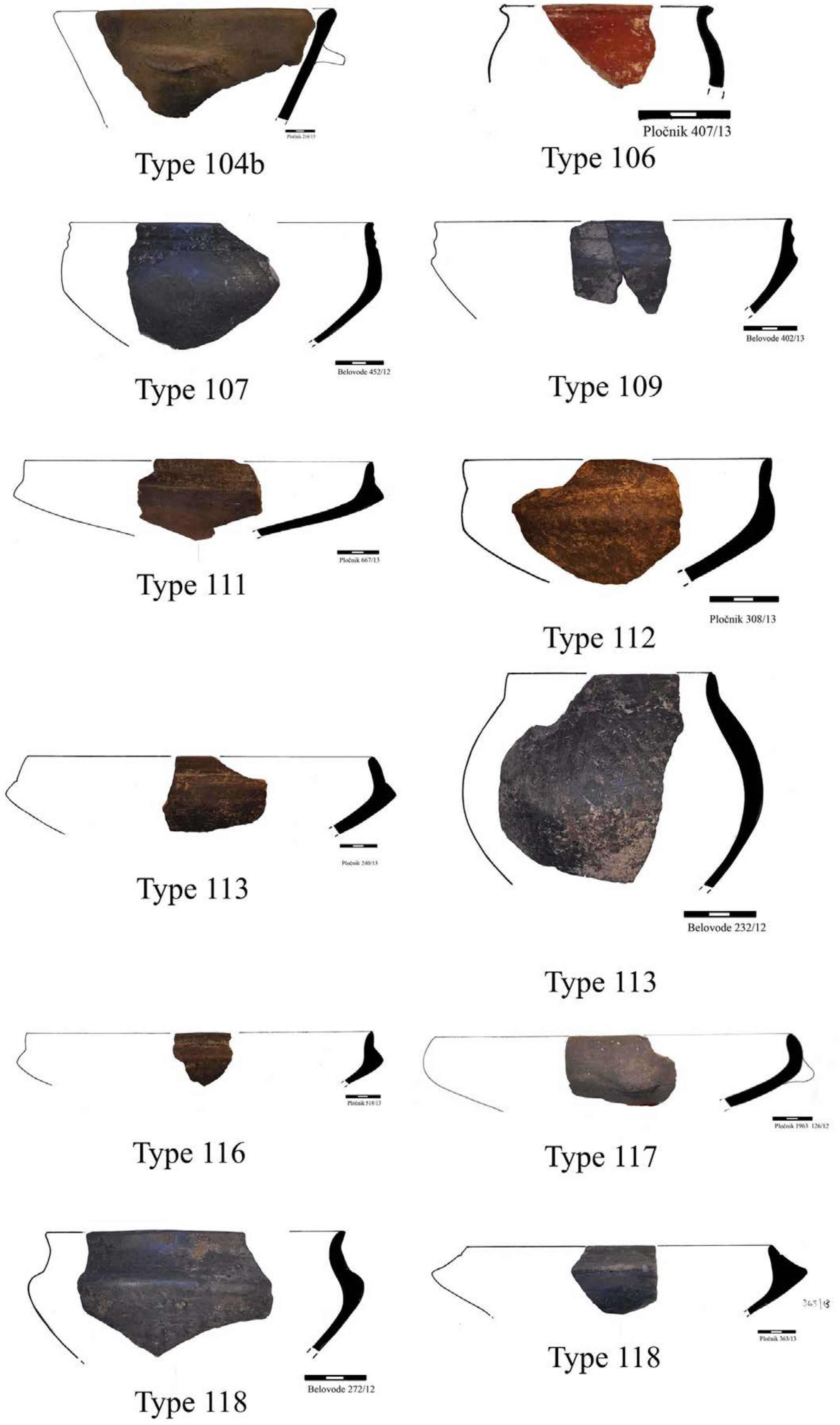


Figure 6.8. Selected sherds from Belovode which show the main macroscopic fabrics: a) BEL 18-162 (sand fabric, fine); b) BEL 18- 34 (sand fabric, coarse); c) BEL 18-101 (shelly fabric, fine); d) BEL 18-96 (shelly fabric, coarse); e) BEL 18-303 (chaff fabric); f) BEL 18-303 (chaff fabric).

Horizon 4

The most important features of horizon 4 are concentrations of daub, fired soil and ash: F29, F30, F31, F32 and F34. Serving vessels account for 53% of the whole pottery assemblage. Most bowls have a profiled rim (type 104b, 42% of all bowls) while other conical bowls (types 100, 101 and 104a) are represented in significantly smaller numbers. Biconical bowls are present in smaller amounts, especially those of type 112, with a short cylindrical neck and rounded shoulder (12.5% of all bowls), as well as other bowls (types 106, 107, 108, 109, 110, 111, 113, 114, 115, 118 and 160). Other vessels common in this horizon include beakers (types 200 and 223), plates, amphorettae (types 304, 305, 306 and 307), amphorae and pithoi (type 404) and pots



Type 104b

Type 106

Type 107

Type 109

Type 111

Type 112

Type 113

Type 113

Type 116

Type 117

Type 118

Type 118

Figure 6.9. Some of the main vessel types found at Pločnik (courtesy of the RoME project).

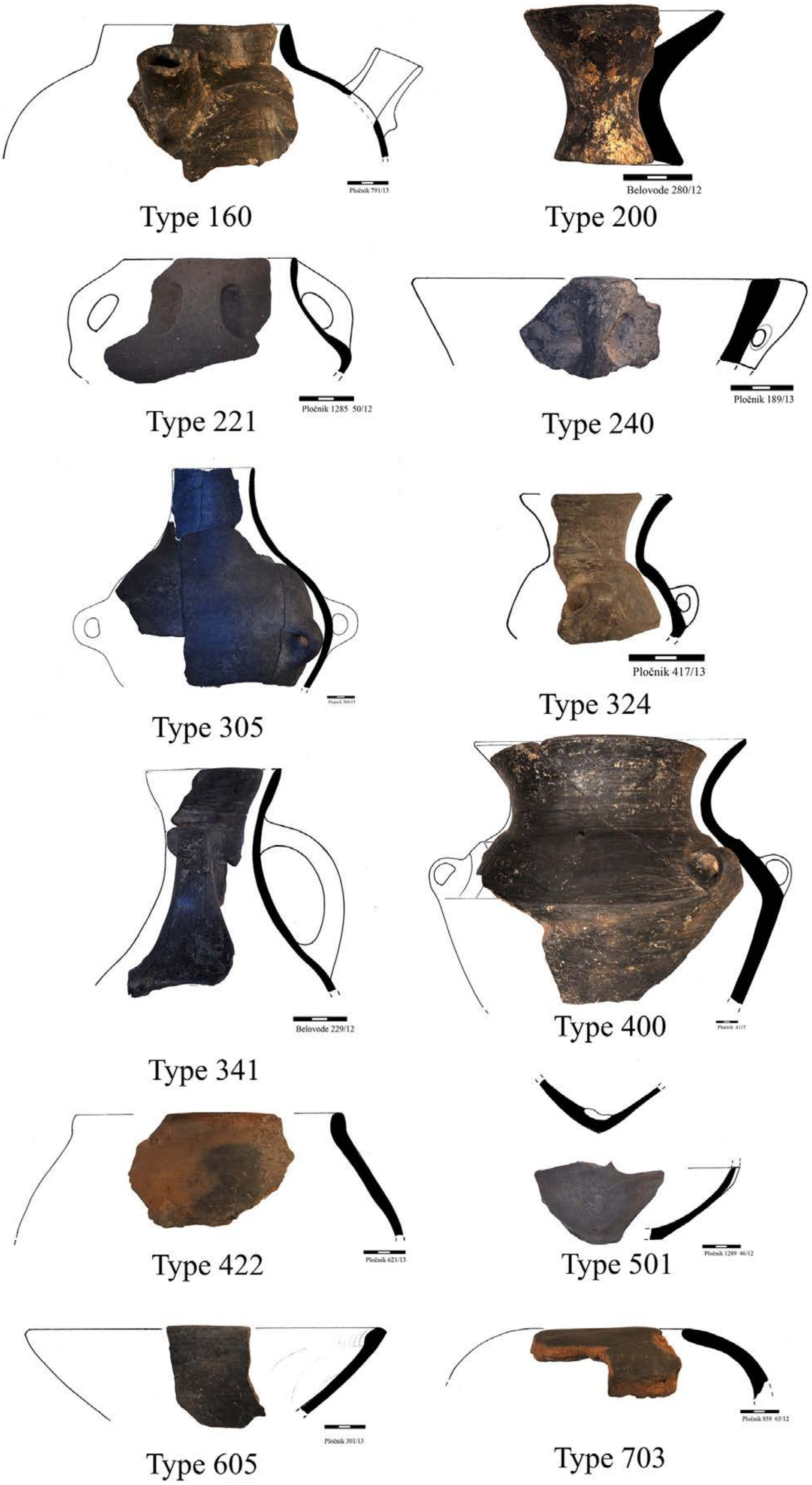

Type 160
Type 200
Type 221
Type 240
Type 305
Type 324
Type 341
Type 400
Type 422
Type 501
Type 605
Type 703

Figure 6.10. Some of the main vessel types found at Pločnik (courtesy of the RoME project).

Table 6.2. List of the most represented vessel types at Pločnik.

ID	Type
100	Conical bowl with straight wall
101	Conical bowl with rounded wall
102	Conical bowl with handles on the rim
104a	Conical bowl with thickened rim
104b	Conical bowln with profiled rim
104c	Conical bowln with massive profiled rim
104d	Conical bowl with thickened rim on the outside
106	Spherical bowl with short cylindrical neck
107	Spherical bowl
108	Hemispherical bowl
109	Biconical bowl with short upper part
110	Biconical bowl with equally high upper and lower part
111	Biconical bowl with short cylindrical neck and angular shoulder
112	Biconical bowl with short cylindrical neck and rounded shoulder
113	Biconical bowl with long cylindrical neck and angular shoulder
114	Biconical bowl with long vertical neck and rounded shoulder
115	Biconical bowl with concave upper part
116	Biconical bowl with funnel-shaped upper part
117	Biconical bowl with turned-in rim
118	Biconical bowl with massive angular shoulder
160	Spouted bowl
200	Pedestal beaker
220	Beakers
221	Biconical beaker with conical neck and handles on the rim
222	Biconical beaker with cylindrical neck and ribbon-shaped handles
223	Biconical beaker with conical neck and ribbon-shaped handles
240	Gradac cups
300	Amphorae
303	Amphora with equally high upper and lower part
304	Pear shaped amphora with elongated conical neck
305	Biconical amphora with cylindrical neck
306	Biconical amphora with conical neck
307	Biconical amphora with funnel-shaped neck
308	Amphora cone shaped neck
320	Amphorettae
323	Pear shaped amphoretta
325	Amphoretta with concave upper part and conical lower part
340	Jugs
400	Pithoi
404	Biconical pithos with conical neck
420	Pots
421	Conical pot with rounded profile
422	Biconical pot
423	Cylindrical pot
424	Biconical pot with a rounded profile
425	Conical pot
450	Cylindrical pots (chimneys)
500	Casserole
600	Plates
601	Plate with thickened rim
602	Plate with profiled thickened rim
604	Conical plate with thickened rim
605	Conical plates with profiled thickened rrim
700	Lids
703	Flat lids without a handle
704	Flat lids with a handle
720	Prosopomorphic lids
800	Miniature vessels
900	Plastic vessles
903	Strainers

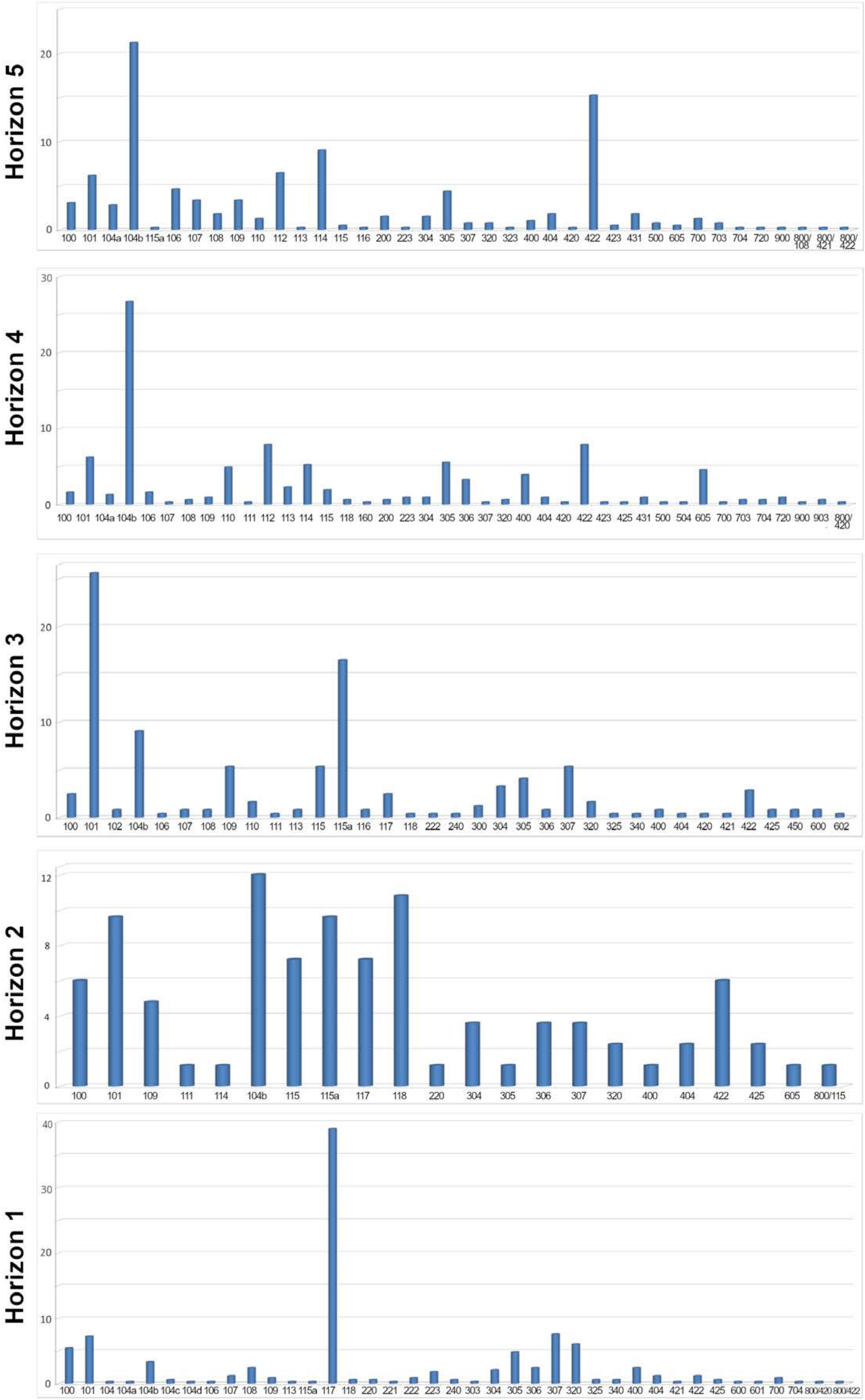


Figure 6.11. Representation of vessel types according to the five horizons from the trenches studied at Pločnik (after Mirković-Marić *et al.* 2021b).

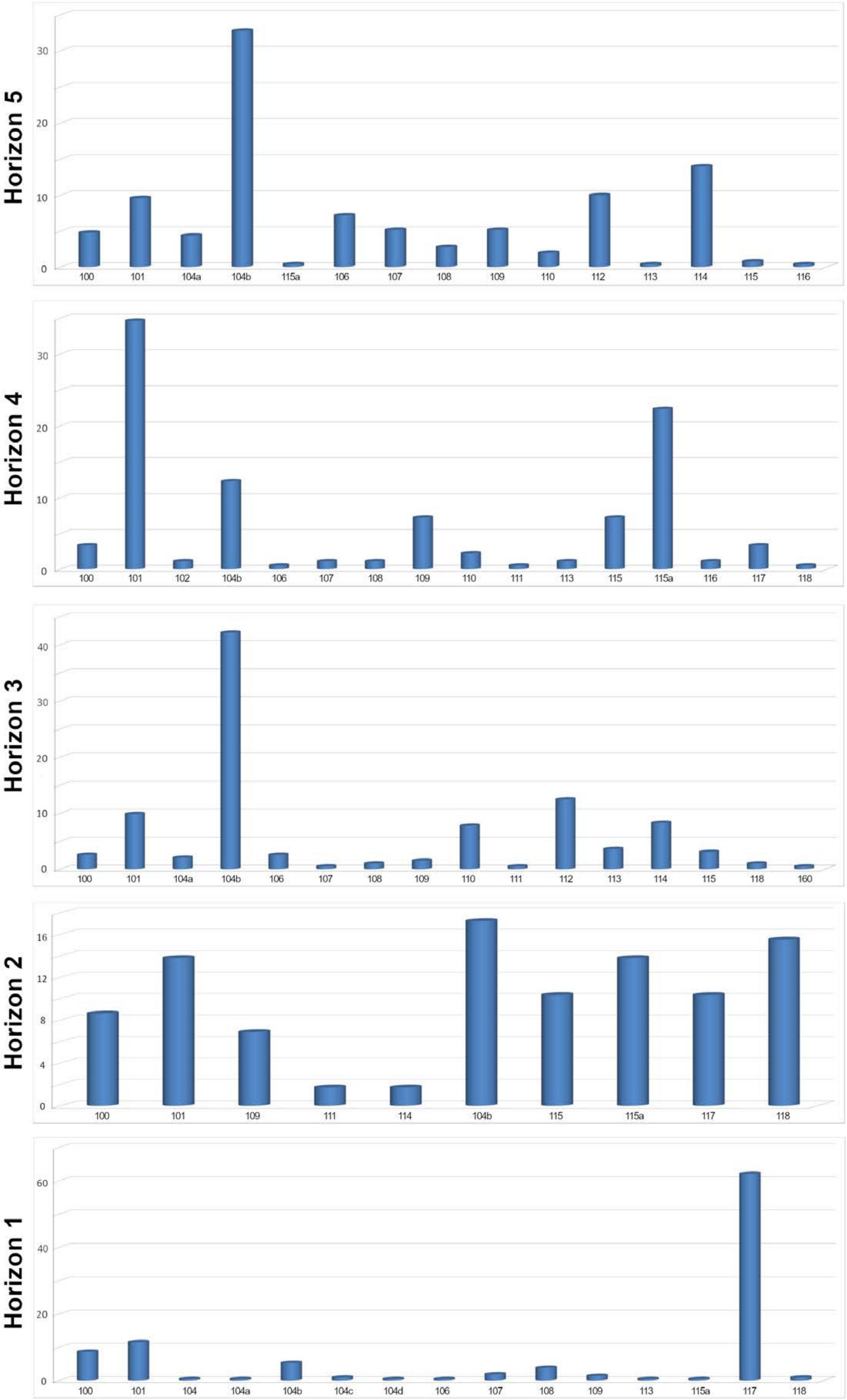


Figure 6.12. Representation of bowl types according to the five horizons from the trenches studied at Pločnick (after Mirković-Marić *et al.* 2021b).

(types 422, 423 and 431). Less frequently found are pans (type 500), plates (types 604 and 605), various types of lids (types 703, 704 and 720), and miniature and plastic vessels.

These repertoires of shapes fit well with earlier phases of the Vinča culture, more specifically, the Vinča B2 phase (Vinča Tordoš II, **Mirković-Marić *et al.* 2021b: 333** and literature therein).

Horizon 3

Relevant features of horizon 3 are F14, F15, F16, F17, F19, F21, F22, F25, F35, F36 and F37, representing a large concentration of finds, daub, pits, post-holes and ovens. Bowls are the most dominant type of vessel (79% of the whole horizon's assemblage). Conical bowls with rounded walls of type 101 (35% of all bowls) and those with a profiled rim of type 104b (12% of all bowls) are the most common. Also frequent are biconical bowls with a concave upper part (type 115; 7% of all bowls), and a long concave upper part (type 115a; 22% of all bowls). Other types of bowls represented are conical (type 102), spherical/hemispherical (types 106, 107 and 108) and biconical (types 109, 110, 111, 112, 113, 114 and 116), although these types occur less frequently. Notably, biconical bowls with a massive profiled angular shoulder of type 118 are well attested (16% of all bowls). It is also interesting to note that the in-turned rim of type 117 became more popular. Other common shapes include beakers (type 222) and jugs. Among these, it is possible to single out Gradac cups and square-shaped vessels. There are also storage vessels, including amphorae (types 304, 305, 306 and 307) and pithoi (type 404), and cooking vessels (types 421, 422 and 425), as well as cylindrical-chimneys (type 450) and lids (type 602).

Overall, the material from this horizon is best compared to the Vinča Tordoš II—Vinča Pločnik or Gradac phase in its classical appearance (**Jovanović 1994: 22**; **Mirković-Marić *et al.* 2021b: 330** and literature therein).

Horizon 2

Most relevant features in horizon 2 are F11, an oven, and F13, a pit. Serving vessels are predominant, especially the turned-in rim bowls of type 117 (10% of all bowls). Other types begin to dominate now, including conical bowls with straight walls of type 100 (9% of all bowls), those with rounded walls of types 101 (14% of all bowls) and 104b with a profiled rim (17% of all bowls). The number of some biconical bowls (types 109, 115 and 115a) also starts to increase significantly. In particular, the biconical bowls with massive profiled angular shoulder (type 118) are very common (16% of all bowls). Other types of vessels include beakers, Gradac cups (type 240), storage vessels (amphorae and pithoi of the types 304, 305, 306, 307 and 404) and pots (types 422 and 425), amphorettae, plates (type 605), and miniature vessels.

This horizon could be paralleled with the final phase of Vinča culture in Belo Brdo (**Mirković-Marić *et al.* 2021b: 330** and literature therein), namely Vinča D2 / Gradac II (Vinča Pločnik II).

Horizon 1

Relevant features of horizon 1 include F1, F2, F4, F5, F6, and F10, forming a wattle and daub structure. The most common vessel types are serving vessels, which represent 64% of the vessels in the entire assemblage. Bowls with a turned-in rim of type 117 are dominant (62% of all bowls), but conical bowls with straight walls (type 100; 9% of all bowls) and rounded walls (type 101; 12% of all bowls) are well represented, while other types of conical and spherical or hemispherical bowls are less frequent (e.g. types 104, 106, 107 and 108).

Biconical bowls occur only sporadically and only a few types (109, 113, 115a and 118) are present. Other vessels represented to a lesser degree include amphorettae (type 325), beakers (types 221, 222 and 223), Gradac cups (type 240), jugs, storage vessels (amphorae and pithoi of the types 303, 304, 305, 307 and 404) and pots (types 421, 422 and 425), plates (type 704), lids (type 704) and miniature vessels. Beakers with conical necks and handles on the rim (type 221) are very characteristic of this horizon. Finally, jugs and lids are present in very low percentages. This pottery repertoire fits well with the Gradac III phase, as defined by Jovanović (**1994: 10**); see also **Mirković-Marić *et al.* 2021b: 330** and literature therein.

We can conclude that during the last phase of this site, a distinct regional variation of the Late Neolithic traditions in the Central Balkans is visible in the material culture of Pločnik. This implies that this site was part of the South Morava regional variant for which some authors (e.g. **Jovanović 1994**) propose a different relative chronology.

In the chronological scheme (**Chapter 3**), this is reflected by the additional subdivisions of Gradac I to Gradac III. The term Gradac III was introduced by Jovanović as it seemed that the Late Neolithic settlements of the South Morava valley survived beyond the 46th century cal. BC, when most late Vinča settlements in the Danube and Vojvodina region (including the eponymous site at Belo Brdo) abruptly ceased to exist (**Tasić *et al.* 2015**). According to Jovanović, Pločnik is one of the main representatives of Gradac phase III settlements (**Jovanović 1994: 1–11**). The radiocarbon analysis shows that horizon 1, which is the final Late Neolithic occupation of Pločnik, dates to 4446–4231 cal. BC (95%

probability). The settlement lasted well into the 45th century BC, long after those of the Danube region ceased to exist (**Marić *et al.* 2021e**). The pottery study **(Mirković-Marić and Marić 2021b)** confirmed that the development fits better within the tripartite division of the Gradac phase as proposed by Jovanović (**1994, 2006**).

In particular, the material from horizon 1 shows some elements that are not commonly attested for the classical variant. For example, there is a considerable increase in bowls with in-turned rims, which suddenly become very dominant in the material record. There is also a significant presence of beakers with two handles, jugs, and conical bowls (types 117 and 221). These elements are typical for the South Morava variant and, together with the small representation of other types of bowls, clearly separate this horizon from those preceding it.

All these elements synchronise well with the Gradac phase III as defined by Jovanović (**1994: 10**). In conclusion, the excavations conducted on trench 24 shed new light on the periodisation of the settlement

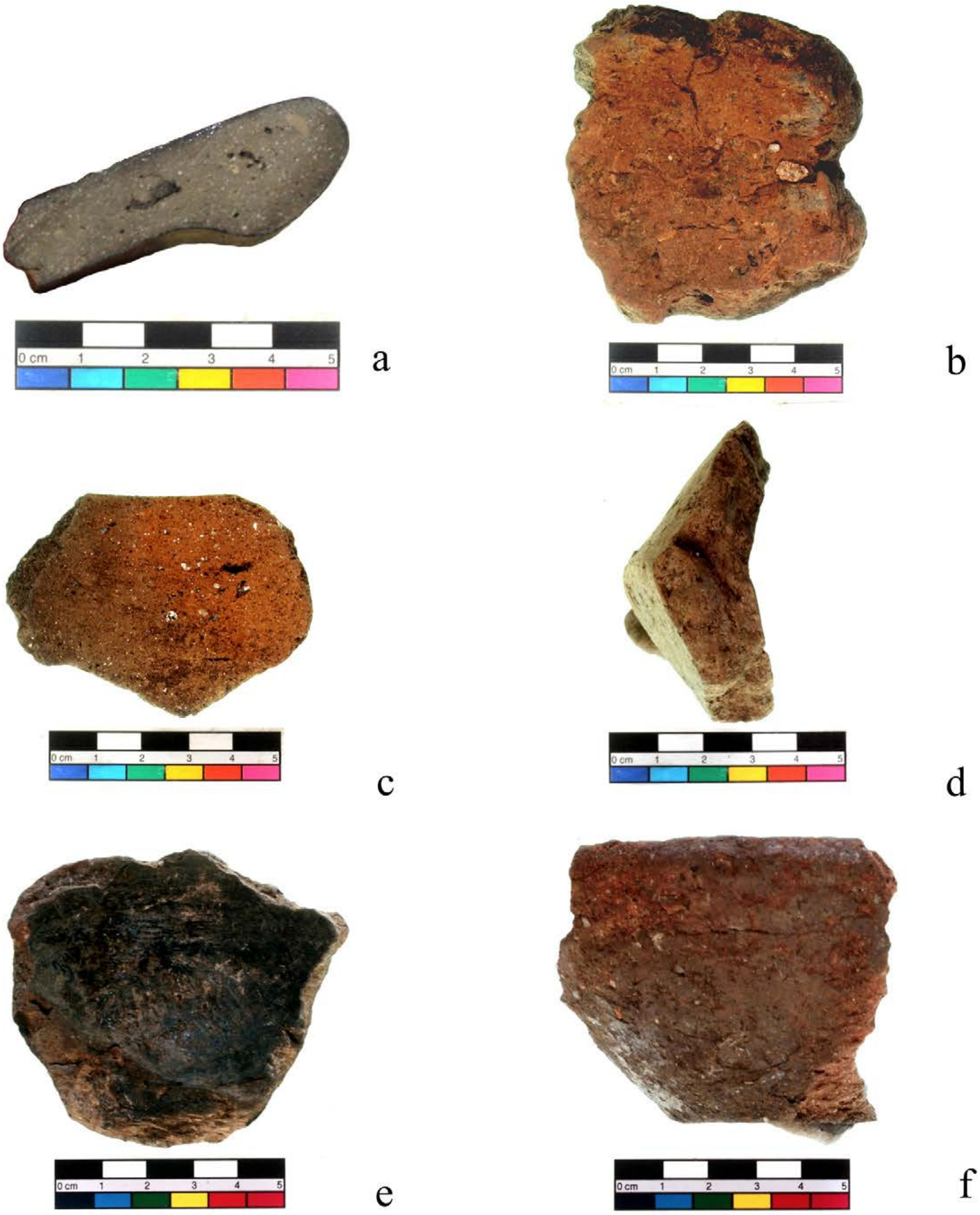


Figure 6.13. Selected sherds from Pločnik which show signs of forming techniques: a) PL 21-20 (coiling); b) PL 24-32 (coiling); c) PL 24-34 (coiling); d) PL 24-84 (coiling); e) PL 24-285 (pinching); f) PL 24-318 (coiling).

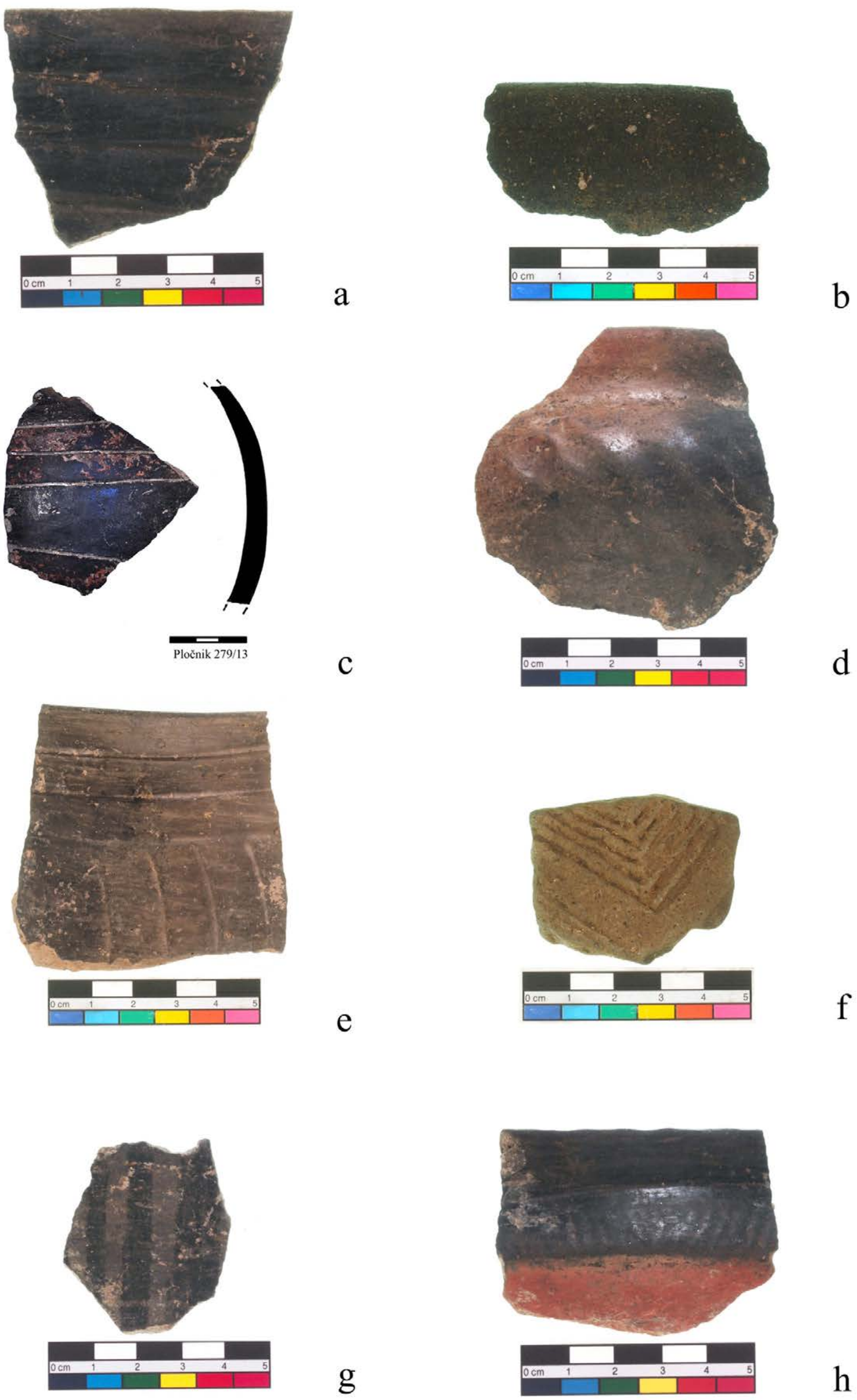


Figure 6.14. Selected sherds from Pločnik that show different surface treatments and decoration techniques: a) PL 24-303: burnished surface; b) PL 24-15: rough surface; c) PL 289/13: incisions with white and red pigment; d) PL 24-313: with inclined channelling decoration; e) PL 24-268: with vertical channelling decoration; f) PL 24-16: with incised decoration; g) PL 24-291: burnished with polished vertical lines; h) PL 24-288: black topped.

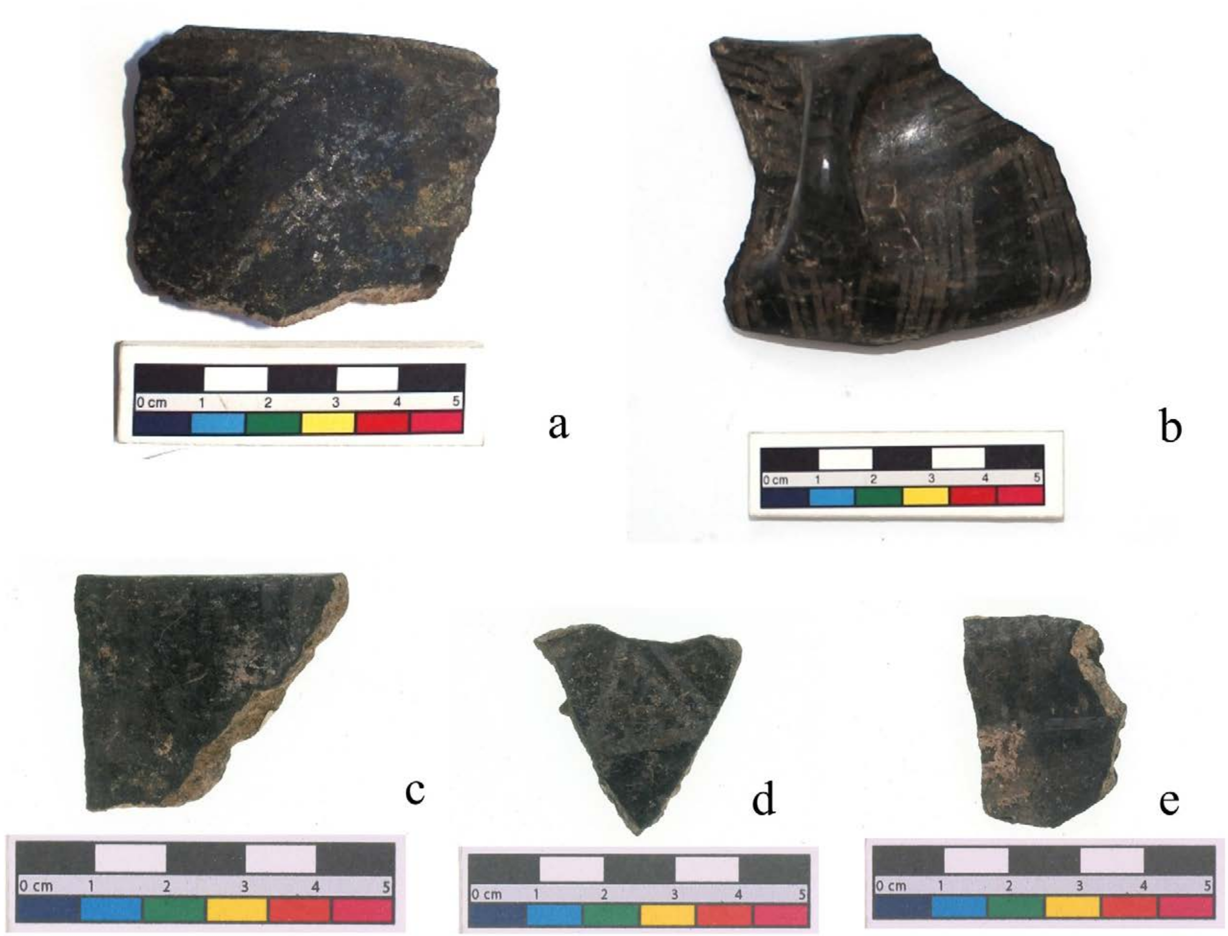


Figure 6.15. Selected sherds from Pločnik that show evidence of graphite decoration: a) PL 24-215; b) PL 24-248; c) PL 24-103; d) PL 24-124; e) PL 24-129.

at Pločnik and highlight the presence of a horizon corresponding to the Gradac III phase, which represents the final development of Vinča material culture. The late Gradac phase is in fact an expression of the Neolithic character of south Serbia in this period (**Jovanović 1994: 11**). The relationship between the late Vinča and early Bubanj-Hum communities which follow them in south and southeast Serbia, is an important field for future inquiries (**Mirković-Marić and Marić 2021b**).

Pločnik - macroscopic technological characterisation of pottery

As with Belovode, an overall assessment of the technological variability of the pottery assemblages from trenches 20, 21 and 24 was conducted with the help of the local pottery team. Special attention was given to technological macro-traces present on the surface of sherds or in their fresh fractures. Analysis to identify pottery forming techniques employed at the site revealed that vessels were mostly made by coiling. Macro-traces suggestive of this technique include points of connection between adjacent coils and the presence of preferential fractures (**Figure 6.13**). Potters probably overlapped one coil per level, but different types of coil orientation (external, internal, U-shaped) can be observed. Only a few sherds (e.g. PL 24-166, PL 24-211, PL 24-282 and PL 24-285), deriving from smaller vessels, show clear evidence of a pinching technique. These vessels do not present preferential fractures, and the thickness of the vessels is less homogeneous.

In addition, clear signs of digital pressure that could be connected to this type of technique have been recognised on sherds marked by pinching. It is also likely that the bases of many of the bowls were made by pinching clay into either shallow or deep hemispheric forms. Squared bowls, which are very rare, could instead have been made by using a slab technique; however, the high fragmentation of the assemblage under examination prevented a more detailed study of forming techniques and the identification of more

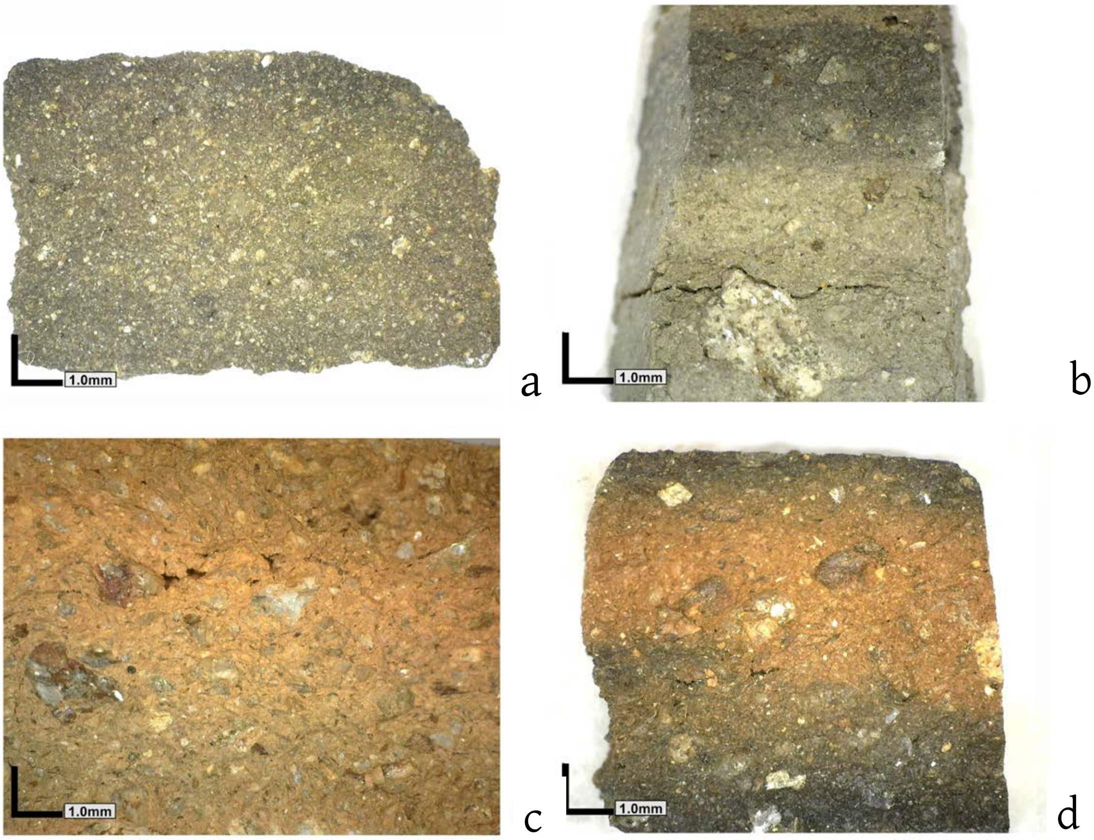


Figure 6.16. Selected sherds from Pločnik which show macroscopic fabric characteristics: a) PL 21-48 (fine); b) PL 21-50 (coarse); c) PL 21-46 (rich in muscovite); d) PL 21-42 (rich in muscovite).

specific gestures employed during the forming of the vessels. Despite this, the overall impression is of strong continuity in forming technique traditions.

The surface treatments employed in pottery production include smoothing, burnishing and polishing, which are all evident throughout all the horizons (**Figure 6.14**), although horizon 1 (Gradac III) contains considerably fewer sherds which feature either burnishing or polishing. Barbotine technique is attested, especially in horizon 5 (Vinča A2–B1), but is not as common as at Belovode (only 4% of the sherds from this horizon). Decorative techniques include incision, impression and channelling (**Figure 6.14**). The latter is particularly common in horizons 4 (Vinča B2) and 3 (Gradac). Channels are oriented horizontally, vertically, diagonally or in spiral forms. The incised decoration is sometimes filled with white material (probably calcite) or with a red pigment (**Figure 6.14c**) that has been proven to be cinnabar (**Gajić-Kvaščev *et al.* 2012b**).

Another very interesting phenomenon is the appearance of graphite decoration (**Figure 6.15**) in relation to horizons 3 and 2 (Gradac I–II). Only 11 graphite decorated sherds were found in trench 24, although examples have been recorded in other sectors of the site (personal communication Julka Kuzmanović-Cvetković). The graphite decoration was investigated in cooperation with the University of Tübingen (**Amicone *et al.* 2020a**) using µ-XRD[2] and µ-Raman analyses to characterise the different structural types of carbon-based pigments. This revealed that both natural graphite and pigments containing carbon were used to achieve this effect. Indeed, several samples that appeared to be decorated with natural graphite were instead found to exhibit the carbon black technique, the final result being very similar. In both cases, the careful control of the firing atmosphere would be important to avoid the oxidisation of the carbon. The use of carbon results in a graphite with a very fine crystalline to almost amorphous structure.

All five horizons indicate a particular taste for black and grey shades of surface colour that are normally associated with burnishing/polishing surface finishes and graphite decoration (more than 60% of the sherds). Most bowls are dark grey/black and burnished; however this type of colouration and surface treatment is also associated with pithoi, amphorae, amphorettae and other larger pots. Interestingly, in horizon 1 (Gradac III), there is still a preference for dark shades, but at this point, as noted before, the pottery surfaces are rather rough, and evidence of burnishing techniques is rare. A few sherds from horizons 5 and 4 (Vinča A2–B1) also have a bi-coloured surface (**Figure 6.14h**). Overall, these changes in the surface treatments largely correspond to developments recognised in the pottery typology at the site.

As with Belovode, a macroscopic fabric assessment was carried out on sherds from Pločnik. In general, the fabric colours of the examined sherds vary from reddish yellow (M 5YR 6/6) to dark reddish brown (M 5YR 3/4) and from light grey (M 5YR 8/1) to very dark grey (M 10YR 3/1). The colour of most of the fabrics is not homogeneous throughout the sherd, although several sherds have a reddish core and become darker towards the surface, or *vice versa.* The colour variability within individual sherds, as seen in fresh fractures, is the result of different atmospheric conditions created during the firing process (e.g. **Rice 2015: 345–346**). Notably, sherds decorated with graphite always show a relatively homogeneous dark fabric colour.

The sherds also differ considerably in the abundance, size, and sorting of inclusions. It was very difficult to distinguish the nature of the inclusions in the hand specimens, and not possible to divide the assemblages into clear macroscopic fabric groups. White, grey, or black mineral/rock fragments and iron-rich red inclusions are frequently observed (**Figure 6.16a, b**); a group of samples from the final building horizon stands out for the abundant presence of glittering particles (**Figure 6.16c, d**). The presence or absence of calcareous inclusions was tested with hydrochloric acid (HCl). A few fragments of loom weights and oven floors reacted, demonstrating the calcareous nature of the clay from which they were made.

Chapter 7
Results of the archaeometric analysis – Belovode

This chapter reports the results of the archaeometric analysis conducted on pottery from trench 18 at Belovode, including thin section petrography, WD-XRF, XRPD and SEM. The samples were selected to reflect the typological and technological variability identified by the preliminary macroscopic observations (**Chapter 6**). The results offer significant insights into technological aspects of pottery production, providing the opportunity to study the development of craft knowledge at Belovode across the pre-metallurgical horizons (4 and 3, Vinča A1–B2) and metallurgical horizons (2 to 1, Gradac-Vinča D2).

Results of the compositional analyses

From the total of 14,288 sherds from Belovode that were macroscopically examined, 151 samples (see **Appendices A1.1** and **A1.2**) were selected for more detailed provenance and technological characterisation using archaeometric techniques. The chosen specimens represented the settlement horizons recognised in trench 18 and covered the typological and technological variability observed in the macroscopic analysis. A combined approach of petrographic and chemical analysis was applied to characterise their mineralogical and chemical composition. All 151 samples were examined via ceramic thin section petrography (**Appendices B1** and **B4**) and a subset of 67 were subjected to WD-XRF (**Appendix C1.1**).

Results of the petrographic analysis

It was possible to divide the 151 samples into three principal petrographic fabrics—BEL-A, BEL-B and BEL-C—based on aplastic inclusions, the matrix, and voids observed in thin section. These correspond well to the macroscopic fabric groups previously observed (**Chapter 6**). Several additional fabrics were also identified, represented only by one or two samples and not distinguished by the macroscopic analysis. In the following paragraphs, a summary description of each fabric is presented. A more detailed account is already published (**Amicone 2021a; Amicone *et al.* 2020b**). A full description of the main petrographic groups (A and B), according to Whitbread's methodology (**1989**) is provided in **Appendices B1** and **B4**.

Fabric BEL-A: metasedimentary rock fabric (Figures 7.1 and 7.2)

Samples assigned to this fabric can be divided into a heterogeneous coarse-grained group (sub-fabric BEL-A1, 61 samples) and a fine-grained group (sub-fabric BEL-A2, 53 samples). This fabric group is characterised by generally poorly sorted sub-angular to sub-rounded inclusions of quartz, polycrystalline quartz and metasedimentary rock fragments. Quartz is the dominant mineral inclusion, with plagioclase, K-feldspars, muscovite, chert, opaque minerals, and clay pellets being common. Inclusions of epidote and amphibole are few, while calcite and mudstone are rare. In the coarse-grained specimens, the common presence of fragments of medium-grade non-foliated metamorphic rocks composed of quartz can be observed. This composition is indicative of metasedimentary rocks, more specifically metarenite. The grain size distribution is generally weakly bimodal. The matrix is non-calcareous and the colour varies from light yellow (e.g. BEL 18-30) and bright orange (e.g. BEL 18-58) to dark red (e.g. BEL 18-106) in PPL. In XP, colours range from light brown (e.g. BEL 18-117), brown (e.g. BEL 18-111), dark reddish (e.g. BEL 18-36) to grey (e.g. BEL 18-2). It is relatively homogeneous, save for core-margin colour differentiation caused by firing. The samples exhibit moderate to weak optical activity in XP, while some are inactive (**Appendices B1** and **B4**). Based upon these compositional and textural characteristics, the raw materials used to produce these ceramics could have been a secondary sandy-clay source. However, significant compositional and textural variation has been noted in this group, which can be subdivided into several smaller subgroups.

Samples BEL 18-193, BEL 18-249, BEL 18-275, BEL 18-295, BEL 18-301, BEL 18-310, and BEL 18-330 (**Figure 7.1c–e**) show a more marked bimodal distribution of the mineral inclusions that could be evidence for tempering. BEL 18-4, BEL 18-10, BEL 18-67, BEL 18-82, BEL 18-104, BEL 18-318 also exhibit indications of the possible addition of aplastic material but do also show some textural and minor compositional variability. More precisely, BEL 18-10 and BEL 18-82 (**Figure 7.1f**) are coarse-grained (average inclusions size 1.5mm) with high abundance of well sorted fragments of metasedimentary rocks, chert and microcline. Samples BEL 18-4 and BEL 18-67 (**Figure 7.2a**) show possible evidence for the addition of mudstone, whereas BEL 18-104 (**Figure 7.2b**) is characterised by the presence of plant material; it is not clear if this is naturally occurring or added as temper. In addition, specimens BEL 18-87, BEL 18-300 and BEL 18-324 (**Figure 7.2c**) contain limestone fragments that were possibly added as temper. Finally, sample BEL 18-318 (**Figure 7.2d**) stands out for the notably higher

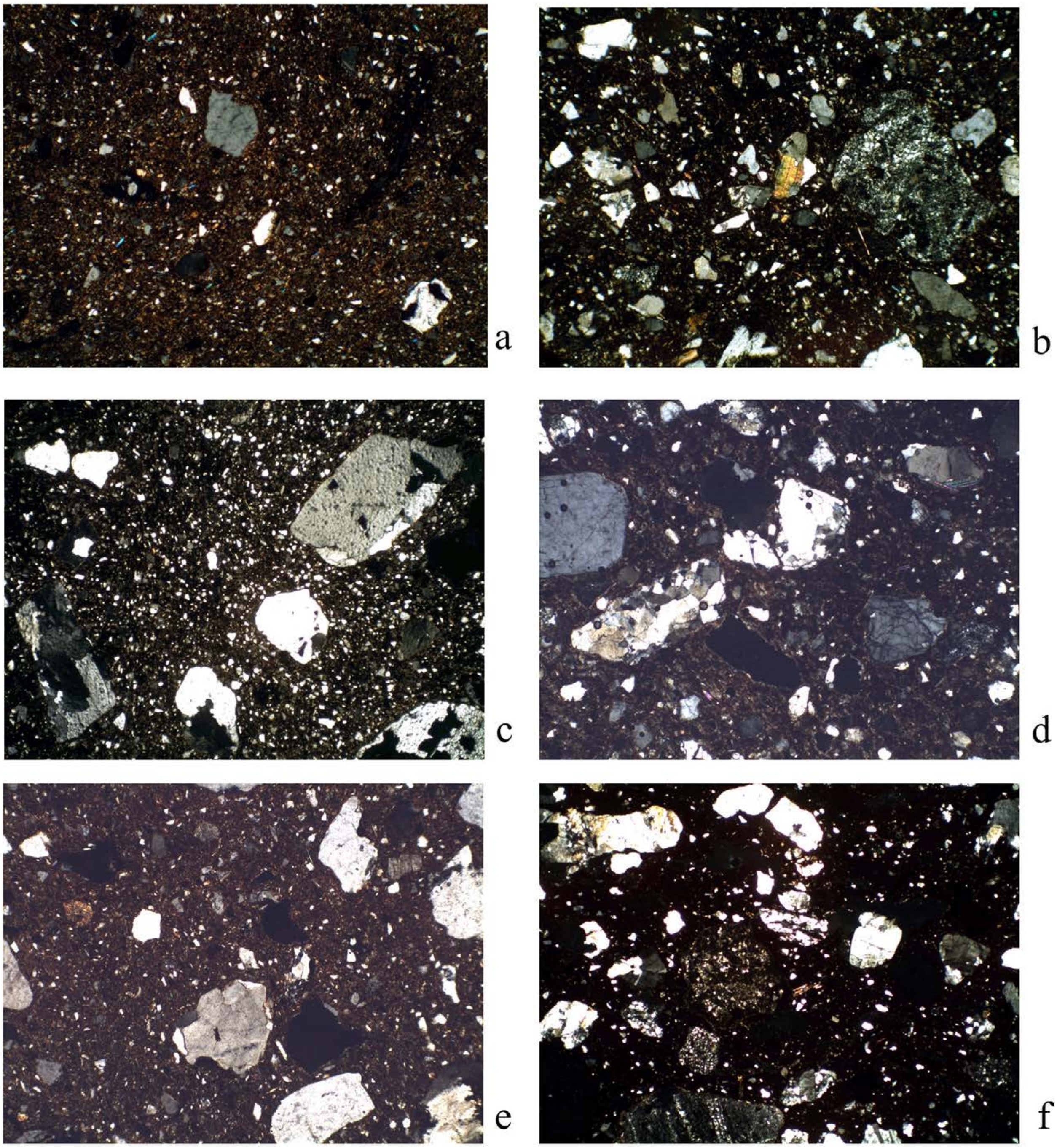


Figure 7.1. Thin section photomicrographs of petrographic fabrics from Belovode: a) Fabric BEL-A (BEL 18-198) with metasedimentary rocks (fine), XP; b) Fabric BEL-A (BEL 18-2) with metasedimentary rocks (coarse), XP; c) Fabric BEL-A (BEL 18-310), bimodal distribution, XP; d) Fabric BEL-A (BEL 18-193), bimodal distribution, XP; e) Fabric BEL-A (BEL 18-275), bimodal distribution, XP; f) Fabric BEL-A (BEL 18-10), bimodal distribution, XP. Field of view = 3 mm (a, b, d, e); 6 mm (c, f).

quantity of clay pellets and chert within the ceramic matrix.

Fabric BEL-B: fossiliferous fabric (Figure 7.3a, b)

Samples of this fabric compose a heterogeneous coarse (sub-fabric BEL-B1, 16 samples) to fine-grained (sub-fabric BEL-B2, 7 samples) group marked by the presence of shell fragments, microfossils and poorly sorted sub-angular to sub-rounded inclusions of quartz. Dominant mineral inclusions comprise quartz and polycrystalline quartz. Shell fragments and microfossils frequently occur, and plagioclase, muscovite, calcite, opaque minerals, chert and clay pellets are common. Epidote and amphibole are only rarely present. In the coarser samples (BEL 18-97, BEL 18-98, BEL 18-108, BEL 18-110

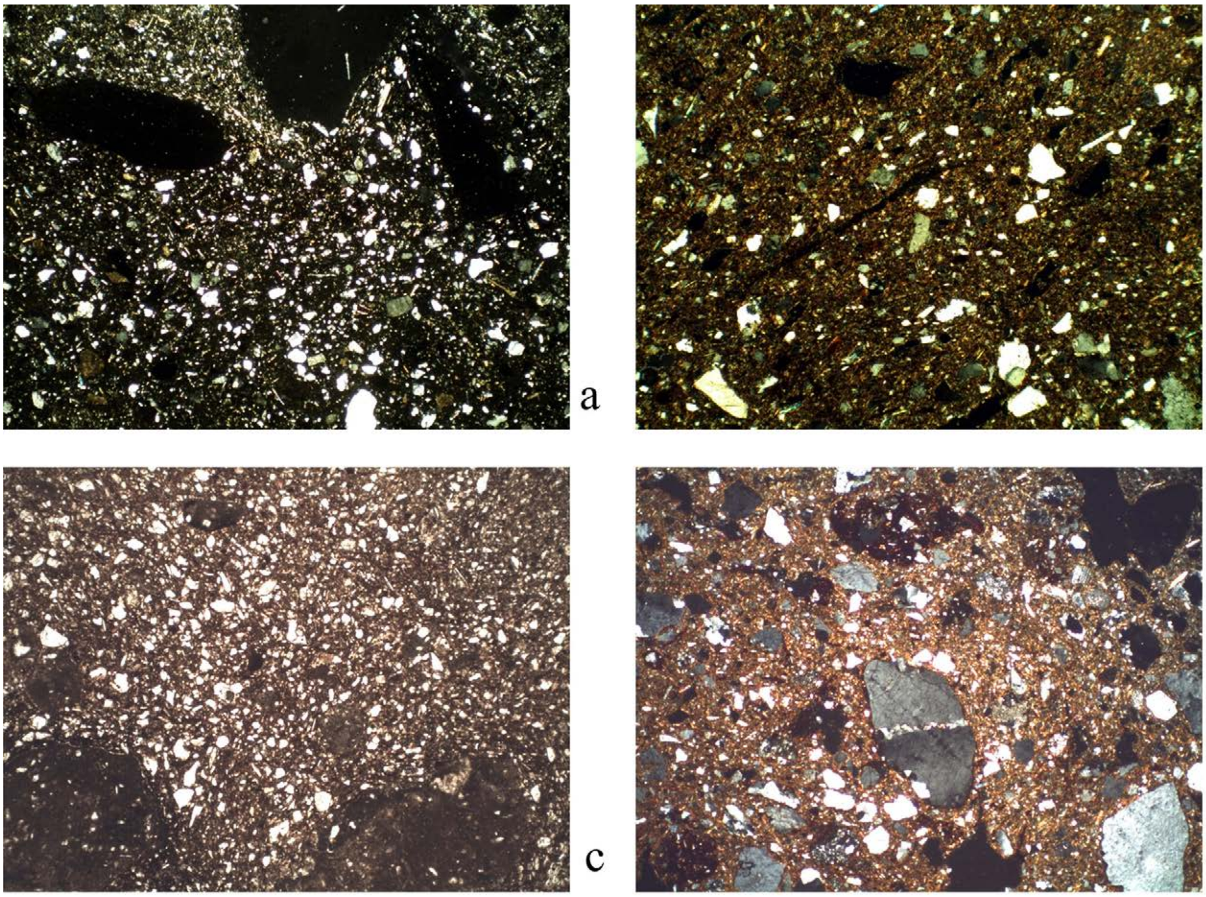


Figure 7.2. Thin section photomicrographs of petrographic fabrics from Belovode: a) Fabric BEL-A (BEL 18-67) with mudstone, XP; b) Fabric BEL-A (BEL 18-104) with organic material, XP; c) Fabric BEL-A (BEL 18-300) with limestone tempering, PPL; d) Fabric BEL-A (BEL 18-318) with abundant clay pellets, XP. Field of view = 6 mm (a, c, d); 3 mm (b).

and BEL 18-114), it was possible to observe common fragments of metasedimentary rocks and mudstone. The grain size distribution is generally polymodal. The colour of the matrix is light yellow in PPL and yellow to dark brown in XP, and often shows the typical layers attributed to irregular firing conditions. It ranges from non-calcareous to calcareous, and samples exhibit low to weak optical activity. The compositional and textural characteristics of this group suggest that the raw material employed to produce these vessels could originate from a secondary sandy-clay source.

Fabric BEL-C: organic tempered fabric (Figure 7.3c)

This fabric includes three samples (BEL 18-303, BEL 18-334, BEL 18-348) and is marked by the presence of organic tempers and generally poorly sorted sub-angular to sub-rounded inclusions of quartz. Quartz is the dominant mineral inclusion. Common minerals include muscovite, plagioclase, amphibole, chert, opaque minerals and clay pellets. A few fragments of metasedimentary rocks also occur and the grain size distribution is polymodal. The matrix is non-calcareous, and its colour is light yellow to dark brown in PPL and light brown to dark brown in XP. It is relatively homogeneous, save for the core-margin colour differentiation. It is also moderately to weakly active. Based upon these compositional and textural characteristics, the raw material used to produce these vessels seems to have been a secondary sandy-clay source to which organic material was added as temper.

Fabric BEL-D: very fine fabric (Figure 7.3d)

This fabric is represented by samples BEL 18-15, BEL 18-31 and BEL 18-298. It is a fine-grained fabric dominated by the presence of well sorted and fine sub-angular inclusions of quartz (mean inclusions size 0.1mm). Muscovite is also frequently included and opaque minerals are also common. The grain size distribution is unimodal. The matrix is of a very fine non-calcareous nature and is light yellow to brown in PPL, and light brown to dark brown in XP. It is very homogeneous and moderately active. Based upon compositional

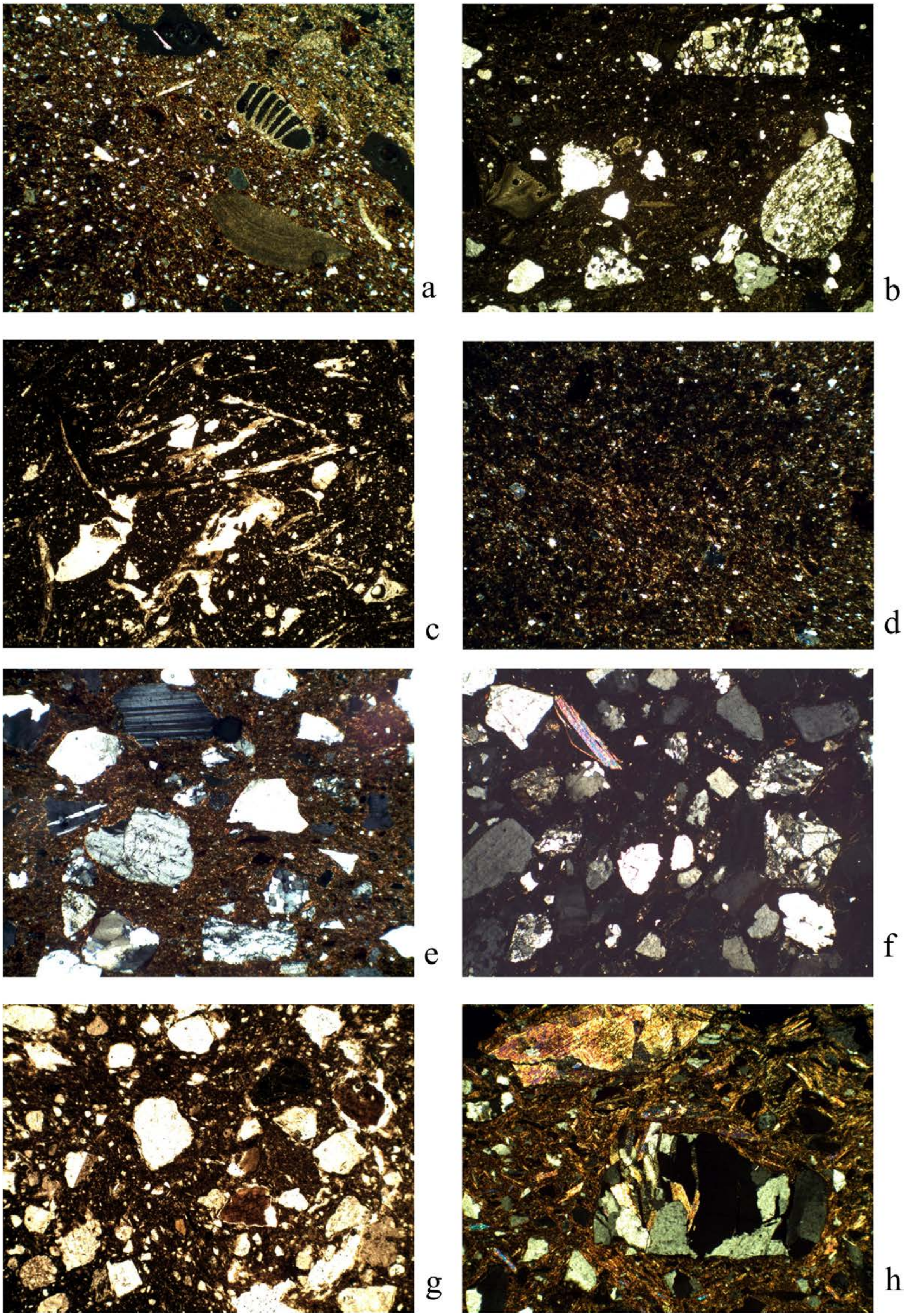


Figure 7.3. Thin section photomicrographs of petrographic fabrics from Belovode: a) Fabric BEL-B (BEL 18-280) with shells and microfossils (fine), XP; b) Fabric BEL-B (BEL 18-97) with shells, microfossils, and metasedimentary rocks (coarse), XP; c) Fabric BEL-C (BEL 18-303) with organic tempering, PPL; d) Fabric BEL-D (BEL 18-31) with very fine matrix, XP; e) Fabric BEL-E (BEL 18-43) with coarse metamorphic rocks, XP; f) Fabric BEL-F (BEL 18-53) with metamorphic rocks, XP; g) Fabric BEL-G (BEL 18-155) with serpentinite, PPL; h) Fabric BEL-H (BEL 18-325) with mica-schist, XP. Field of view = 3 mm (a, d, e, f, g, h); 6 mm (b, c).

and textural characteristics, the raw material used to produce these vessels appears to have come from a very fine secondary clay source.

Fabric BEL-E: coarse metamorphic fabric (Figure 7.3e)

This fabric includes samples BEL 18-43 and BEL 18-60 and is coarse-grained (mean inclusion size 2mm) and marked by the presence of very well sorted sub-rounded inclusions of quartz and metamorphic rocks. Besides the dominant quartz inclusions and the medium-grade non–foliated metamorphic rock fragments composed of quartz, there are minor quantities of muscovite present. Opaque minerals and clay pellets are common while amphibole occurs only rarely. The grain size distribution is bimodal. The moderately active matrix is non-calcareous and very homogeneous, brown in PPL and dark brown in XP. The compositional characteristics and bimodal grain size distribution suggest that these vessels were probably made from a fine secondary clay source with the addition of sand derived from the weathering of metasedimentary rock (metarenite).

Fabric BEL-F: metamorphic fabric with weathered plagioclase (Figure 7.3f)

This fabric is represented by samples BEL 18-53, BEL 18-288, and BEL 18-321. These do not constitute a homogeneous group and show some differences between them, but they are all marked by the presence of metamorphic rocks. BEL 18-53 is characterised by very well sorted sub-angular to sub-rounded inclusions of quartz, weathered plagioclase and metamorphic rocks (average 0.6mm). The dominant mineral inclusions are quartz and polycrystalline quartz. Plagioclase, muscovite, chert, opaque minerals and medium-grade non–foliated metamorphic rock fragments composed of quartz are also common. There are only a few inclusions of epidote and amphibole. The grain size distribution is strongly bimodal. The non-optically active matrix is homogeneous and non-calcareous. Its colour is dark brown in both PPL and XP. In BEL 18-321, amphibole, epidote and microcline are more common. There are also a few fragments of foliated low-grade metamorphic rocks composed of muscovite and a minor quantity of quartz (phyllite). The matrix has a moderate optical activity. These characteristics are shared with sample BEL 18-288, but the latter has coarser fraction (average 1mm) with a greater abundance of metamorphic rock fragments rich in quartz and highly weathered plagioclase. Based on the compositional and textural characteristics, it can be assumed that the raw material employed for making these vessels was a secondary clay source to which sand derived from weathering of metamorphic rocks was added.

Fabric BEL-G: serpentinite fabric (Figure 7.3g)

This fabric is solely represented by sample BEL 18-155. It is a medium to coarse-grained fabric marked by the presence of poorly sorted, sub-angular inclusions of quartz and rounded fragments of serpentinite. Dominant mineral inclusions comprise quartz while plagioclase and muscovite are frequent. Fragments of serpentinite, opaque minerals and clay pellets are common and there are also a few inclusions of amphibole, metasedimentary and volcanic rocks. Grain size distribution is polymodal. The matrix is homogeneous and non-calcareous, dark brown in PPL and XP and moderately active. Textural and compositional characteristics suggest that this vessel was made from a secondary clay source.

Fabric BEL-H: mica-schist fabric (Figure 7.3h)

This fabric characterises samples BEL 18-247 and BEL 18-325 and is marked by the presence of mica-schist. The dominant mineral inclusion is quartz, while other common inclusions are muscovite, plagioclase, amphibole, chert, opaque minerals and clay minerals. Fragments of medium-grade foliated metamorphic rocks rich in quartz and muscovite are common (mica-schist). Grain size distribution is polymodal. The matrix is non-calcareous, homogeneous and its colour is light brown in PPL and dark brown in XP; samples exhibit weak optical activity. The angularity of the inclusions and their poor degree of sorting suggest that the clay used to produce these vessels was residual in origin, transported a minimal distance, and might have derived from the weathering of mica-schist rocks.

Results of the chemical analysis

Sixty-seven samples representing the petrographically diverse fabrics were selected for geochemical analysis. Quantitative analysis was performed for each sample, calculating the concentration of major and minor elements expressed as wt% of their oxide form (Na_2O, MgO, Al_2O_3, SiO_2, K_2O, CaO, TiO_2, Fe_2O_3, P_2O_5, MnO) and in ppm for the trace elements (V, Cr, Co, Ni, Cu, Zn, Rb, Sr, Y, Zr, Ba, La, Ce, Nd, Pb, Th).

A preliminary review of the dataset (**Appendix C1.1**) indicated that the coarse and medium-coarse specimens of fabric BEL-A (i.e. sub-fabric BEL-A1) have similar concentrations of major, minor and trace elements to samples of sub-fabric BEL-A2, including the medium-fine and fine samples. However, samples of sub-fabric BEL-A1 are characterised by a relatively higher proportion of SiO_2 (between 65 and 72%) in comparison to sub-fabric BEL-A2 due to the presence of abundant quartz inclusions. Both sub-fabrics contain a low CaO content (1–3%) compared to samples assigned to fabric BEL-B (CaO between 4 and 9%). The latter fabric group

Table 7.1. Results of a descriptive statistical analysis of the WD-XRF dataset comprising the 67 samples from Belovode (Els: Elements; StDev: Standard Deviation; Var: Variance; CV: Coefficient of Variation; Min: Minimum; Q1: First Quartile; Q3: Third Quartile; Max: Maximum).

Els	Mean	StDev	Var	CV	Min	Q1	Median	Q3	Max	p-value
Na_2O %	1.12	0.30	0.09	26.32	0.38	0.95	1.11	1.3	2.03	> 0.100
MgO %	1.47	0.33	0.11	22.61	0.89	1.25	1.41	1.59	2.73	< 0.010
Al_2O_3 %	14.5	1.43	2.03	9.81	12	13.59	14.33	15.1	20.29	< 0.010
SiO_2 %	64.28	4.92	24.20	7.65	47.78	62.98	65.26	67.5	71.84	< 0.010
K_2O %	2.48	0.50	0.25	20.38	1.65	2.28	2.38	2.53	5.02	< 0.010
CaO %	3.10	2.47	6.08	79.47	1.12	1.95	2.19	2.81	13.11	< 0.010
TiO_2 %	0.82	0.11	0.01	13.26	0.51	0.76	0.84	0.9	1	< 0.010
Fe_2O_3 %	5.68	0.78	0.60	13.69	3.99	5.06	5.64	6.1	7.93	0.069
P_2O_5 %	1.40	0.87	0.75	61.77	0.16	0.78	1.18	1.89	3.77	< 0.010
MnO %	0.01	0.03	0.001	32.8	0.03	0.08	0.1	0.12	0.22	0.039
V ppm	111.78	18.14	329.24	16.23	70	98	112	119	182	< 0.010
Cr ppm	113.1	42.38	1795.79	37.47	70	100	110	118	438	< 0.010
Co ppm	17.61	9.75	95	55.34	11	15	16	18	93	< 0.010
Ni ppm	64.69	32.38	1048.46	50.06	36	51	58	68	255	< 0.010
Cu ppm	78.93	41.11	1690.4	52.09	31	50	69	98	244	< 0.010
Zn ppm	102.18	17.98	323.45	17.6	64	90	101	110	167	0.019
Rb ppm	97.49	11.81	139.53	12.12	72	89	98	106	121	> 0.100
Sr ppm	202.6	105	11025.6	51.84	89	147	169	212	807	< 0.010
Y ppm	32.61	5.42	29.42	16.63	20	29	33	37	42	> 0.100
Zr ppm	259.78	68.95	4753.57	26.54	108	202	279	315	348	< 0.010
Ba ppm	885.5	313.2	98101.4	35.37	446	627	816	1052	1593	< 0.010
La ppm	37.88	7.66	58.74	20.23	20	33	38	44	53	> 0.100
Ce ppm	79.58	15.93	253.7	20.01	33	69	82	90	117	0.043
Nd ppm	35.60	7.45	55.52	20.93	20	29	36	40	54	> 0.100
Pb ppm	32.66	7.18	51.59	21.99	21	28	31	36	68	< 0.010
Th ppm	13.01	2.83	8.01	21.75	6	11	13	15	20	< 0.010

is also characterised by a lower concentration of SiO_2 and higher Sr. The high content of CaO and Sr is due to the presence of microfossils, shells and fragments of limestone that characterise this fabric.

The chemical composition of the samples of fabric BEL-C, tempered with organic material, does not differ significantly from that of samples assigned to fabric BEL-A, although BEL 18-303 shows slightly higher concentrations of V, Ni and Cu. Finally, samples representative of the other fabric outliers all show considerably different concentrations of major and minor elements compared to the three main petrographic groups. For example, sample BEL 18-155, with serpentinite, is characterised by higher Ni (255ppm) and Cr (438ppm) content, while BEL 18-15 and BEL 18-31 show higher concentrations of Al_2O_3 (*c.* 20%) and Fe_2O_3 (*c.* 7%).

Following these preliminary observations, a descriptive statistical approach was applied to the geochemical dataset (**Table 7.1**). The mean, standard deviation, variance, coefficient of variation, minimum, first quartile (Q1), median, third quartile (Q3), and maximum were calculated to describe the central tendency and dispersion of the data distributions (**Sheldon 2003**). In addition, to examine whether the data follow a normal distribution, a Shapiro-Wilk normal probability test was performed to calculate the p-value. The samples analysed showed compositional heterogeneity, expressed by the standard deviations and wide distribution intervals. The coefficient of variation of CaO, P_2O_5, Co and Ni is greater than 50% and reaches 74% for CaO. Most of the variables do not show a normal distribution because they have p-values below 0.05. To gain a better understanding of the source of variability in the WD-XRF dataset, a variation matrix (VM) of the 26 chemical elements measured was calculated. This matrix also allowed the calculation of the total variance of the dataset (*vt*) providing information about its mono- or polygenic nature and helping to estimate the likelihood of the presence of different groups related to different provenances. The results (**Figure 7.4**) show that the *vt* of the dataset is quite high (1.93), suggesting that these data are polygenic; in other words, not all individuals show similar compositions. The elements which most contribute to an increase in the *vt* value are P_2O_5, CaO and Cu but these are known to be subject to post-depositional effects (e.g. **Freestone *et al.* 1985; Gascón and Buxeda i Garrigós 2013: 81; Maritan 2020**). Thus, the high variability could have been induced by post-depositional effects instead of reflecting the original variability of composition and texture. It was therefore decided to recalculate the VM, excluding P_2O_5 and Cu from the dataset, together with Ba, Pb and Co, which are also prone to similar post-depositional effects and contamination. CaO was included because it was possible to determine—via thin section analysis—that its presence was primary. Only one sample, BEL 18-53, showed evidence of secondary

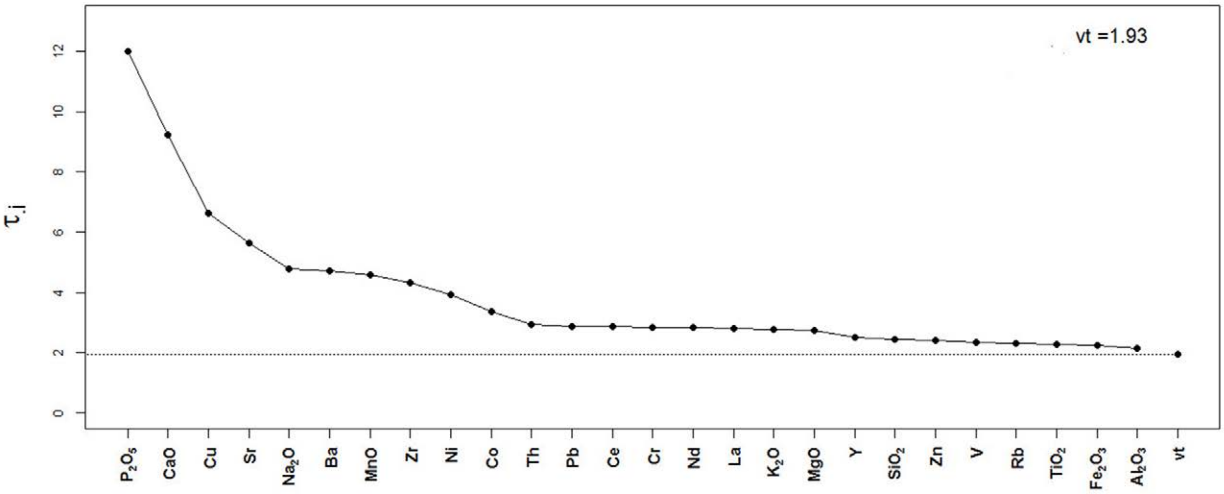


Figure 7.4. Evenness chemical variability graph for all 67 samples characterised (26 elements). vt: total variation; τ.i: trace of the covariance matrix in ALR transformation using that element as divisor.

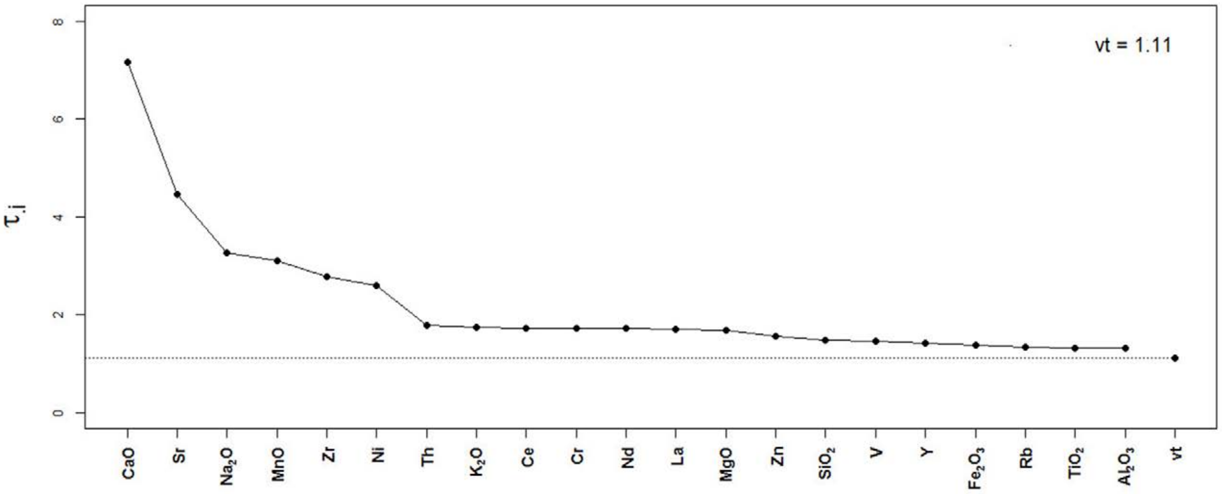


Figure 7.5. Evenness chemical variability graph for all 67 samples characterised (21 elements). vt: total variation; τ.i: trace of the covariance matrix in ALR transformation using that element as divisor.

calcite in its pores. Following these adjustments, the total variance dropped significantly, from 1.93 to 1.11 (**Figure 7.5** and **Appendix C1.2**), however this value is still relatively high and confirms the heterogeneity of the dataset.

Multivariate statistical analysis was then run on the non-normalised WD-XRF dataset, comprising 67 specimens and 21 elements. Principal Component Analysis (PCA) was applied to the dataset, which was first transformed to logarithmic base -10, then with a centred log ratio (CLR), and finally an asymmetric log ratio (ALR). In the ALR transformation, Al_2O_3 was used as divisor since it showed the lowest variance (**Buxeda I Garrigós 1999: 300**). The PCA on these three different datasets produced similar patterns, however the scatter-graph based on the first two principal components calculated on the ALR-transformed dataset has the highest cumulative variance for principal components 1 and 2 (52.2%) and was thus chosen to illustrate the results here. The comparison between the score plot and the variable plot (**Figure**

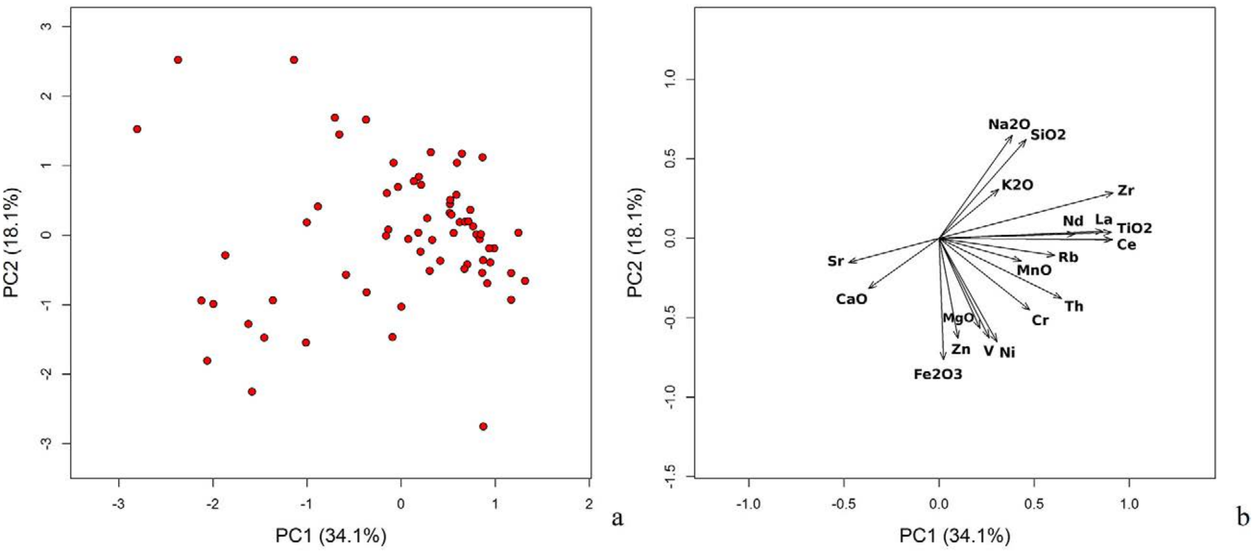


Figure 7.6. A score plot (a) and variable plot (b) based on the first two components from the PCA run on the non-normalised ALR transformed WD-XRF Belovode dataset comprising 67 samples and 21 variables.

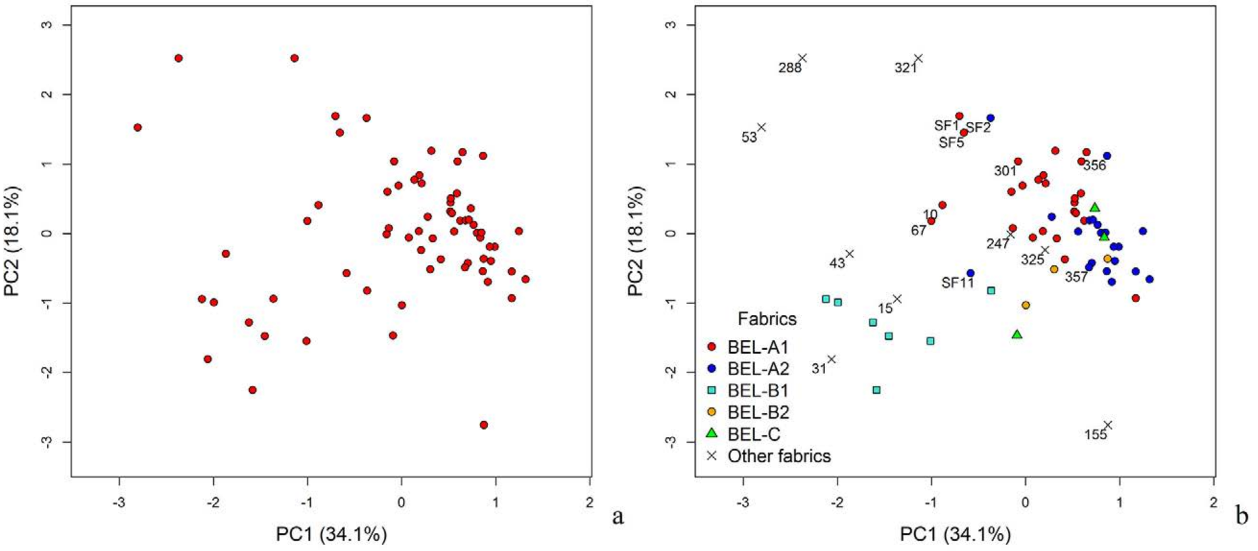


Figure 7.7. Comparison between score plots based on the first two components from the PCA run on non-normalised ALR transformed WD-XRF Belovode dataset comprising 67 samples and 21 variables. In score plot b) colours correspond to different fabrics observed in thin section analysis.

7.6a, b) shows that the analysed samples tend to scatter in different areas of the graph according to different element concentrations. Notably, several specimens plot in the lower left section of the graph because of the higher concentration of Sr and CaO, while three other samples scatter in the upper left part due to their low Cr content. Most samples, however, constitute a group that plots in the centre right section of the graph. If this scatter plot is compared with that in which petrographic fabrics are taken into consideration, it is clear that this larger group corresponds to the samples assigned to fabric BEL-A (**Figure 7.7**). Furthermore, it can be observed that, in this group, the coarse samples (sub-fabric BEL-A1) slightly separate from the group with finer samples (sub-fabric BEL-A2). This is most likely due to the higher concentration of SiO_2 resulting from the greater abundance of quartz inclusions and rock fragments rich in quartz present in this coarse sub-fabric. In addition, samples of sub-fabric BEL-A2 have a more homogeneous composition and tend to plot more closely. Conversely, samples within sub-fabric BEL-A1 are more dispersed in the PCA scatter plot.

Three samples of loom-weights assigned to fabric BEL-A (BEL 18-SF1, BEL 18-SF2, BEL 18-SF3) tend to separate slightly from the main group, probably due to their slightly lower content of V and Cr, while BEL 18-10 and BEL 18-67 separate because of their lower concentration of Ce and Zr in comparison to the other specimens attributed to fabric BEL-A. Finally, samples of oven fragments (BEL 18-356 and BEL 18-357) assigned to fabric BEL-A plot together with the pottery specimens assigned to the same fabric group.

Samples classified as fossiliferous fabric BEL-B plot into two separate areas. Specimens of sub-fabric B1 that include coarse samples clearly scatter in a separate section of the plot, while those of sub-fabric BEL-B2 tend to plot together with specimens attributed to fabric BEL-A. Cross comparison between the PC scatter-graph (**Figure 7.7b**) and the graph variable plot (**Figure 7.6b**), shows that samples attributed to subgroup BEL-B1 concentrate towards the direction of CaO and Sr and that these two elements are mainly responsible for the separation of this group. It is also apparent that both petrographic and chemical analyses show that the group of samples assigned to sub-fabric BEL-B1 is not homogeneous and is marked by a compositional variability due to the different amounts of shell, microfossils, rocks and limestone fragments. This explains why these samples do not plot together in terms of their geochemistry. On the other hand, specimens of sub-fabric BEL-B2, including those with rare occurrences of microfossils and shells, have a lower concentration of CaO and Sr and form a more homogeneous group. The only exception is BEL 18-280, which has a considerably lower concentration of SiO_2 and higher concentration of Fe_2O_3, V, Ni and CaO in comparison to the other samples of this sub-fabric. The results also confirm that specimens attributed to fabric BEL-C, with organic tempering, have a very similar chemical composition to specimens assigned to fabric BEL-A.

Finally, statistical classification also shows that samples representative of the other fabrics (BEL 18-15 and BEL 18-31; BEL 18-43; BEL 18-53; BEL 18-288 and BEL 18-321, and BEL 18-155) have significantly different concentrations of major, minor and trace elements compared to specimens in the main group, while specimens BEL 18-247 and BEL 18-325 do not separate clearly from this group, despite being distinctive in terms of their petrography.

Thus, the PCA of the bulk chemical data seems to be largely in agreement with petrographic analysis, providing a more robust, integrated classification of the ceramics. The analysis also produces a more detailed compositional characterisation of the samples under examination. Hierarchical cluster analysis (average linkage) was also performed on the principal components, calculated on the non-normalised ALR transformed dataset. As mentioned in **Chapter 5**, PCA can be used in this way as a pre-processing step for cluster analyses in order to denoise the data (**Husson *et al.* 2010**).

Clusters were calculated and the dendrogram then cut at 6 (**Figure 7.8**); for a better visualisation they were plotted on the score plot based on the first two components. Clusters calculated in this way tend to correspond to the groups recognised in petrographic analysis and to those highlighted in the score plot based on the first two components of the PCA run on the ALR transformed dataset (**Figure 7.9**). Interestingly, samples belonging to sub-fabrics BEL-A1 and BEL-A2 are classified in the same cluster of samples assigned to fabric BEL-C, suggesting that the raw material used to produce them was very similar. The graph also confirms the presence of compositional outliers already highlighted by the PCA.

A chemical dataset including pottery samples of fabric BEL-A and fabric BEL-C was then analysed separately, to investigate possible compositional differences within these samples. Firstly, the chemical VM (**Figure 7.10**) was calculated on a dataset including 21 elements. This revealed that total variance was very low (*vt*=0.51), meaning that, from a compositional perspective, this dataset is far more homogeneous than the previous one. As before, CaO and Sr are among the variables that account for the largest variance in the dataset. Principal component and hierarchical cluster analysis were then applied to the same dataset after it was subject

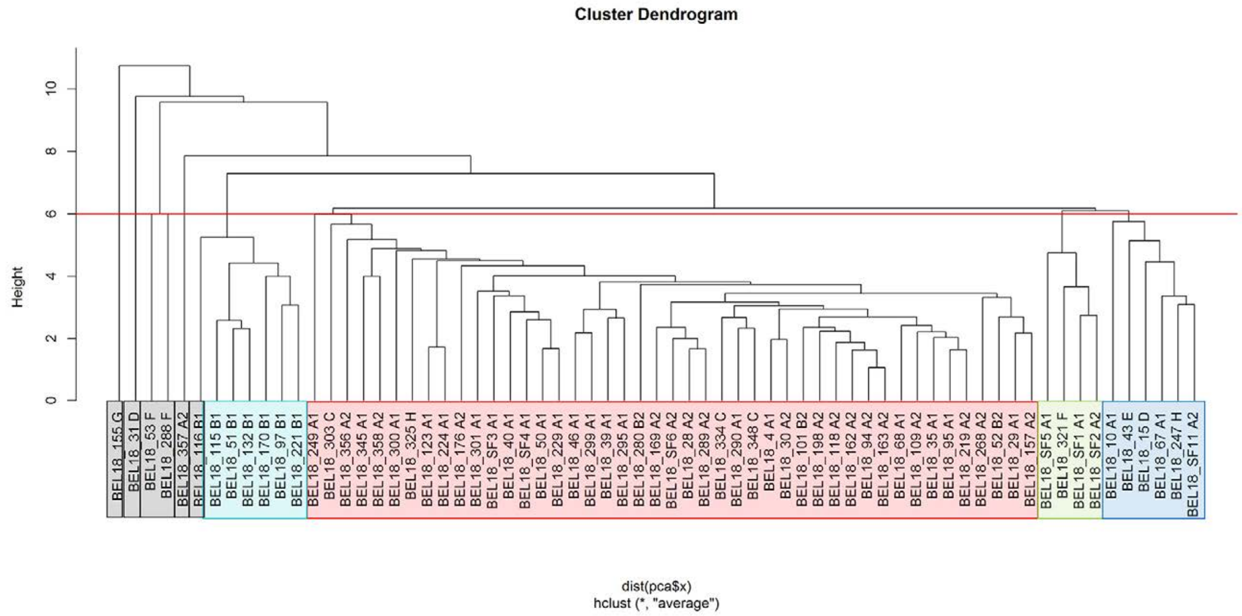


Figure 7.8. Dendrogram obtained by applying Hierarchical Agglomerative Cluster Analysis (average linkage method) on the principal components calculated via the PCA of the non-normalised ALR transformed WD-XRF dataset from Belovode. The dataset comprises of 67 samples and 21 variables.

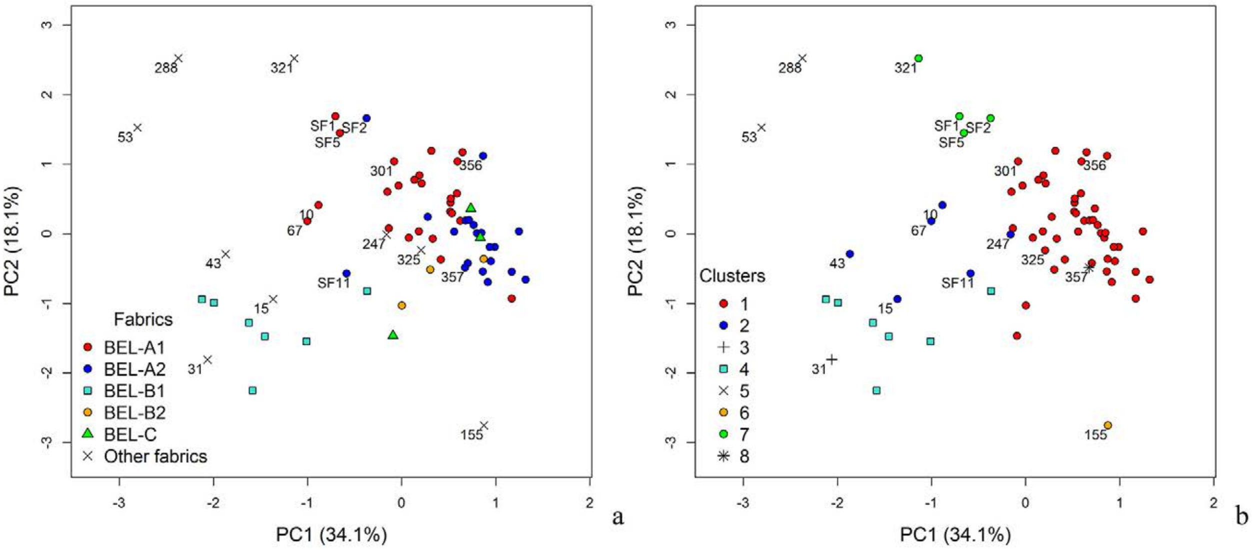


Figure 7.9. Comparison between score plots based on the first two components from the PCA run on non-normalised ALR transformed WD-XRF Belovode dataset comprising the 67 samples and 21 variables: a) colours correspond to different fabrics as observed in thin section analysis; b) colours correspond to the hierarchical clusters calculated by cutting the tree at 6.

to ALR transformation. The results (**Figures 7.11** and **7.12**) highlight the presence of several samples which separate from the main group/cluster.

Among the samples that plotted separately, BEL 18-10, BEL 18-67, and BEL 18-300 show evidence of a different type of clay paste preparation. BEL 18-10 was tempered with sand rich in quartz and metasedimentary rocks. This explains the high content of SiO_2 (68.33%) which characterises this sample. BEL 18-67 is marked by high concentrations of Fe_2O_3, Al_2O_3, Zn and a lower quantity of Zr in comparison to the other samples; this may be a result of the observed mudstone temper. BEL 18-300 has a high CaO content (7.42%), possibly the result of the addition of limestone fragments to the paste. Finally, BEL 18-123 and BEL 18-224 plot separately because of their low concentrations of both CaO and Sr. These two specimens stand out for the complete absence of optical activities of their matrix. This indicates that the vessels probably underwent high firing temperatures,

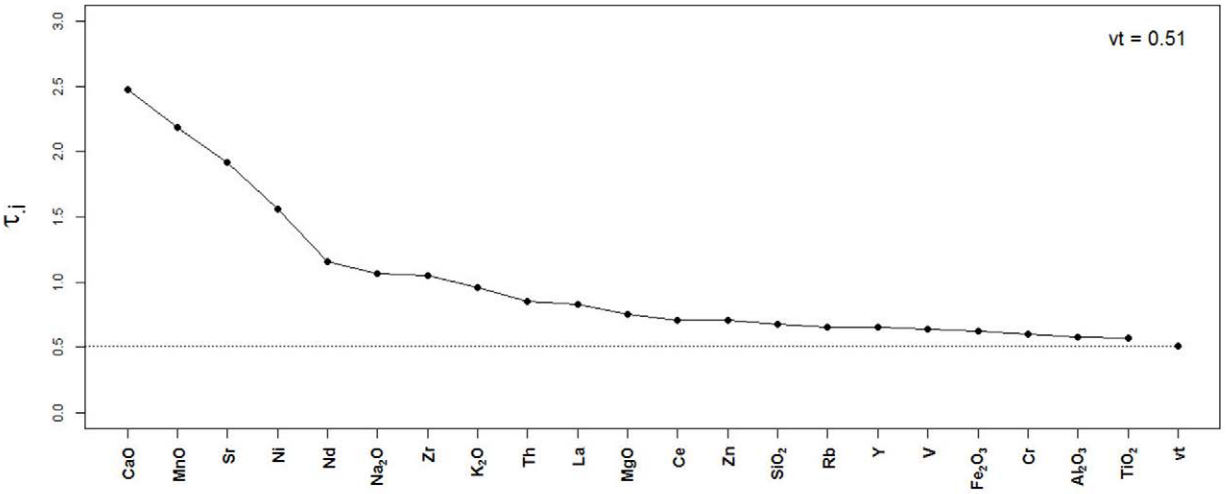


Figure 7.10. Evenness chemical variability graph 38 samples characterised (21 elements). vt: total variation; τ.i: trace of the covariance matrix in ALR transformation using that element as divisor.

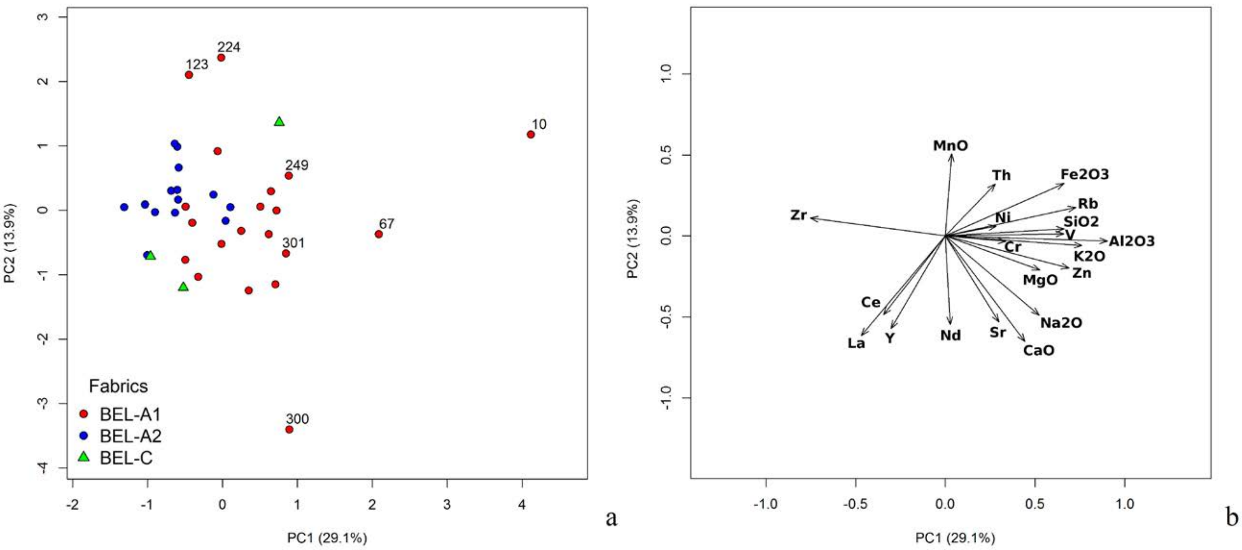


Figure 7.11. A score plot (a) and a variable plot (b) based on the first two components from the PCA run on non-normalised ALR transformed WD-XRF Belovode dataset comprising samples of fabrics BEL-A, BEL-C and 21 variables.

which could also account for the lowered content of these two correlated chemical elements.

In conclusion, the various analyses revealed a small number of samples that stand out for their mineralogical and chemical differences, possibly the result of diverging technological processes (e.g. tempering and firing) that altered the original composition of the clay. However, it is apparent that most Belovode samples constitute a homogeneous group that does not separate into clearly defined sub groups relating either to different vessel types or to building horizons (**Figure 7.13**).

Results of the XRPD and SEM analyses

Twenty-nine samples from Belovode were analysed by XRPD diffraction. These included dark-burnished pottery, but also other ceramic types. The results (**Table 7.2** and **Figures 7.14-7.18**) revealed that most of the samples could contain illitic clay, which can be distinguished by a main diffraction peak at 8.82 2θ° (10 Å d spacing) and further peaks at increasing 2θ° with variable intensities. The main peak of illite overlaps with that of muscovite. However, muscovite is present only in minor quantities and probably below the

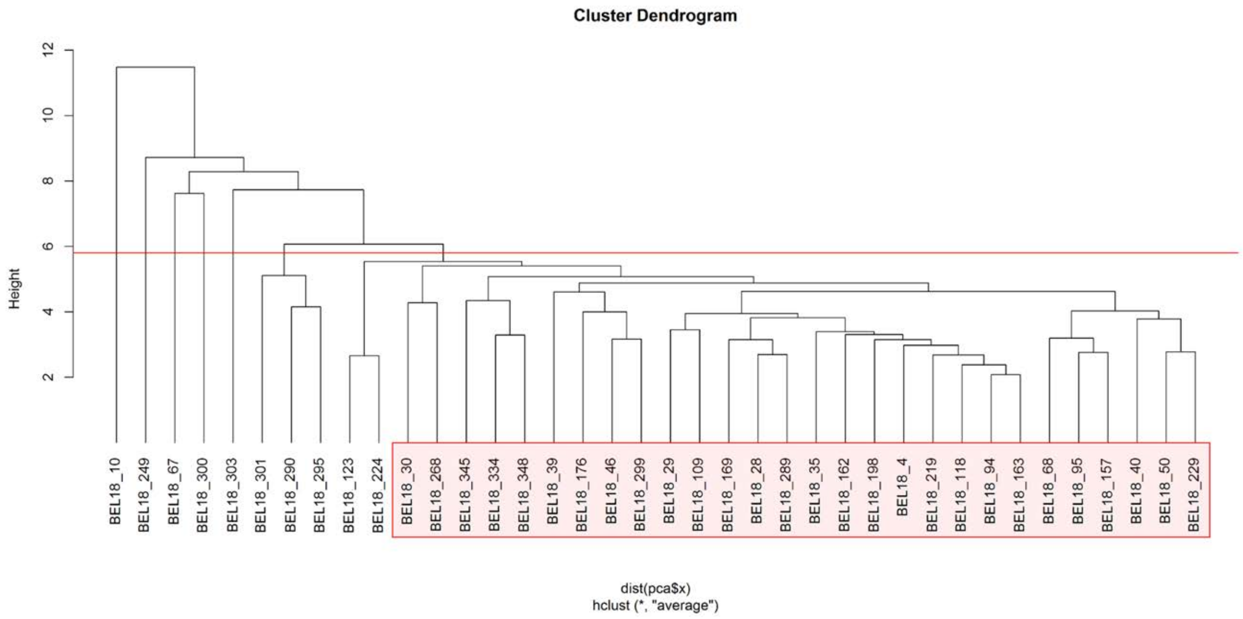


Figure 7.12. Dendrogram obtained by applying Hierarchical Agglomerative Cluster Analysis (average linkage method) on the principal components calculated via the PCA that was run on the non-normalised ALR transformed WD-XRF Belovode dataset comprising samples of fabrics BEL-A, BEL-C and 21 variables.

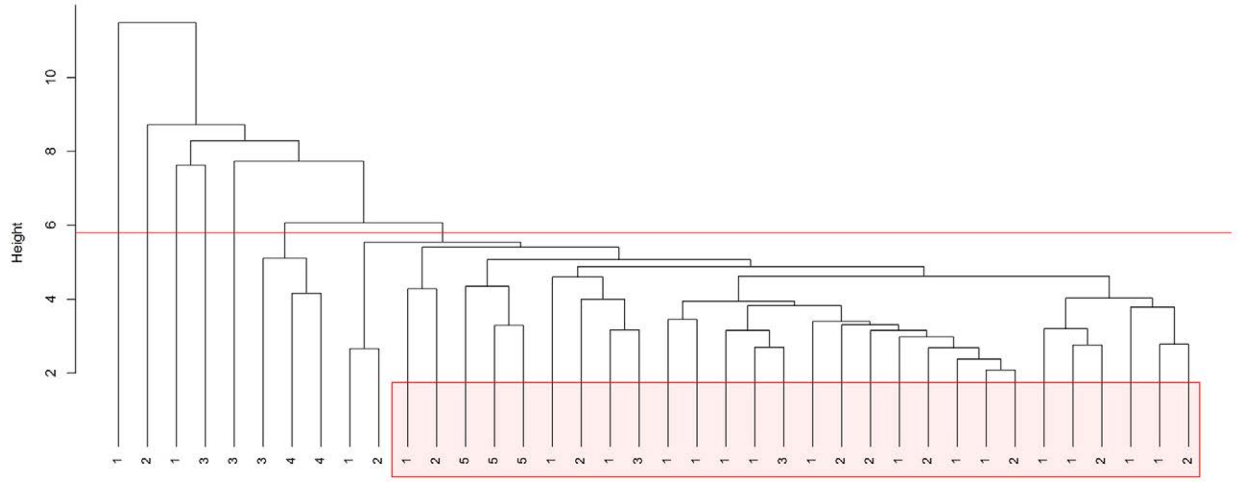


Figure 7.13. Dendrogram obtained by applying Hierarchical Agglomerative Cluster Analysis (average linkage method) on the principal components calculated via the PCA that was run on the non-normalised ALR transformed WD-XRF dataset comprising samples of fabrics BEL-A, BEL-C and 21 variables. Below the tree, the associated building horizons (1–5) of the analysed samples are given.

detection limits of the XRPD instrument. This could confirm that, in our sample, the peak at 8.82 2θ° (10 Å d spacing) could relate to illite.

Some samples exhibit a weak diffraction peak corresponding to a d-value of approximately 6.30 2θ° (14 Å d spacing), which points to either montmorillonite or, more likely, chlorite as montmorillonite decomposes at relatively low temperatures (**Gliozzo 2020**).

Overall, the other main mineralogical assemblages that were detected through XRPD analysis comprised quartz, feldspars, and calcite. In addition, the presence of amphibole was verified, with its main characteristic peak at about d ~ 8 Å. Finally, 3 samples (BEL 18-46, BEL 18-123, and BEL 18-224) show weak peaks of haematite, cristobalite, and spinel (**Figure 7.18**).

The fresh fractures of 14 samples were examined via SEM analysis to assess their degree of vitrification

Table 7.2. Summary of the XRPD results (DB = dark-burnished; GP = graphite-painted).

Sample	Chronological Horizon	DB	GP	Optical Activity	Qtz	Fsp	Cc	Am	Ill	Msc	Hem	Cri	Spl	Temp
BEL 18-31	1 (C-D)	X		high	X	X			X					< 900°C
BEL 18-46	1 (C-D)			absent	X	X					X	X	X	> 1000°C
BEL 18-52	1 (C-D)			weak	X	X	X		X					< 900°C
BEL 18-68	1 (C-D)	X		moderate	X	X			X					< 900°C
BEL 18-94	1 (C-D)	X		moderate	X	X			X					< 900°C
BEL 18-95	1 (C-D)	X		high	X	X			X					< 900°C
BEL 18-101	1 (C-D)	X		high	X	X	X		X					< 900°C
BEL 18-109	1 (C-D)	X		weak	X	X		X	X					< 900°C
BEL 18-115	1 (C-D)			moderate	X	X	X		X					< 900°C
BEL 18-116	1 (C-D)			high	X	X	X		X					< 900°C
BEL 18-118	1 (C-D)	X		weak	X	X			X					< 900°C
BEL 18-123	1 (C-D)			absent	X	X					X	X	X	> 1000°C
BEL 18-132	1 (C-D)			weak	X	X	X		X					< 900°C
BEL 18-162	2 (Gradac-C)	X		moderate	X	X		X	X					< 900°C
BEL 18-163	2 (Gradac-C)	X		high	X	X			X					< 900°C
BEL 18-169	1 (C-D)	X		weak	X	X			X					< 900°C
BEL 18-176	2 (Gradac-C)	X		weak	X	X			X					< 900°C
BEL 18-198	2 (Gradac-C)	X		weak	X	X			X					< 900°C
BEL 18-219	2 (Gradac-C)	X		moderate	X	X		X	X					< 900°C
BEL 18-221	2 (Gradac-C)			absent	X	X	X		X					< 900°C
BEL 18-224	2 (Gradac-C)			absent	X	X					X	X	X	> 1000°C
BEL 18-288	4 (A)			absent	X	X			X					< 900°C
BEL 18-289	3 (B1-B2)	X		moderate	X	X			X					< 900°C
BEL 18-290	4 (A)			absent	X	X			X					< 900°C
BEL 18-295	4 (A)			weak	X	X			X					< 900°C
BEL 18-299	3 (B1-B2)	X		moderate	X	X			X					< 900°C
BEL18-300	3 (B1-B2)	X		high	X	X	X		X					< 900°C
BEL 18-303	5 (Starčevo/A)			weak	X	X			X					< 900°C
BEL 18-334	5 (Starčevo/A)			weak	X	X			X					< 900°C

(**Maniatis and Tite 1981**). All samples (**Table 7.3** and **Figure 7.19**) showed an initial degree of vitrification. Only samples BEL 18-46, BEL 18-123, and BEL 18-224 (**Figure 7.19e–g**) show an extensive or continuous degree of vitrification.

Five dark-burnished samples were refired in reducing conditions at temperature intervals from 700–1100°C (**Chapter 5**); their degree of vitrification started to increase in the interval between 750 and 800°C (**Figure 7.20**).

Table 7.3. Summary of the results of the SEM analysis (IV= initial vitrification 750–800°C; V= extensive vitrification 900–950°C; C= continuous vitrification 1000–1050°C; DB = dark-burnished; GP = graphite-painted).

Sample	Chronological Horizon	DB	GP	Fabric	Refiring	Degree of Vitrification
BEL 18-46	1 (C-D)			BEL-A1		C
BEL 18-68	1 (C-D)	X		BEL-A1	X	IV
BEL 18-94	1 (C-D)	X		BEL-A2	X	IV
BEL 18-95	1 (C-D)	X		BEL-A1	X	IV
BEL 18-115	1 (C-D)			BEL-B1		IV
BEL 18-116	1 (C-D)			BEL-B1		IV
BEL 18-118	1 (C-D)	X		BEL-A2	X	IV
BEL 18-123	1 (C-D)			BEL-A1		C
BEL 18-132	1 (C-D)			BEL-B1	X	IV
BEL 18-224	2 (Gradac-C)			BEL-A1		C
BEL 18-288	4 (A)			BEL-F		IV
BEL 18-295	4 (A)			BEL-A1		IV
BEL 18-303	5 (Starčevo/A)			BEL-C		IV
BEL 18-334	5 (Starčevo/A)			BEL-C		IV

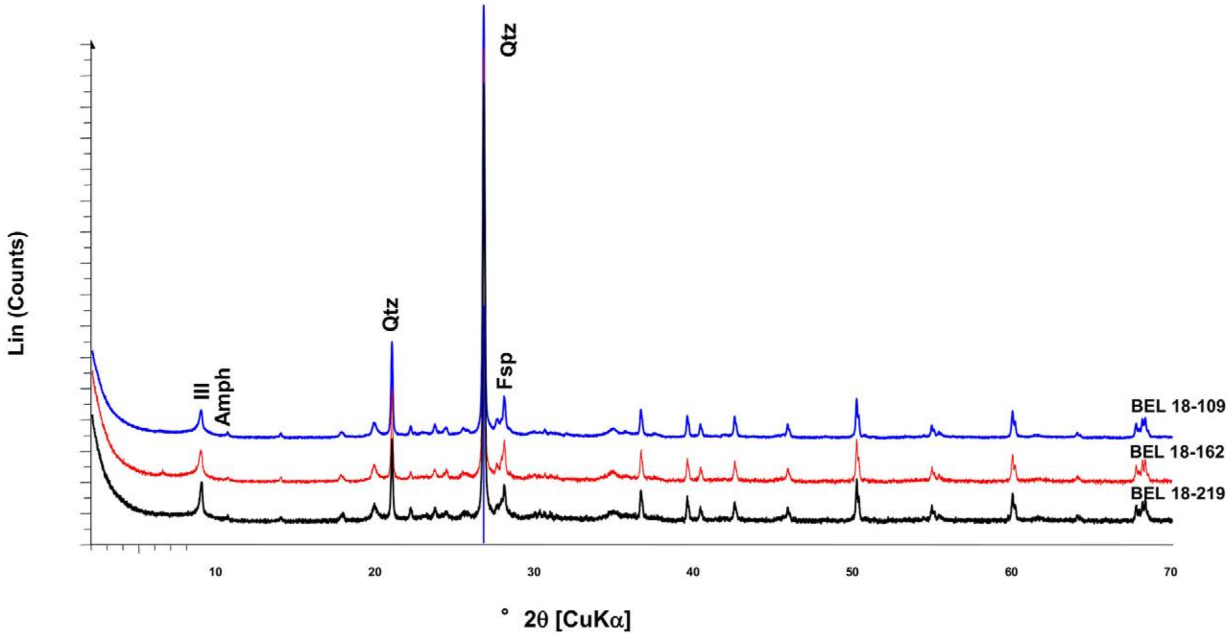


Figure 7.14. Diffractograms of samples BEL 18-219, BEL 18-162, and BEL 18-109 (dark-burnished ware). Ill: illite; Amph: amphibole; Qtz: quartz; Fsp: feldspar.

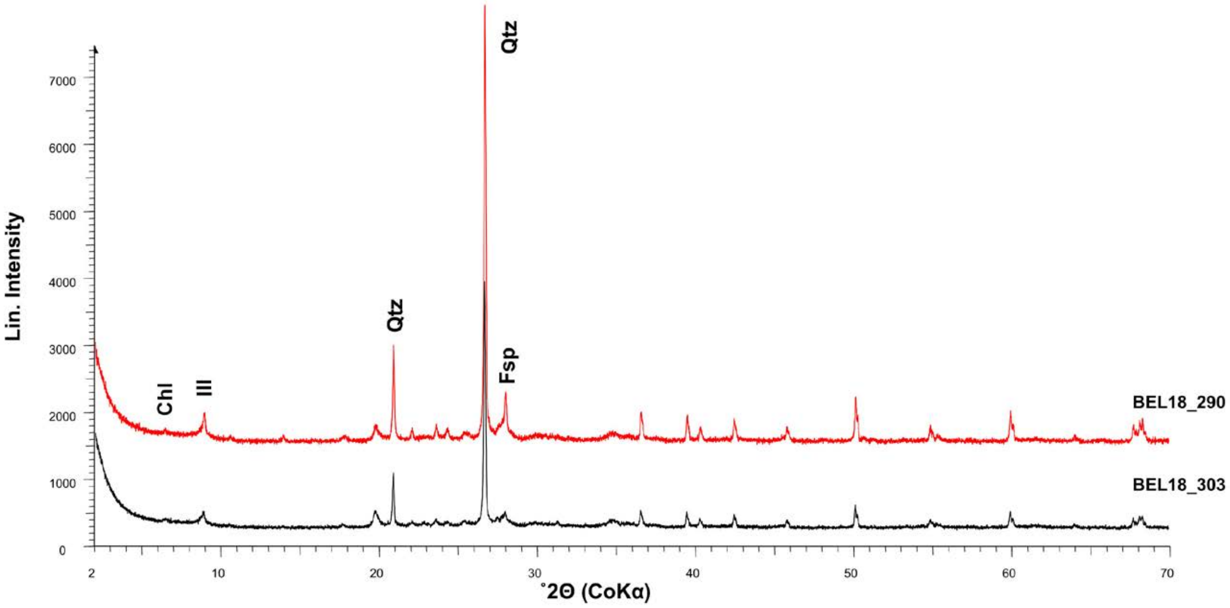


Figure 7.15. Diffractograms of samples BEL 18-303 (Starčevo style pottery) and BEL 18-290 (barbotine decorated vessel). Chl: Chlorite: illite; Qtz: quartz; Fsp: feldspar.

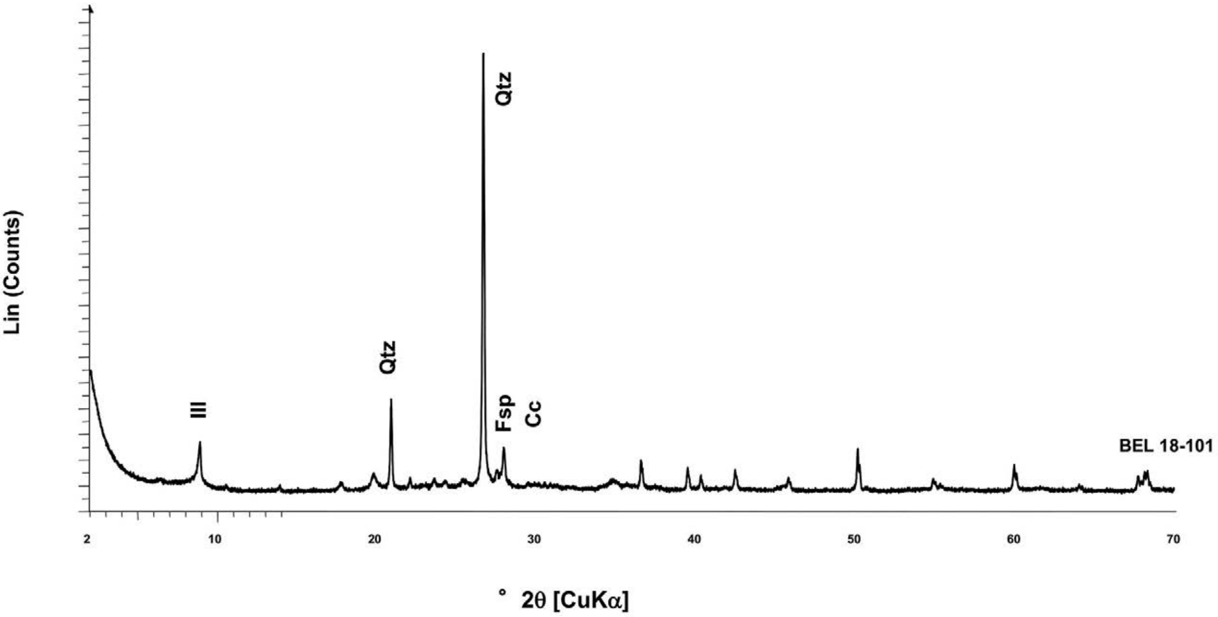


Figure 7.16. Diffractogram of sample BEL 18-101 (dark-burnished ware). Ill: illite; Qtz: quartz; Fsp: feldspar; Cc: calcite.

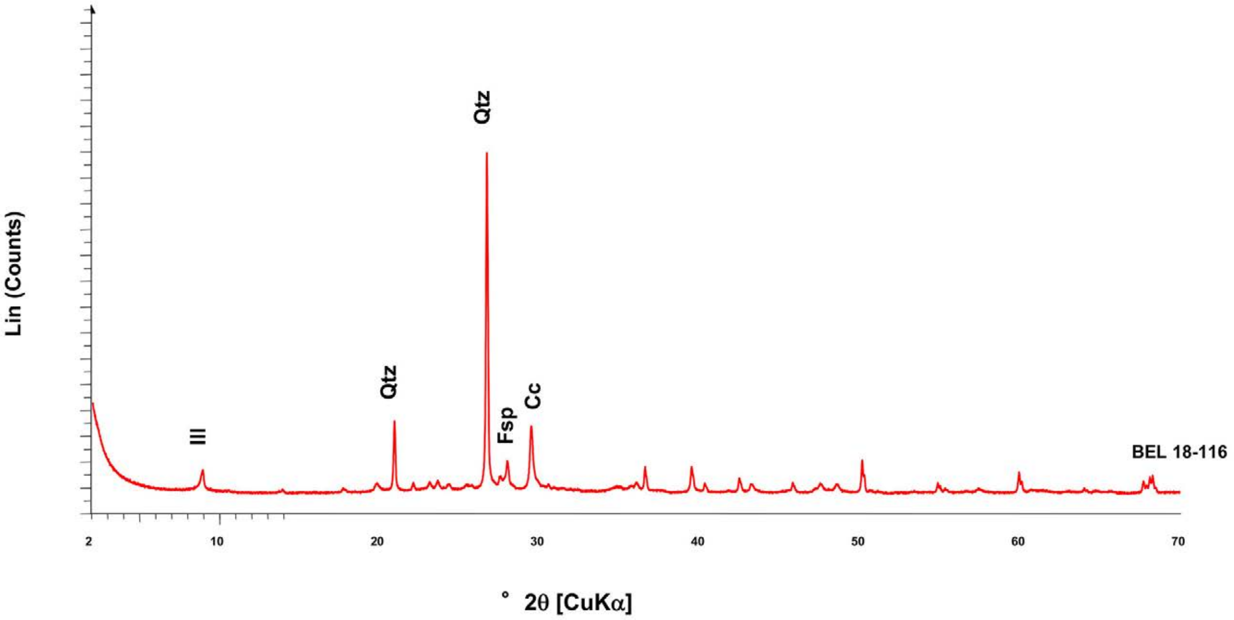


Figure 7.17. Diffractogram of sample BEL 18-116 (cooking pot). Ill: illite; Qtz: quartz; Fsp: feldspar, Cc: calcite.

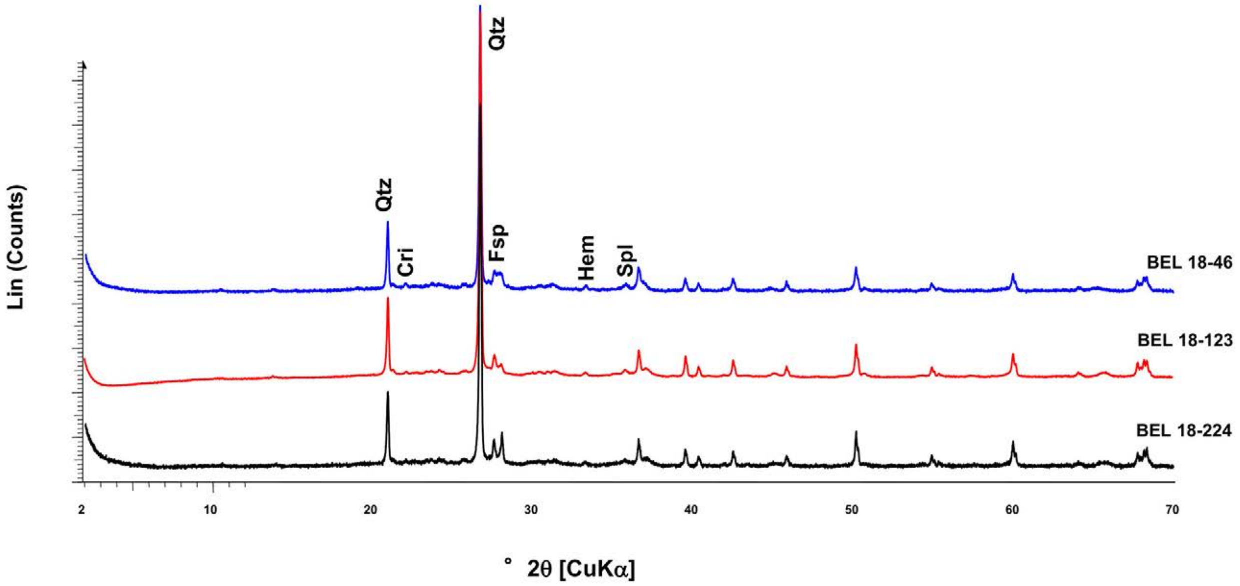


Figure 7.18. Diffractograms of samples BEL 18-224 (chimney), BEL 18-123 (chimney), and BEL 18-46 (pithos). Cri: cristobalite; Qtz: quartz; Fsp: feldspar; Hem: hematite; Spl: spinel.

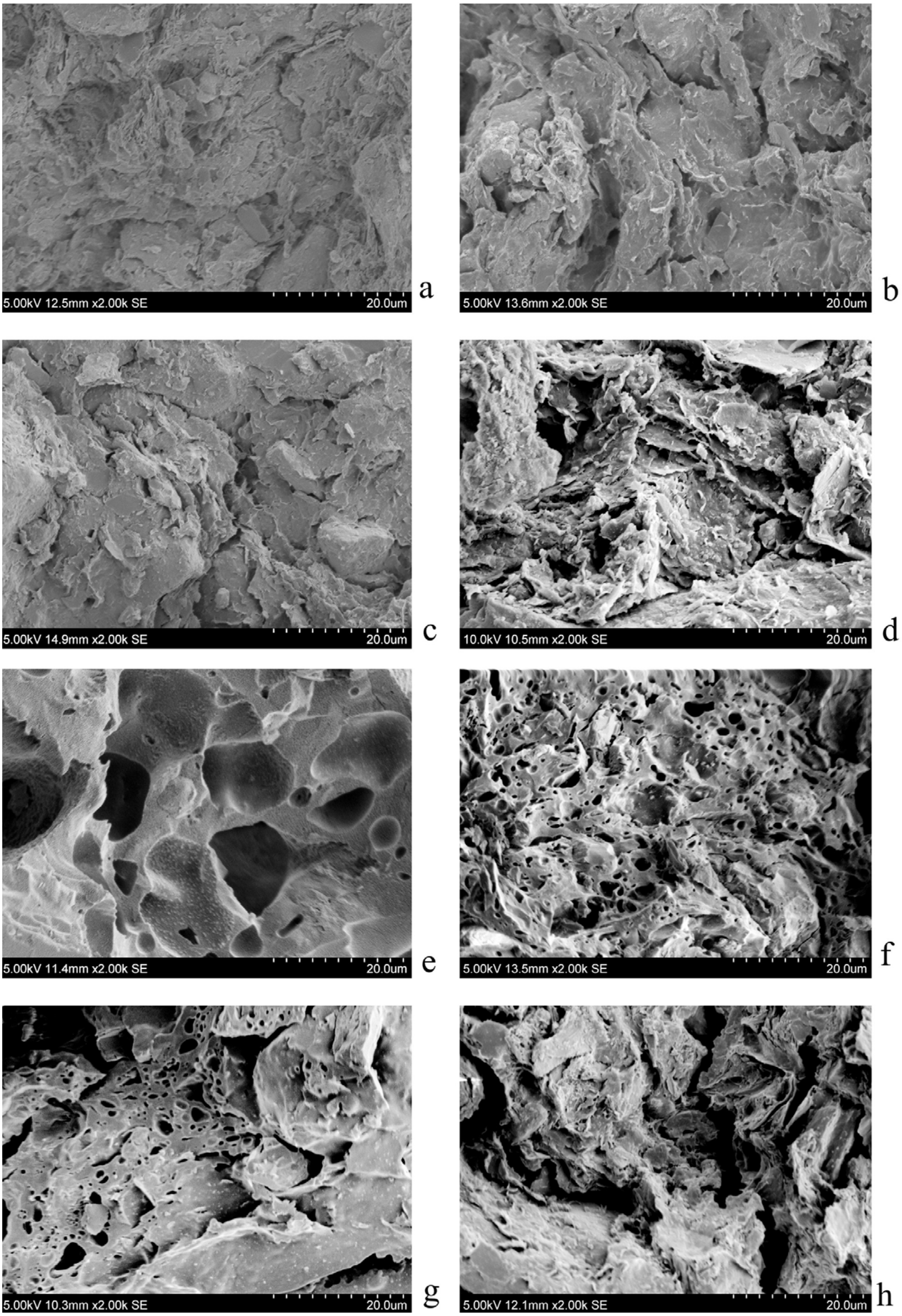


Figure 7.19. SEM photomicrographs of ceramic samples from Belovode: a) BEL 18-68: bowl, dark-burnished ware; b) BEL 18-95: bowl, dark-burnished ware; c) BEL 18-118: amphora, dark-burnished ware; d) BEL 18-116: cooking pot; e) BEL 18-46: amphora; f) BEL 18-123: chimney; g) BEL 18-224: chimney; h) BEL 18-334: bowl, Starčevo style.

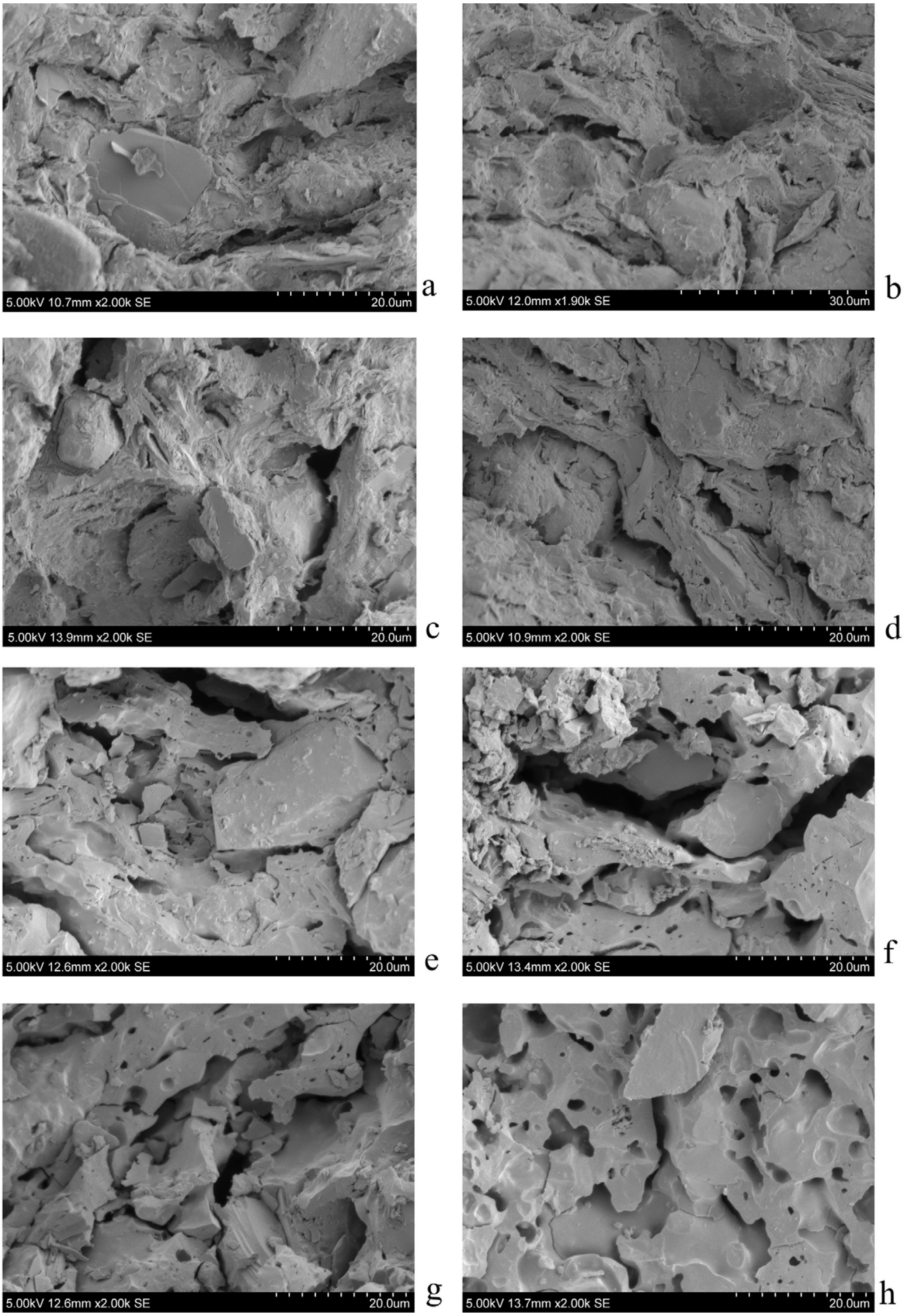


Figure 7.20. SEM photomicrographs of BEL 18-94 (bowl, dark-burnished ware) refired in reducing atmosphere at different temperatures a) as received; b) 700°C; c) 750°C; d) 800°C; e) 850°C; f) 900°C; g) 950°C; h) 1000°C.

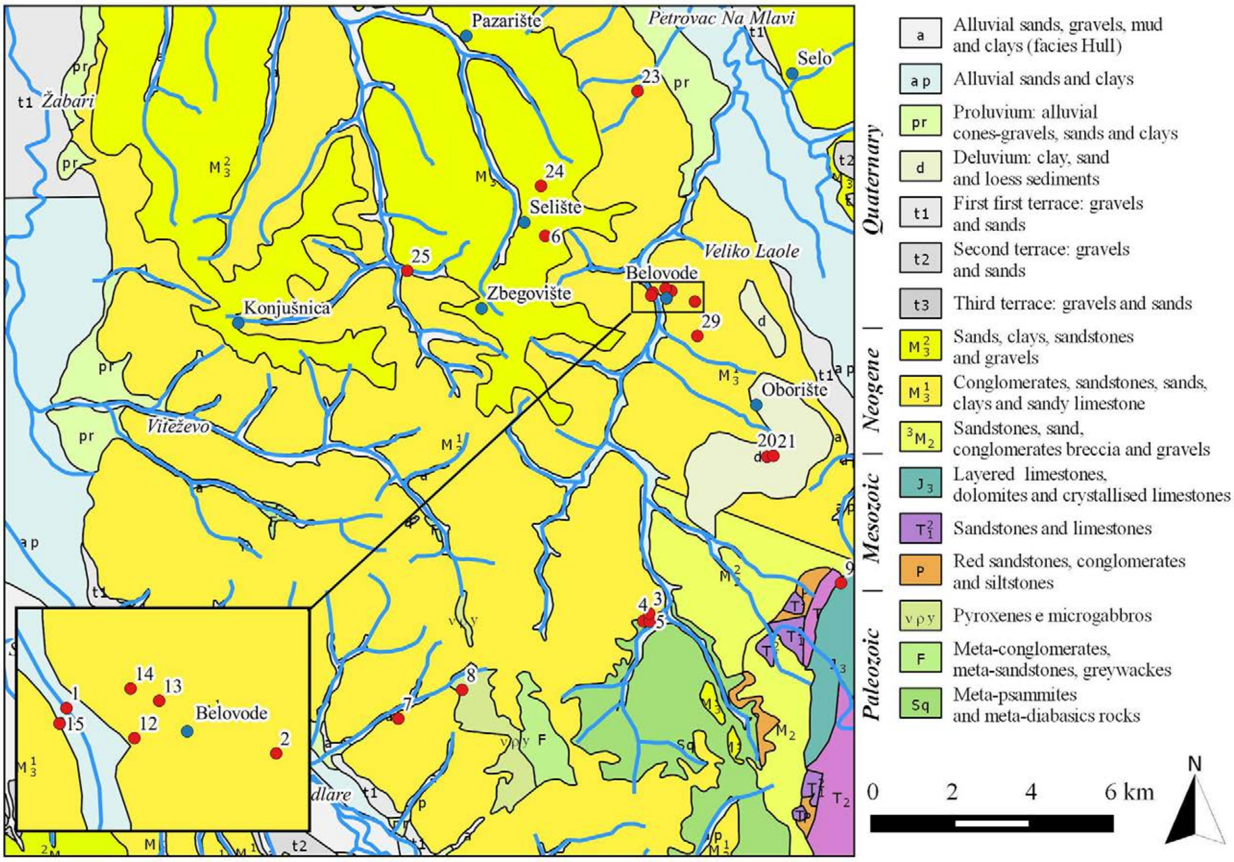


Figure 7.21. Geological map of the area surrounding Belovode (based on Yugoslavia Geological Map issued by the Federal Geological Institute. Sheets L34-127; L34-128; L34-139; L34-140 - 1: 100 000, prepared by Enrico Croce). Sample locations are indicated by red dots, Neolithic archaeological sites by blue dots. Black dots correspond to relevant modern topographic locations.

Characterisation of the raw materials

As described in **Chapter 5**, in 2013 a raw material survey was carried out in the area around Belovode. The full list of the samples collected and analysed can be found in **Appendix D3**, together with a brief description and a geological map that shows the exact location of all sampled sites. The following section provides a brief compositional characterisation for those geological samples that are relevant to the subsequent discussion concerning the selection of raw materials in the vicinity of the site.

As mentioned in **Chapter 3**, Belovode lies in the Kupinovačka Glavica–Busur area that is part of the upper complex of the Serbo-Macedonian composite unit (SMM) (**Dimitrijević 1997: 115**). More specifically, it is situated on the Neogene formation consisting of conglomerate, sandstone, mudstone and sandy limestone (**Figure 7.21**). Superficial and recent deposits include alluvial sand and clay deposited by the nearby Bosur River. Samples of Neogene sandy clays collected close to the site show the presence of quartz, opaque minerals and metasedimentary rocks (**Figure 7.22a–d**). There are also a few inclusions of amphibole and epidote. Neogene limestone sampled near the site has a shelly oolitic composition (**Figure 7.22f**). This limestone weathered to a sandy clay that was sampled in the same area and is marked by shells, microfossils and calcite (**Figure 7.22e**).

The results of the WD-XRF analysis (**Appendix C1.1**) on 10 samples collected from different points of the area's geological formations (**Figure 7.21**) provide useful information about the geochemical variability of the clay sources around Belovode. It must be stressed, however, that comparisons between the geochemical profiles of pottery samples and those of geological samples should always be interpreted with caution. The chemical profile of a pottery sherd is defined not only by the raw material from which it is produced but also by technological processes used during paste preparation (e.g. cleaning, mixing) as well as during firing (**Montana 2020**). These processes inevitably alter the chemical profile of the original material. It was therefore decided that multivariate statistics on

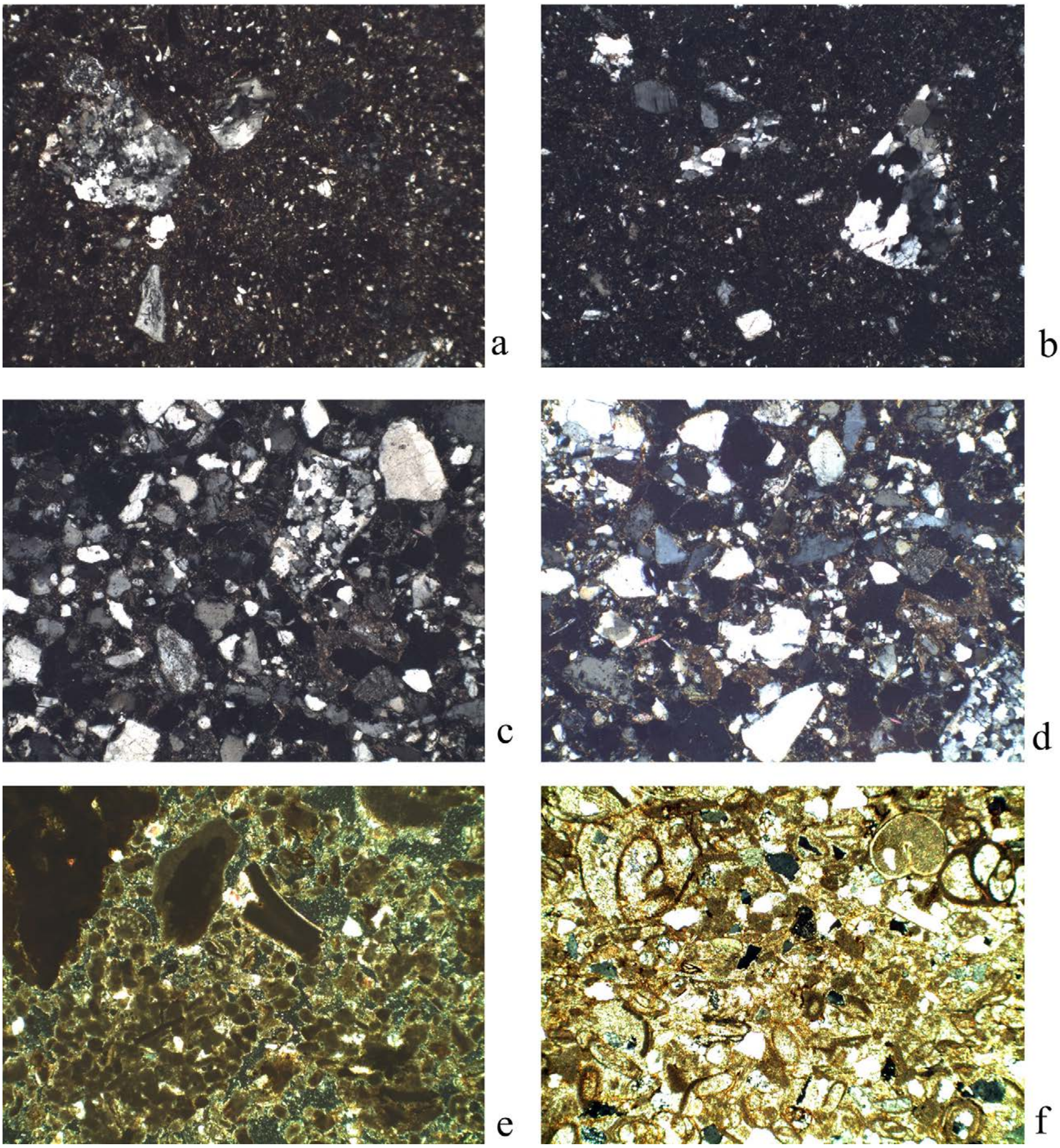


Figure 7.22. Thin section photomicrographs of selected geological samples from Belovode: a) sandy clay (point 2, sample 3), XP; b) sandy clay (point 12, sample 13), XP; c) sandy clay (point 14, sample 15), XP; d) sandy clay (point 24, sample 26), XP; e) sandy clay rich in shells and microfossils (point 1, sample 1), XP; f) shelly limestone (point 1, sample 2), XP. Field of view = 3 mm.

a dataset including both archaeological and geological samples would not be useful. The raw data does, however, raise some important questions.

Firstly, the sandy clay specimen (sample 1) collected at point 1 (**Appendix D1.1**) is rich in shells and microfossils and has a relatively high content of CaO and Sr. Among the non-calcareous sandy clays analysed, those collected in the vicinity of the site from formation M^1_3 (sample 3 from point 2; sample 13 from point 12; sample 32 from point 29) all show a homogeneous composition. Only sample 15 from point 14 reveals a different chemical profile, since this particularly sandy clay sediment is very coarse and rich in quartz. On the other hand, sample 24 (point 23), collected from the same geological formation, M^1_3, but about 6km from

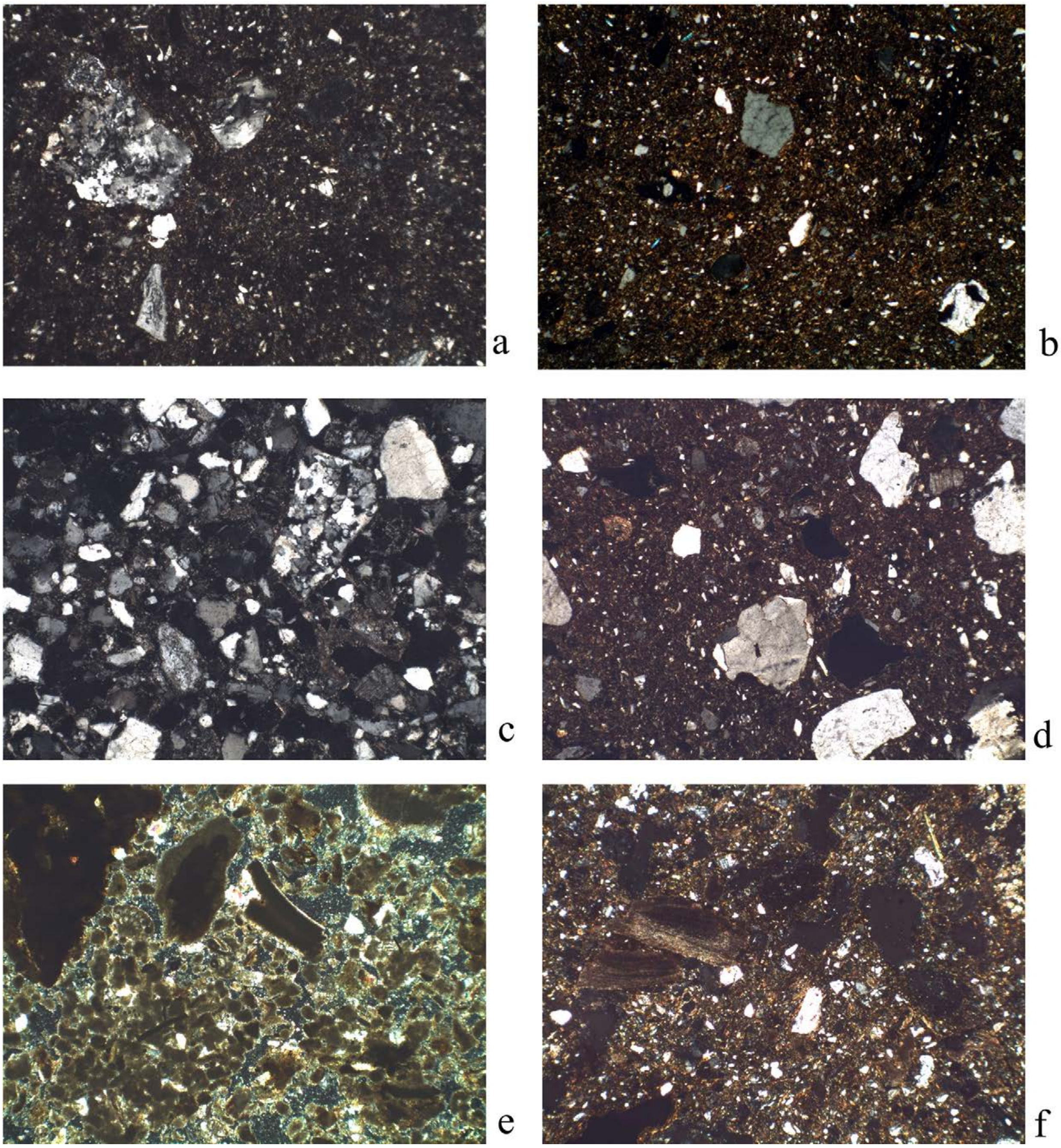


Figure 7.23. Thin section photomicrographs of selected geological and pottery samples from Belovode: a) sandy clay (point 2, sample 3), XP; b) Fabric BEL-A (BEL 18-198) with metasedimentary rocks (fine), XP; c) sandy clay (point 14, sample 15), XP; d) Fabric BEL-A (BEL 18-275) with metasedimentary rocks (coarse), XP; e) sandy clay rich in shells and microfossils (point 1, sample 1), XP; f) Fabric BEL-B (BEL 18-116) with shells, microfossils, and metasedimentary rocks (coarse), XP.
Field of view = 3 mm.

Belovode, has a chemical profile very similar to the specimens sampled in the immediate vicinity of the site. The remaining clay samples analysed via WD-XRF come from other geological formations: sample 6 (point 5) from formation Sq; sample 22 (point 21) from formation d; sample 24 and 27 (point 25) from formation M^2_3. These show considerable differences in their chemical profiles compared to the samples collected close to Belovode.

Discussion

Raw material selection and provenance

Comparison between the results of the petrographic analysis of the ceramic samples from Belovode and the geological specimens collected during the raw material prospection revealed several interesting aspects of the clay selection process. As previously observed, samples ascribed to fabrics BEL-A, BEL-B and BEL-C contain quartz, plagioclase, muscovite, amphibole and epidote that seem to be derived from metasedimentary rocks. Samples of Neogene sandy clay collected close to the site (**Figure 7.23a, c**) have a composition comparable with the coarser fraction identified in the thin section analysis of samples attributed to fabric BEL-A (**Figure 7.23b, d**) that is rich in quartz and metasedimentary rocks. This clay could therefore have been used for ceramic manufacturing at Belovode. The sample of sandy clay, rich in shell, microfossils and calcite collected at point 1 (**Figure 7.23e**), shows striking petrographic similarities with samples attributed to fabric BEL-B (**Figure 7.23f**).

The chemical analysis indicates that both the clay source and the specimens attributed to fabric BEL-B are marked by high CaO and Sr content, but this clay source is relatively sandy and not very plastic, and so unsuitable for pottery making. It is more likely that pottery of the fossiliferous fabric, BEL-B, was produced from a mixture of the sandy clay that characterises fabric BEL-A and another material that was rich in shells but not sufficiently plastic to be used on its own. An alternative explanation for the presence of inclusions of different lithology in fabric BEL-B could be the existence of mixed alluvial clay sources that have not been sampled during the brief fieldwork in this area. The pottery assigned to fabric BEL-C could, on the other hand, have been produced by adding organic material to the same type of clay that characterises fabric BEL-A. Interestingly, the compositional analysis revealed that loom-weights, figurines and building materials are made from the same raw material employed for pottery assigned to fabric BEL-A.

Several observations can also be made for the other petrographic fabrics. The mineralogical and chemical compositions of these samples differ markedly from those of other fabrics. Some samples (e.g. BEL 18-155 with serpentinite; BEL 18-247 and BEL 18-325 with mica-schist) do not seem compatible with the geological environment around Belovode and are very likely non-local productions manufactured in other villages. Serpentinite and mica-schist can be found in geological formations around 20km (formation Se) and 30km (formation Sm) east of Belovode, respectively (**Appendix D1.1**).

Conversely, samples representative of other fabrics seem to have been produced by nearby communities with access to clay sources more similar to those exploited at Belovode. Archaeological surveys carried out in the region (**Jacanović 1988; Jacanović and Šljivar 1995**) revealed the existence of other Late Neolithic sites nearby (**Figure 7.21**), however the low geological variability of the area, together with the stylistic homogeneity that characterises the material culture of this region at that time, makes the identification of pottery exchange among these sites very difficult. It is notable, however, that the petrographic and chemical compositions of samples BEL 18-15 and BEL 18-31 (fabric BEL-D), both made from a very fine clay, rich in Al_2O_3 (20%) and F_2O_3 (6%), match very well with the compositional characteristics of sample 22, collected at point 21, a location not far from the Neolithic site of Oborište (**Figure 7.21**).

Paste preparation

The comparisons between the results of the petrographic analysis and the typological information suggests that potters in Belovode deliberately selected different raw materials and manipulated them to produce a set of paste recipes suited to the vessels they were manufacturing. For instance, when producing dark-burnished ware bowls, they seem to have refined clay via sieving and levigation; when manufacturing pithoi and amphorae, they used coarser pastes. Of particular interest is the fabric that characterises most of the cooking pots (BEL-B2), since it is associated with the presence of shells and larger fragments of limestone. The advantages and limitations of having calcite within the clay paste are well known (**Rice 2015**). One benefit is reduced shrinkage during the drying process. Calcite also increases the thermal shock resistance, not only for the firing process but also during use. Above 750–800°C however, calcite starts to lose CO_2, which is then recovered during the cooling phase. This results in first a decrease and then an increase of calcite volume. However, as the clay shrinks during firing, there is no longer sufficient space inside the ceramic body for the re-formed calcite, resulting in breaks in the ceramic matrix (**Picon 1995**).

In fabrics BEL-A and BEL-B, it is not always clear whether inclusions are naturally occurring or were added as temper. The bimodal distribution of the inclusions (**Quinn 2013; Whitbread 1995**) in coarser samples of these fabrics could provide evidence for the intentional addition of aplastic material to the paste (**Figure 7.1**). These tempering practices seem to be more common in the earliest phase of the settlement. As previously observed, among the tempered samples attributed to fabric BEL-A, samples BEL 18-4, BEL 18-67, BEL 18-87, BEL 18-300 and BEL 18-324 could reflect slightly different tempering techniques. The first two samples (BEL 18-4 and BEL 18-67) show evidence for the possible addition of mudstone, while the other three specimens (BEL 18-87, BEL 18-300 and BEL 18-324) could have been produced with the addition of limestone fragments. This variability may reflect different tempering traditions at Belovode, but the possibility cannot be excluded that these sherds were produced by nearby communities who shared raw materials with Belovode but used different tempering traditions. The presence of a chaff tempered fabric (BEL-C) with a dark core and oxidised surface will be discussed in more detail below but, briefly, vessels characterised by chaff tempering are usually connected to the Early/Middle Neolithic Starčevo cultural phenomenon (e.g. **Spataro 2019b**).

Estimation of firing temperatures

The diffractograms of most samples revealed the presence of illite, which indicates that the maximum firing temperature must have been below 850–900°C (**Kulbicki 1958; Maggetti 1982**). The presence of chlorite in a few samples might suggest even lower temperatures—below 700°C for some specimens (**Gliozzo 2020**). Two of the dark-burnished samples (BEL 18-52 and BEL 18-101) and the cooking pot (BEL 18-116) also revealed the presence of calcite in their diffraction patterns (**Figures 16 and 17**), which suggests that these vessels could have not been fired at temperatures above 850°C, at which point calcite decomposes (**Maggetti 1982; Maritan 2004**).

The overall composition of the samples suggests that they were probably fired to a maximum temperature of between 750 and 850°C. Three samples, however (BEL 18-46, BEL 18-123 and BEL 18-224), showed the presence of mineral phases (cristobalite and spinel) normally associated with higher temperatures (**Figure 7.18**). They also showed the presence of haematite which, along with magnetite, when present in non-calcareous clays begins to nucleate at about 550°C under oxidising and reducing conditions respectively. In calcareous clays, it begins to nucleate at about 725–750°C. None of the other samples show the presence of these two minerals, but they may occur in most specimens at levels below the limits of detection.

The observations based on the XRPD results were confirmed by the SEM analysis.

Only samples BEL 18-46, BEL 18-123, and BEL 18-224 (**Figure 19f–h**) exhibit an extensive or continuous degree of vitrification. Notably, two of these samples (BEL 18-123 and BEL 18-224) are classified as 'chimney'.

Summary

The analyses presented in this chapter provide important information for the reconstruction of different elements of the pottery making recipes employed at Belovode, from clay sourcing and paste-making to forming, finishing and firing. Compositional analysis shows that various local clay sources were selected and manipulated to produce a set of paste recipes suited to the production of particular vessel types. Clay used for dark-burnished ware bowls was refined by sieving and levigation and coarser pastes were used for pithoi and amphorae; most of the cooking pots (BEL-B2) have fabrics containing shells and larger fragments of limestone.

Tempering is uncommon but some samples, especially from the earliest horizons, may show the intentional addition to the clay of sand rich in metasedimentary rocks. The chaff tempered fabric (BEL-C) with a dark core and oxidised surface is, however, restricted to the earliest horizon of the settlement (Vinča A1–A2) and relates to Early to Middle Neolithic Starčevo pottery traditions. Finally, a few specimens of fabric BEL-A (BEL 18-4, BEL 18-67, BEL 18-87, BEL 18-300 and BEL 18-324) could reflect slightly different tempering techniques at Belovode but may have been produced by nearby communities who shared similar raw materials but used different processes. This is not implausible, especially since the results suggest the presence of other, non-local ceramic vessels in the assemblage.

The analyses also provide insights into pottery pyrotechnology. The mineral phases detected by XRPD suggest that most of the analysed sherds were fired at temperatures between 750 and 800°C. This is confirmed by the optical activity of the clay matrix in the studied thin sections (**Quinn 2013: 190–198**) and the SEM results. Thus, it can be demonstrated that pottery at Belovode was usually fired at reasonably high temperatures (at least *c.* 750—800°C), especially when producing dark-burnished ware, but firing temperatures did not get anywhere close to 1000°C, as Kaiser suggests (**Kaiser *et al.* 1986**).

Higher optical activity and light surface colours characterised the samples of cooking pots (fabric BEL-B2) and the Starčevo materials (fabric BEL-C), indicating that these were fired in oxidising conditions and at a slightly lower temperature. The employment of oxidising conditions is more common in the earliest horizon. The variation in the surface and fabric colour of dark-burnished vessels suggests that the firing redox conditions were not always perfectly controlled.

Overall, the results indicate a scenario of continuity, with the only major technological discontinuity being the disappearance of Starčevo traditions during the first horizon, and the introduction of a clay source rich in shells and microfossils that does not seem to be attested before horizon 3. These results will be further discussed in **Chapter 9** where they will be compared with those of similar analyses carried out on samples from Pločnik, and with evidence provided by other technological studies on Vinča culture pottery (e.g. **Kaiser 1984; Spataro 2014**).

Chapter 8
Results of the archaeometric analysis – Pločnik

This chapter presents the results of the archaeometric study carried out on pottery assemblages from trenches 20, 21 and 24 at Pločnik. The methods of analysis are the same as those applied to the pottery from Belovode (**Chapter 7**) and include thin section petrography, WD-XRF, XRPD and SEM. The assemblages from Pločnik offer the additional opportunity to study the pyrotechnology behind pottery decorated with graphite which, together with plain dark-burnished ware, has been suggested to be a technical precursor to the discovery of copper pyrometallurgy (e.g. **Gardener 2004; Renfrew 1969**). The results provide important insights that help to trace the development of manufacturing traditions across the pre-metallurgical horizons (5 and 3 A2–B2) and metallurgical horizons (2–1, Gradac I–III).

Results of the compositional analyses

From the total of 15,235 sherds from Pločnik that were macroscopically examined, 230 samples were selected for a more detailed compositional characterisation using various archaeometric techniques (**Appendices A2.1, A2.2** and **A.2.3**). These samples represent all horizons recognised in trench 24, horizon 1 of trench 20 and horizons 1, 2 and 3 of trench 21. In addition, the selection covers the typological and technological variability observed through the macroscopic analysis. A combined approach using petrographic and chemical analyses was applied to the selected samples to characterise their mineralogical and chemical composition. All samples were examined via ceramic thin section petrography (**Appendices B2, B3** and **B4**). A subgroup of 137 specimens were selected for further analysis via WD-XRF (**Appendix C2.1**).

Results of the petrographic analysis

Petrographic analysis revealed that the 230 samples from Pločnik can be divided into different fabrics based on their aplastic inclusions, matrix, and voids observed in thin section. In the following paragraphs, a summary description of each fabric is provided. More detailed descriptions are published elsewhere (**Amicone 2021b; Amicone *et al.* 2020b**). A full description of the main petrographic groups A and B according to Whitbread's methodology (**1989**) is also provided (**Appendices B2, B3** and **B4**).

Fabric PL-A: sedimentary rock fabric (Figure 8.1a–f)

Fabric group PL-A is the dominant petrographic group and includes 187 samples. Samples assigned to this fabric can be divided into a heterogeneous coarse-grained group (sub-fabric PL-A1, 96 samples) as well as a finer-grained group (sub-fabric PL-A2, 91 samples). The fabric is marked by generally poorly sorted, sub-angular to sub-rounded inclusions of quartz and plagioclase that seem to derive from quartz-arenite or arkosic-arenite sandstones. Dominant inclusions comprise quartz, while plagioclase and fragments of sandstone rocks (arenite) are also common. Other inclusions are opaque minerals, calcite, muscovite, K-feldspars, chert, and clay pellets. Siltstone fragments, amphibole and epidote are rare. The grain size distribution varies from polymodal to weakly bimodal. Some samples from horizons 5 and 4 show a stronger bimodality (**Appendix B4**). The matrix is non-calcareous and ranges from light yellow to bright orange to dark red in PPL, and from light brown to dark reddish to grey in XP. It is relatively homogeneous, with the observed inhomogeneity generally being due to different atmospheric conditions used during the firing process. The matrix is moderately active to weakly active/inactive. The compositional and textural characteristics and grain size distribution seem to suggest that the raw material used for producing ceramics assigned to this fabric was a secondary clay containing clasts of sedimentary rocks.

Fabric PL-B: mica-schist rock fabric (Figure 8.1g–h)

Fabric group PL-B is a heterogeneous group that features 26 specimens. It is a coarse to medium-coarse grained fabric characterised by the presence of generally well sorted, angular to sub-angular inclusions of quartz and medium-grade metamorphic rock fragments rich in quartz and muscovite (probably mica-schist). Quartz and muscovite are the dominant inclusions, while metamorphic rocks, plagioclase, arenite, and phyllites are common to few; biotite, K-feldspars, chert, and opaque minerals are very few, while amphibole and epidote are rare. The grain size distribution in many samples assigned to this fabric is weakly to strongly bimodal (**Appendix B4**). The matrix is non-calcareous and its colour ranges from light brown to bright yellow to light orange in PPL and from light brown to reddish yellow in XP. The matrix is largely homogeneous, save for the core-margin colour differentiation caused by the firing process. Samples exhibited moderate to weak optical activity in XP. The compositional characteristics and bimodal grain size distribution suggest that the raw material used to produce these vessels was a secondary clay tempered with mica-schist rock fragments.

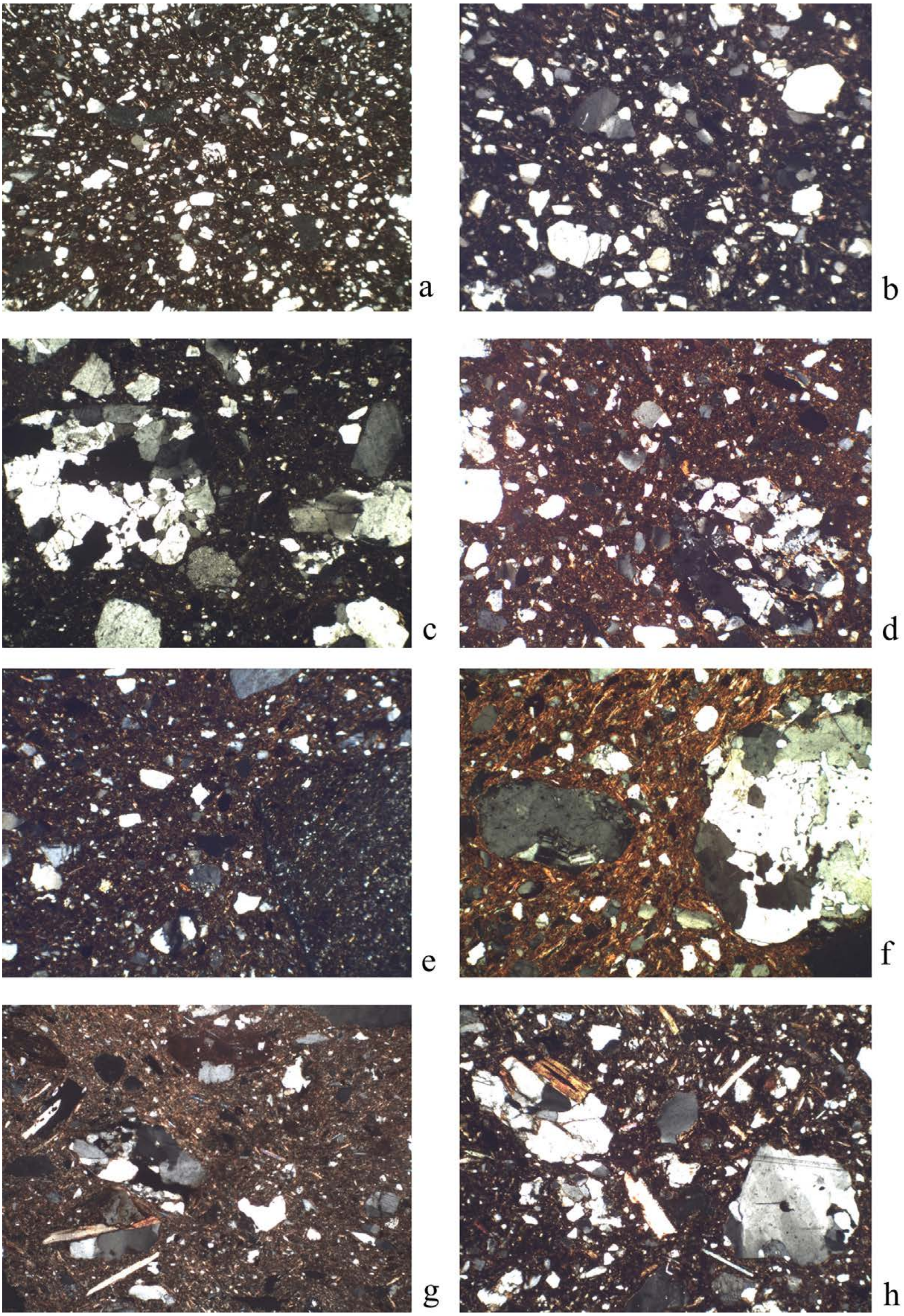


Figure 8.1. Thin section photomicrographs of petrographic fabrics from Pločnik: a) Fabric PL-A (PL 24-69) with sedimentary rocks (fine), XP; b) Fabric PL-A (PL 24-219) with sedimentary rocks (medium-fine), XP; c) Fabric PL-A (PL 24-132) with sedimentary rocks (coarse), XP; d) Fabric PL-A (PL 20-78) with arkosic arenite, XP; e) Fabric PL-A (PL 21-53) with siltstone, XP; f) Fabric PL-A (PL 24-306) with sedimentary rocks and abundant muscovite, XP; g) Fabric PL-B (PL 21-19) with mica-schist, XP; h) Fabric PL-B (PL 24-54) with mica-schist, XP. Field of view = 3mm.

Fabric PL-C: muscovite and amphibole fabric (Figure 8.2a)

Fabric PL-C comprises four samples (PL 21-6, PL 21-66, PL 20-68 and PL 20-72). This homogeneous fine-grained fabric is marked by the presence of poorly sorted angular inclusions of amphibole and muscovite. Quartz and muscovite are dominant inclusions. Amphibole, plagioclase, opaque minerals, clay pellets and small fragments of metarenite rocks are common. Grain size distribution is polymodal. The matrix is non-calcareous, quite homogeneous and its colour is dark red in PPL and XP. It is optically inactive. The compositional and textural characteristics may indicate that the raw material used to produce these vessels was a secondary clay rich in muscovite and amphibole.

Fabric PL-D: mica-schist and phyllite rock fabric (Figure 8.2b)

Fabric PL-D includes samples PL 24-82 and PL 24-315. This fabric is dominated by abundant, well-sorted and rounded fragments of medium-grade and low-grade metamorphic rock fragments (schist and phyllite). Other common minerals are quartz, epidote and, more rarely, fragments of mudstone and clay pellets. Grain size distribution is bimodal. The matrix is non-calcareous and is light brown in PPL and dark brown in XP. It is quite homogeneous and weakly active. The strong bimodality and roundness of the coarse fraction suggest that the clay used to produce these vessels might have been tempered with a sand derived from the erosion of metamorphic rocks.

Fabric PL-E: epidote fabric (Figure 8.2c)

Fabric PL-E includes samples PL 21-69 and PL 24-319, both marked by frequent epidote. Other common minerals include poorly sorted sub-angular to sub-rounded inclusions of quartz, feldspars, muscovite, and amphibole, as well as medium-grade metamorphic rock fragments and opaque minerals. Grain size distribution is polymodal. The matrix is non-calcareous, homogeneous and optically inactive, appearing dark red in both PPL and XP. The compositional and textural characteristics suggest that the raw material used to produce these vessels was a secondary clay containing fragments of metamorphic rocks rich in epidote.

Fabric PL-F: volcanic rock fabric (Figure 8.2d)

Fabric PL-F is represented by samples PL 24-23 and PL 24-211, which are characterised by the presence of poorly sorted, sub-angular fragments of medium-grained volcanic igneous rocks (andesite), composed of plagioclase, amphibole, and biotite. Plagioclase is the dominant inclusion, while fragments of volcanic rocks, biotite, and amphibole are common. Other inclusions include quartz and muscovite. Grain size distribution is polymodal to weakly bimodal. The matrix is non-calcareous, light brown in PPL and brown in XP, and quite homogeneous. Sample PL 24-23 is optically inactive, while PL 24-211 is moderately active. The angularity of the inclusions and the poor degree of sorting suggest that the clay used to produce these vessels was residual in origin or transported over a minimal distance.

Fabric PL-G: grog fabric (Figure 8.2e)

The two samples in fabric group PL-G (PL 24-202 and PL 24-258) are fragments of loom weights. They are characterised by abundant tiny fragments of quartz, muscovite, opaque minerals, and grog, which was added as temper. Grain size distribution is bimodal. The matrix is optically active and is yellow in PPL and light orange in XP. The compositional characteristics indicate that the raw material used to produce these loom weights was a calcareous secondary clay tempered with grog.

In addition to the fabric groups detailed above, several outliers were identified:

Fabric PL-H: marl fabric (Figure 8.2f)

This medium-coarse fabric, represented by sample PL 24-336, is marked by poorly sorted sub-angular to sub-rounded inclusions of quartz. Quartz is the dominant inclusion, while calcite and fragments of sandstone rocks are frequent. Other common inclusions are muscovite, opaque minerals and clay pellets. Amphibole is rare. Grain size distribution is polymodal. The matrix is homogeneous and highly calcareous. It is light yellow in both PPL and XP and it is optically active. These compositional and textural characteristics indicate that this sample of kiln floor was made from a highly calcareous clay, probably a marl, rich in sedimentary clasts.

Fabric PL-I: serpentinite fabric (Figure 8.3a)

This fabric, represented by sample PL 24-32, is medium-fine grained and characterised by the presence of poorly sorted sub-angular to sub-rounded inclusion of quartz along with rounded inclusions of serpentinite. Quartz is the dominant inclusion, while muscovite, serpentinite, clay pellets and opaque minerals are common. Grain size distribution is polymodal. The matrix is non-calcareous, homogeneous and optically active. It is light brown in both PPL and XP. The compositional and textural characteristics suggest that the raw material used to produce this vessel was a secondary clay rich in serpentinite.

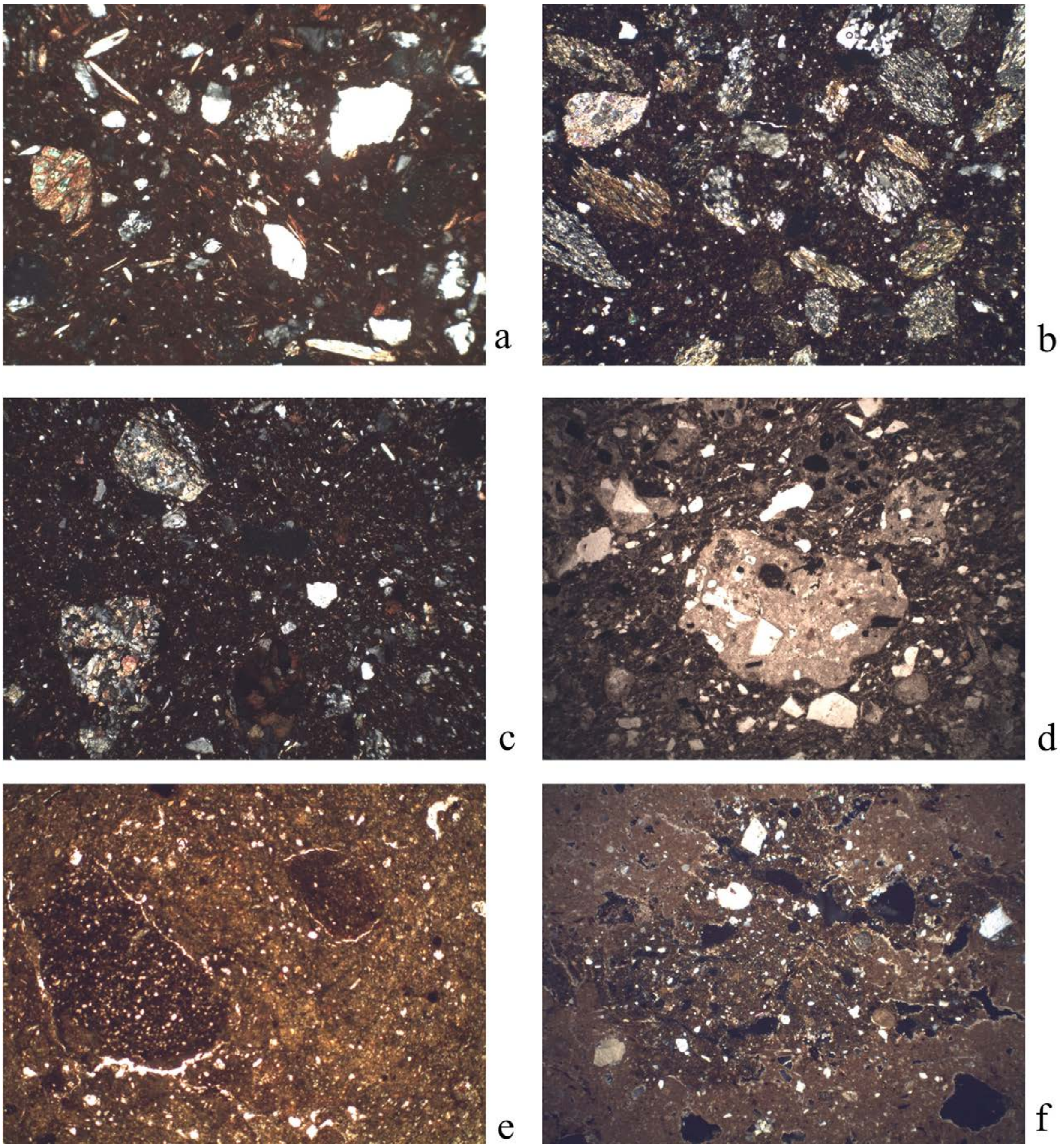


Figure 8.2. Thin section photomicrographs of petrographic fabrics from Pločnik: a) Fabric PL-C (PL 21-6) with abundant muscovite and amphibole, XP; b) Fabric PL-D (PL 24-315) with mica-schist and phyllite, XP; c) Fabric PL-E (PL 21-69) with abundant epidote, XP; d) Fabric PL-F (PL 24-23) with volcanic rocks, PPL; e) Fabric PL-G (PL 24-202) with grog tempering, PPL; f) Fabric PL-H (PL 24-336) made from calcareous clay, XP. Field of view = 3 mm (a–d, f); 6 mm (e).

Fabric PL-J: amphibole fabric (Figure 8.3b)

This medium-fine grained fabric, represented by sample PL 20-63, is marked by the presence of poorly sorted angular fragments of amphibole and quartz. Quartz is the dominant mineral inclusion, while amphibole is frequent. Feldspars and muscovite are common. Fragments of low-grade metamorphic rocks (possibly metarenite) and opaque minerals are rare. Grain size distribution is polymodal. The matrix is non-calcareous, optically inactive and homogeneous. It appears grey in both PPL and XP. The compositional and textural characteristics suggest that the raw material used to produce this vessel was a secondary clay rich in amphibole.

Fabric PL-K: amphibolite fabric (Figure 8.3c)

This fabric, represented by sample PL 24-113, is compositionally similar to PL 20-63 but is coarser and distinguished by a higher quantity of amphibole, which is the dominant inclusion, along with possible fragments of amphibolite. Quartz, muscovite, and foliated medium-grade metamorphic rocks composed of quartz and, muscovite are also common. Grain size distribution is polymodal. The matrix is non-calcareous, homogeneous and weakly active. It appears yellow in PPL and brown in XP. The angularity of the inclusions and the polymodal grain size distribution suggest that the raw material used to produce this vessel was residual in origin or was transported a minimal distance, and could have derived from the erosion of metamorphic rocks (probably amphibolite).

Fabric PL-L: metamorphic fabric (Figure 8.3d)

This fabric was identified in PL 24-208, a very coarse sample marked by the presence of poorly sorted angular fragments of high-grade foliated metamorphic rocks composed of quartz. Quartz and polycrystalline quartz are the dominant inclusions whilst feldspars and opaque minerals are common. Grain size distribution is bimodal. The matrix is non-calcareous, homogeneous and optically inactive. The colour in PPL is orange and dark orange in XP. The compositional characteristics and the bimodal grain size distribution suggest that the clay used to produce this vessel was a secondary clay tempered with gneiss.

Results of the chemical analysis

WD-XRF analysis was carried out on a sub-selection of 137 specimens. These included sherds representative of all petrographic fabrics described above. Preliminary observation of the raw data (**Appendix C2.1**) identified that some samples clearly stand out for their elemental concentration. Firstly, samples PL 24-82 and PL 24-315, assigned to fabric PL-D and marked by mica-schist and phyllite, are notable for their relatively low concentration of Ni (88ppm and 77ppm respectively), Rb (55ppm and 65ppm) and Ce (54ppm and 78ppm) in comparison to samples assigned to fabric group PL-A. Specimens PL 24-69 and PL 24-319, of the epidote-rich fabric, PL-E, have a relatively high concentration of Fe_2O_3 (8.88% and 7.26% respectively), Cr (228ppm and 280ppm) and Zr (231ppm and 187ppm). Samples PL 24-23 and PL 24-211, assigned to fabric PL-F, with volcanic rocks, show lower concentrations of both Cr (97ppm and 81ppm respectively) and Ni (50ppm and 48ppm) contrasted with high levels of Sr (569ppm and 767ppm)

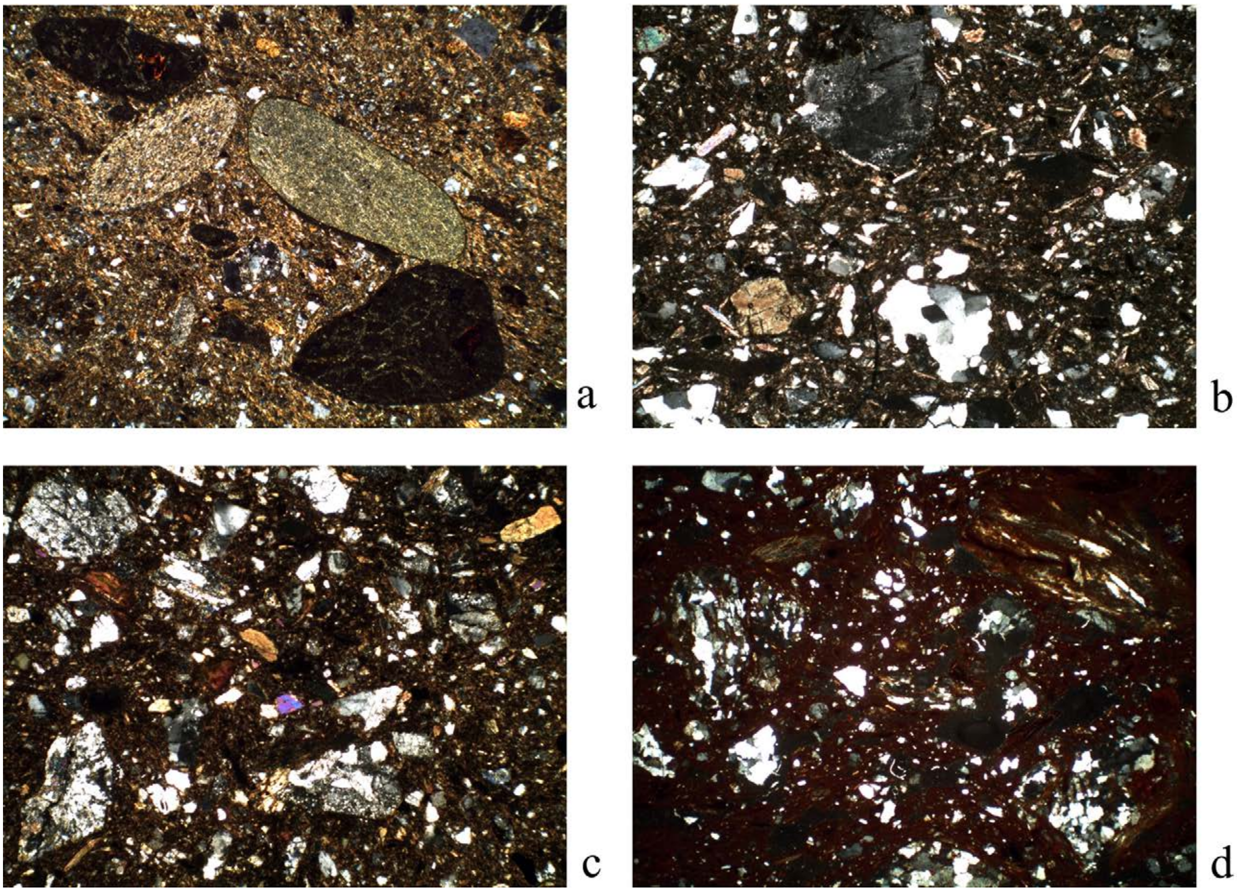


Figure 8.3. Thin section photomicrographs of petrographic fabrics from Pločnik: a) Fabric PL-I (PL 24-32) with serpentinite, XP; b) Fabric PL-J (PL 20-63) with abundant amphibole and fragments of metamorphic rocks, XP; c) Fabric PL-K (PL 24-113) with amphibolite, XP; d) Fabric PL-L (PL 24-208) with gneiss, XP. Field of view = 3mm.

when compared to the specimens belonging to fabric PL-A, the main fabric group marked by sedimentary rocks fragments. Finally, the loom weights PL 24-202 and PL 24-258, representative of fabric PL-G and characterised by the addition of grog, have a very high CaO content (12.04% and 17.49% respectively) and present some significant differences in the concentration of the trace elements in comparison to samples of other fabrics.

The other fabrics, each represented by only one sherd, show a very distinctive chemical profile. The relatively high content of CaO (28.62%) and low concentration of SiO_2 and Al_2O_3 (32.83% and 6.99% respectively) which characterise fabric PL-H (PL 24-336), suggests that the raw material used to produce this oven fragment was a highly calcareous clay, yet the other analysed oven fragment (PL 24-339) shows compositional characteristics very similar to specimens assigned to fabric PL-A. Sample PL 24-32 (fabric PL-I) stands out for its relatively high Cr and Ni content (1359ppm and 894ppm respectively) in comparison with the other specimens in the dataset. The thin section petrography showed that this sample contains serpentine, which could have been responsible for the high concentration of these two elements. Finally, sample PL 24-63 (fabric PL-J), rich in amphibole, has a relatively low SiO_2 content (53.89%) and high contents of Fe_2O_3 (9.94%), Cr (396ppm), Ni (162ppm), Sr (355ppm), Zr (285ppm) and

Table 8.1. Results of a descriptive statistical analysis of the WD-XRF dataset comprising the 68 samples from Pločnik (Els: Elements; StDev: Standard Deviation; Var: Variance; CV: Coefficient of Variation; Min: Minimum; Q1: First Quartile; Q3: Third Quartile; Max: Maximum).

Els	Mean	StDev	Var	CV	Min	Q1	Median	Q3	Max	p-value
Na_2O %	1.11	0.346	0.1195	31.23	0.56	0.885	1.08	1.25	2.53	< 0.010
MgO %	1.55	0.488	0.2283	30.92	0.83	1.22	1.46	1.81	3.08	< 0.010
Al_2O_3 %	14.9	1.608	2.584	10.82	6.99	13.88	14.68	15.89	20.03	< 0.010
SiO_2 %	65.2	5.395	29.108	8.28	32.83	63.82	66.6	68.245	84.58	< 0.010
K_2O %	2.11	0.316	0.0998	14.99	0.88	1.935	2.1	2.29	2.89	< 0.010
CaO %	2.29	2.883	8.258	125.46	0.82	1.455	1.82	2.1	28.62	< 0.010
TiO_2 %	0.88	0.146	0.0213	16.89	0.39	0.8	0.85	0.925	1.88	< 0.010
Fe_2O_3 %	6.2	0.982	0.964	15.83	2.95	5.61	5.99	6.63	10.86	< 0.010
P_2O_5 %	1.1	0.98	0.9599	89.28	0.12	0.45	0.8	1.39	4.25	< 0.010
MnO %	0.09	0.028	0.0008	30.38	0.03	0.08	0.09	0.11	0.21	< 0.010
V ppm	121	20.36	414.83	16.85	61	110	118	128.5	226	< 0.010
Cr ppm	164	111.5	12423	68.12	81	130	146	168	1359	< 0.010
Co ppm	19	5.314	28.234	28.01	8	16	18	20	58	< 0.010
Ni ppm	96.6	85.59	5813.6	88.29	48	82.5	85	100.5	894	< 0.010
Cu ppm	41.2	11.33	128.4	28.5	23	35	39	45	91	< 0.010
Zn ppm	104	18.84	318.12	18.23	60	92	100	111	180	< 0.010
Rb ppm	90.8	14.58	212.43	16.06	34	83	90	99	138	< 0.010
Sr ppm	191	89.09	6255.8	41.41	64	149.5	185	210	868	< 0.010
Y ppm	29.4	4.896	22.999	16.29	16	28	29	32	41	> 0.100
Zr ppm	239	39.38	1549.9	16.5	98	218	241	266	321	< 0.010
Ba ppm	1038	382.8	146526	36.88	308	888.5	955	1211	2450	< 0.010
La ppm	36	8.068	49.963	19.62	15	32	36	40	59	0.043
Ce ppm	81.5	13.66	186.53	19.09	38	63	80	89	118	< 0.010
Nd ppm	31.8	5.992	35.905	18.91	12	28	32	35	50	0.086
Pb ppm	28.8	6.804	46.291	24.52	9	23	28	32	59	< 0.010
Th ppm	11.1	2.516	6.328	22.86	4	9	11	12	19	0.035

Ce (117ppm). This is very different to other samples that are rich in amphibole, e.g. PL 24-113 (fabric PL-K), which displays much lower contents of Cr (95ppm), Ni (63ppm) and Zr (147ppm). Following these preliminary observations, a descriptive statistical approach was applied to the WD-XRF dataset, calculating the mean, standard deviation, variance, coefficient of variation, minimum, first quartile (Q1), median, third quartile (Q3), and maximum. (**Table 8.1**).

Normal distribution of the data was tested using the Shapiro-Wilk normal probability test, with the p-value calculated accordingly. This dataset showed compositional heterogeneity that is expressed by the standard deviation and wide distribution intervals. The coefficient of variation of CaO, P_2O_5, Cr and Ni is greater than 50% and reaches 125.46% for CaO. Most variables do not show a normal distribution, because they have p-value <0.05. Following the method proposed by Buxeda i Garrigós **(1999)**, the variation matrix (VM) was calculated on a dataset that included 26 measured elements (Na_2O, MgO, Al_2O_3, SiO_2, K_2O, CaO, TiO_2, Fe_2O_3, P_2O_5, MnO, V, Cr, Co, Ni, Cu, Zn, Rb, Sr, Y, Zr, Ba, La, Ce, Nd, Pb, Th). The total variation (**Figure 8.4**) was high (*vt*=1.87), confirming the heterogeneity of the dataset (**Buxeda i Garrigós 1999**). Following the same routine applied for Belovode, the VM was re-calculated excluding those elements (P_2O_5, Co, Cu, Ba, Pb) whose concentration could have been altered by post-depositional processes and sample preparation. The results (**Appendix C2.2**) show that even though the *vt* dropped significantly (**Figure 8.5**), it was still relatively high (*vt*=0.98).

Principal component analysis (PCA) was then performed, first on the dataset comprising 137 samples, and 21 elements transformed to logarithmic base -10, and then on the dataset transformed through centred log ratio (CLR) and asymmetric log ratio (ALR) analyses. The three different procedures gave very similar results, however PCA run on the dataset transformed to logarithmic base -10 displayed the highest cumulative variance for principal components 1 and 2 (52.8%) and was therefore chosen to illustrate the results (**Figure 8.6**). This scatterplot shows that most of the samples analysed have a very similar chemical composition and plot closely together, but a number of specimens plot in clearly separate areas. Comparing the score plot (**Figure 8.6a**) with the variable plot (**Figure 8.6b**), it is possible to observe that CaO, Sr, Ni, MnO, Cr, Na_2O and MgO most strongly influence the results, because of their high relative variance (**Table 8.1** and **Figure 8.5**).

These results were then compared to the groups defined via thin section analysis (**Figure 8.7**). The specimens classified as fabric PL-A, marked by fragments of sedimentary rocks, tend to plot together. Samples of other fabrics (PL-D, PL-E, PL-F, PL-G, PL-H, PL-I, PL-J, PL-K, PL-L) which, as noted above, also have a very distinctive chemical profile in comparison to fabric group PL-A, tend to plot separately.

The results of the first PCA confirmed the observations made through petrographic analysis, with the exception of the loom-weight sample, PL 24-256, attributed to fabric PL-A. This specimen plots in a separate area and shows significant differences in its chemical profile in comparison to the other samples attributed to fabric PL-A. More specifically, it has a higher content of Fe_2O_3 (8.86%), V (169ppm), Cr (338ppm), Co (28ppm), Zn (185ppm), Rb (120ppm), and Sr (263ppm) when compared to specimens of the same fabric. It is also

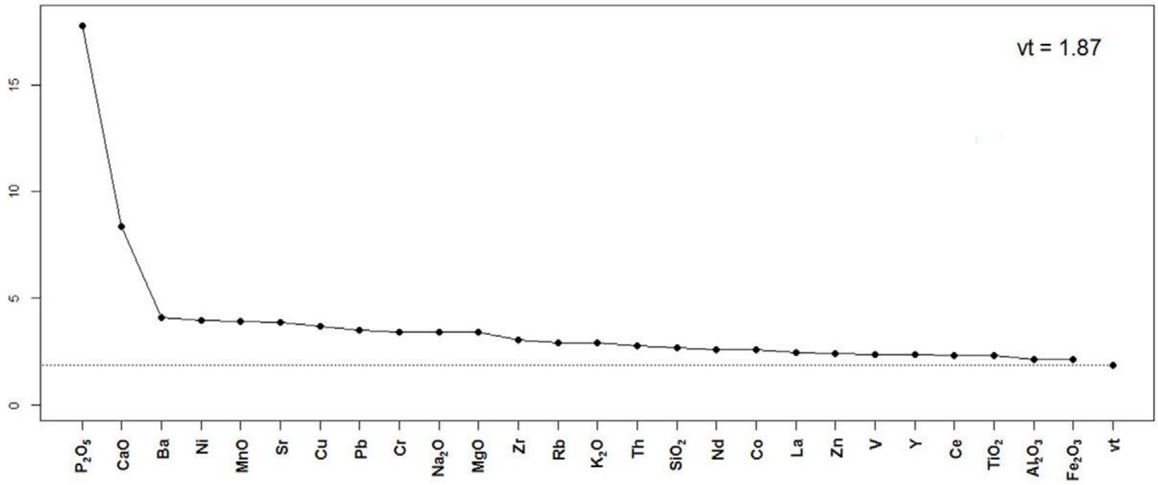


Figure 8.4. Evenness chemical variability graph for all 137 samples characterised (26 elements). vt: total variation. τ.i: trace of the covariance matrix in ALR transformation using that element as divisor.

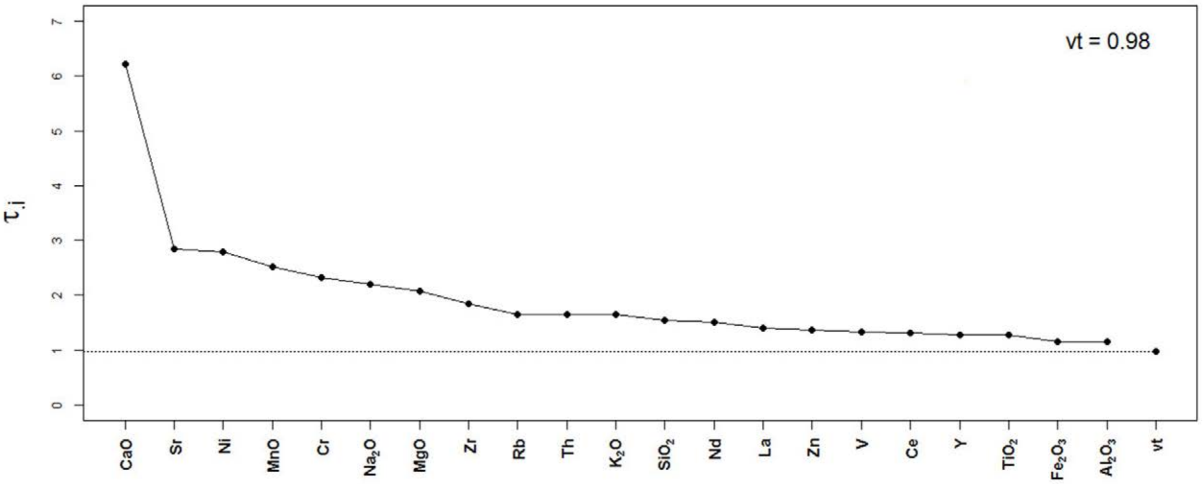


Figure 8.5. Evenness chemical variability graph for all 137 samples characterised (21 elements). vt: total variation. τ.i: trace of the covariance matrix in ALR transformation using that element as divisor.

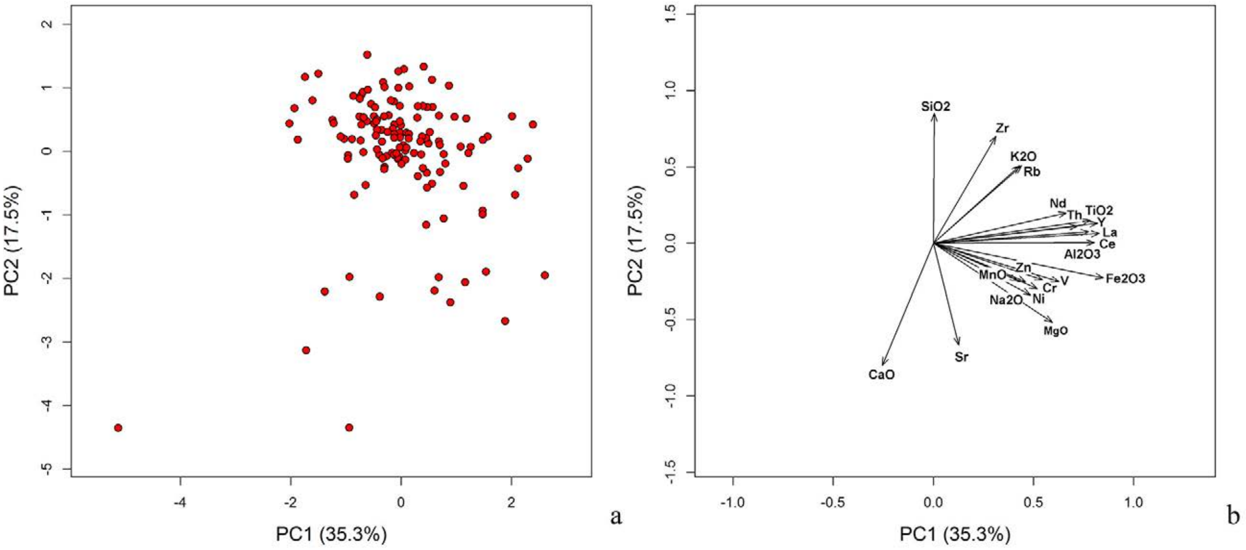


Figure 8.6. A score plot (a) and a variable plot (b) based on the first two components from the PCA run on the non-normalised Pločnik WD-XRF dataset transformed to logarithmic base -10. The dataset comprises 137 samples and 21 variables.

worth noting that six specimens (PL 24-299, PL 24-300, PL 24-306, PL 24-313, PL 24-318, and PL 24-329) assigned to fabric PL-A, plot slightly separately. These have a high SiO_2 content (around 69%); thin section analysis showed that they are possibly tempered with a quartz-rich sand.

Specimens of fabric PL-B, marked by the presence of mica-schist fragments, and samples of fabric PL-C, characterised by muscovite and amphibole inclusions, separate less clearly from samples attributed to fabric PL-A. If, however, the raw data is taken into consideration, these specimens do, in fact, show some compositional differences. Specifically, samples belonging to fabric PL-B all contain lower amounts of SiO_2 and higher Al_2O_3 than samples of fabric PL-A. They are also marked by slightly higher concentrations of La, Ce, and Nd, while specimens assigned to fabric PL-C show higher concentrations of Cr, Ni, and Sr. Hierarchical cluster analysis (HCA) was performed via the average linkage method on the principal components calculated on the non-normalised dataset transformed to logarithmic base -10 (**Figure 8.8**). Clusters were then calculated by cutting the dendrogram at 5.4. These were plotted based on the first two components of the PCA that was run on the non-normalised dataset transformed

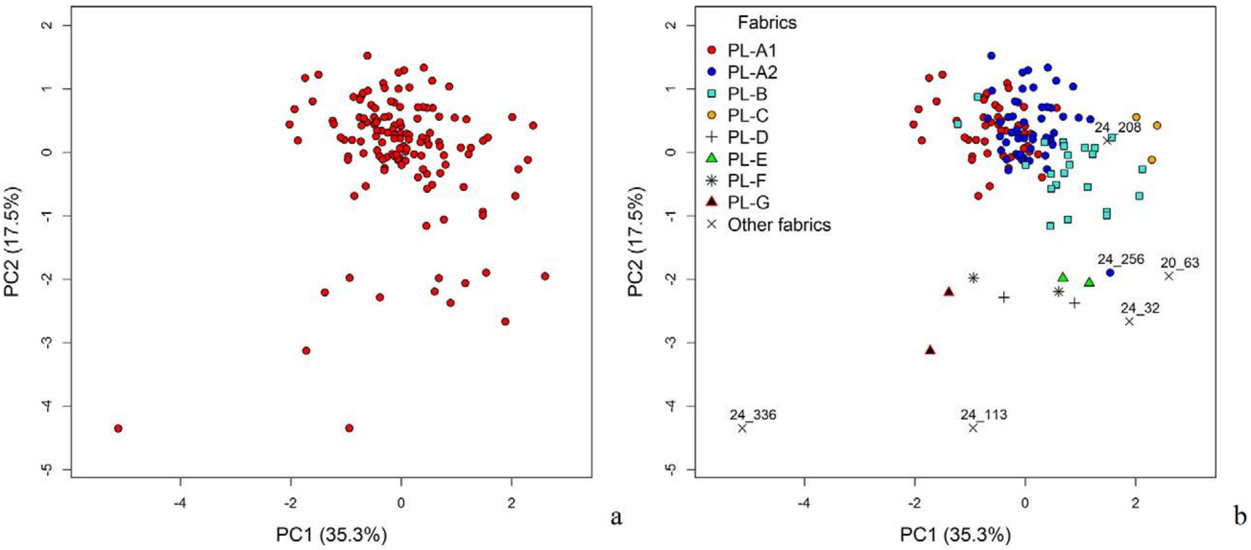


Figure 8.7. Comparison between score plots based on the first two components from the PCA run on the non-normalised Pločnik WD-XRF dataset transformed to logarithmic base -10. The dataset comprises 137 samples and 21 variables. In score plot b) colours correspond to different fabric observed in thin section analysis.

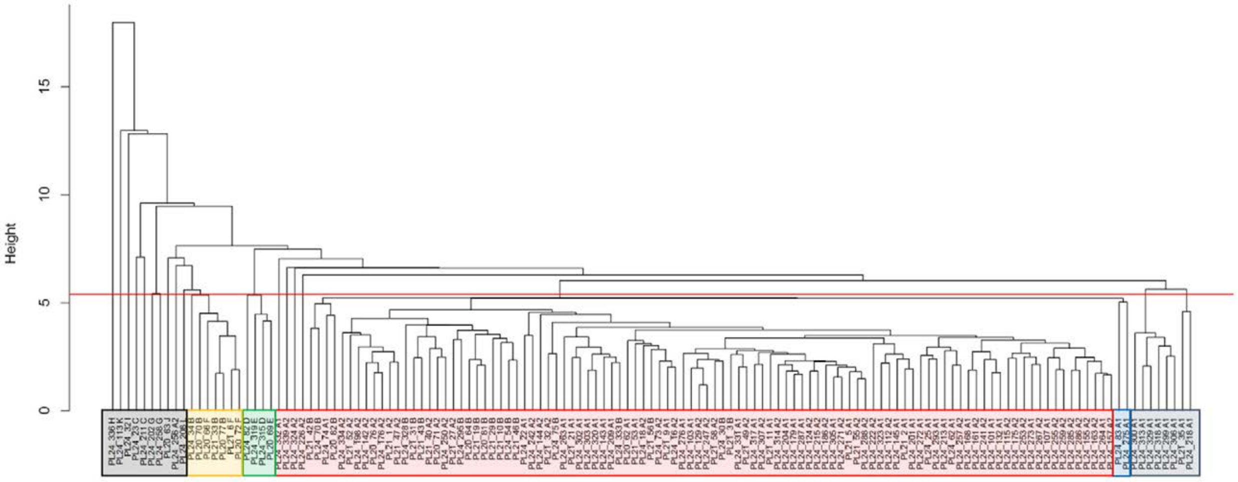


Figure 8.8. Dendrogram obtained by applying hierarchical agglomerative cluster analysis (average linkage method) on the principal components calculated via the PCA run on the non-normalised Pločnik WD-XRF dataset transformed to logarithmic base -10. The dataset comprises 137 samples and 21 variables.

to logarithmic base -10. The results of HCA confirmed the presence of a large cluster of samples that includes most of the specimens of fabrics PL-A and PL-B (number 1 in **Figure 8.9b**).

Additional smaller clusters include specimens assigned to the other fabrics. Interestingly, samples that show possible evidence of tempering (PL 24-299, PL 24-300, PL 24-306, PL 24-313, PL 24-318, PL 24-329) form a separate cluster (number 3 in **Figure 8.9b**). Also, samples PL 21-35, PL 24-218, PL 24-324, PL 24-332, PL 24-226 and PL 24-339, assigned to fabric PL-A, do not fall within the main cluster. It is noteworthy that, among these, PL 24-226 and PL 24-339 are daub and an oven fragment respectively. Comparing this score plot (that plotted clusters) and that in which petrographic groups are outlined, it appears that the observed concentrations tend to correspond with the groups recognised in thin section analysis (**Figure 8.9a**).

The VM was then calculated on a dataset including only samples of fabric PL-A marked by sedimentary rocks

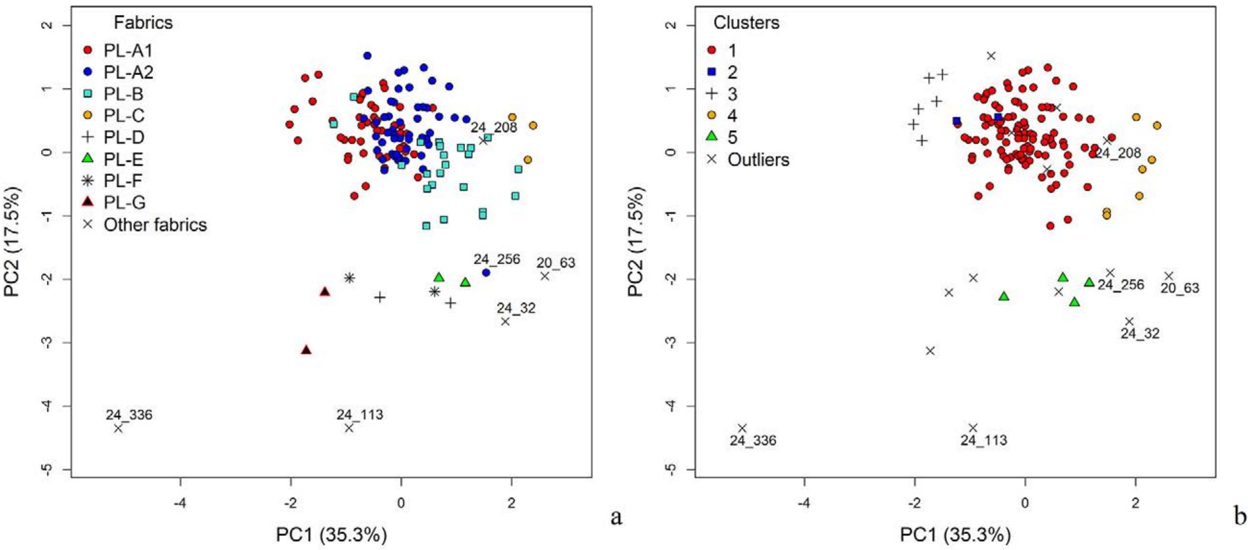


Figure 8.9. Comparison between score plots based on the first two components from the PCA run on the non-normalised Pločnik WD-XRF dataset transformed to logarithmic base -10. The dataset comprises 137 samples and 21 variables: a) colours correspond to different fabrics as observed in thin section analysis; b) colours correspond the hierarchical clusters calculated by cutting the dendrogram at 5.4.

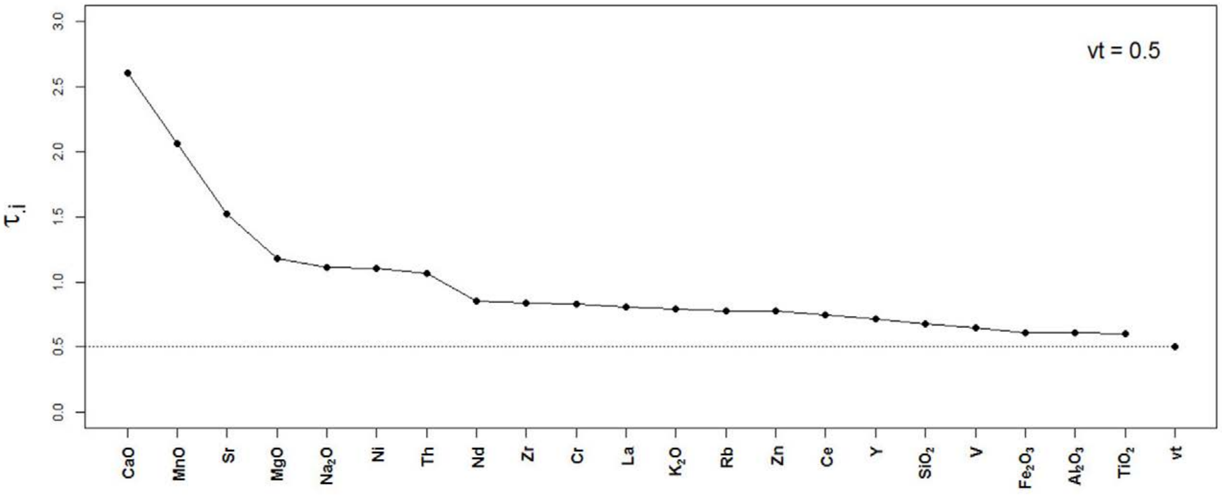


Figure 8.10. Evenness chemical variability graph for samples of fabric PL-A (21 elements). vt: total variation. τ.i: trace of the covariance matrix in ALR transformation using that element as divisor.

fragments, in order to investigate minor compositional differences in these sherds. The total variance of this dataset was equal to 0.5 (**Figure 8.10**). A *vt* smaller than 1 is considered low and *vt* of 0.5 could reflect the monogenetic character of this dataset. Although the possible presence of sub-groups cannot be excluded, these would show only slight variations and it is therefore very difficult to explore their existence via multivariate statistics (**Buxeda i Garrigós and Kilikoglou 2003; Gascón and Buxeda i Garrigós 2013: 81**).

Although this problem was taken into consideration, PCA was then run on this log -10 transformed dataset. The scatter plot (**Figure 8.11**) based on the first two principal components (Variance 47%) shows that the samples tend to scatter in different areas of the graph. This could be explained by the heterogeneity of this petrographic group, connected to differences in grain size distribution and minor compositional variability. The six specimens that show evidence of tempering again plot separately because of their high concentration of SiO_2. Other samples (e.g. PL 24-83, PL

24-275, PL 21-40, PL 21-52, PL 24-324) plot separately because of minor differences in the concentration of Al_2O_3, SiO_2, CaO, Cr, Sr, Zr. For example, PL 24-83 and PL 24-275 have relatively high concentrations of CaO in comparison to the other samples. This observation matches quite well with the results of the petrographic analysis, which highlighted the presence of minor quantities of calcite in these samples.

Hierarchical cluster analysis (average linkage method) was performed on the principal components of the PCA run on this dataset. The results (**Figure 8.12**) confirmed previous observations but also highlighted the possible presence of an outlier (PL 24-332). This sample shows higher concentrations of Rb and Sr in comparison to other samples. Finally, the results were plotted according to different vessel types, but no clear pattern emerged. On the other hand, when samples were plotted according to building horizon (**Figure 8.13**) it appeared immediately evident that one of the sub-clusters of the main group corresponded to most of the samples from horizon 1 (Gradac III).

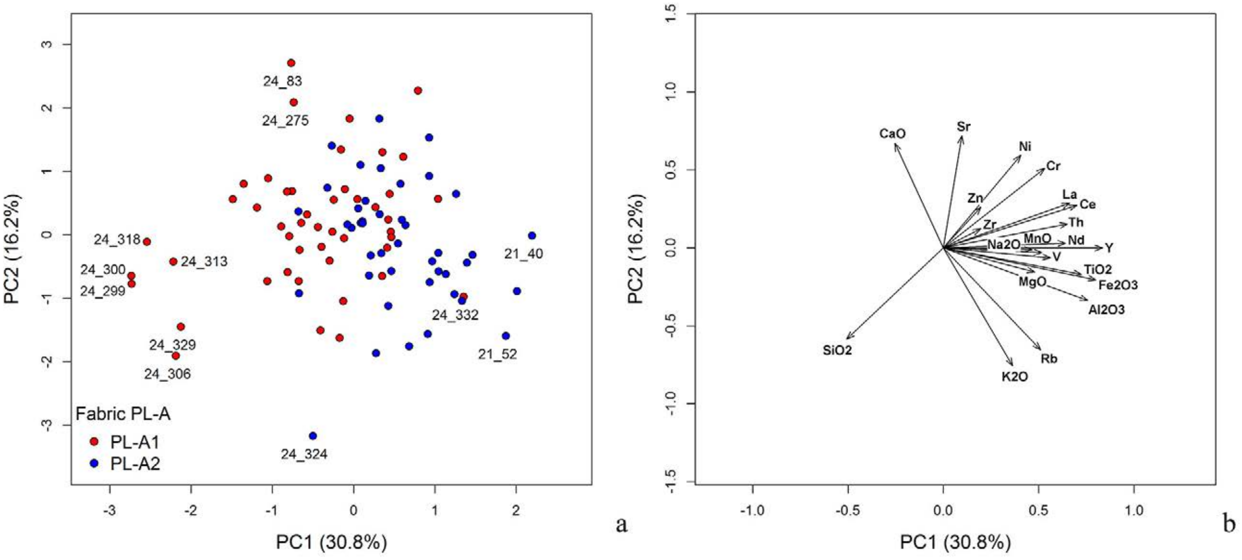


Figure 8.11. A score plot (a) and a variable plot (b) based on the first two components from the PCA run on the non-normalised Pločnik WD-XRF dataset transformed to logarithmic base -10. The dataset comprises samples of fabric PL-A and 21 variables PCA.

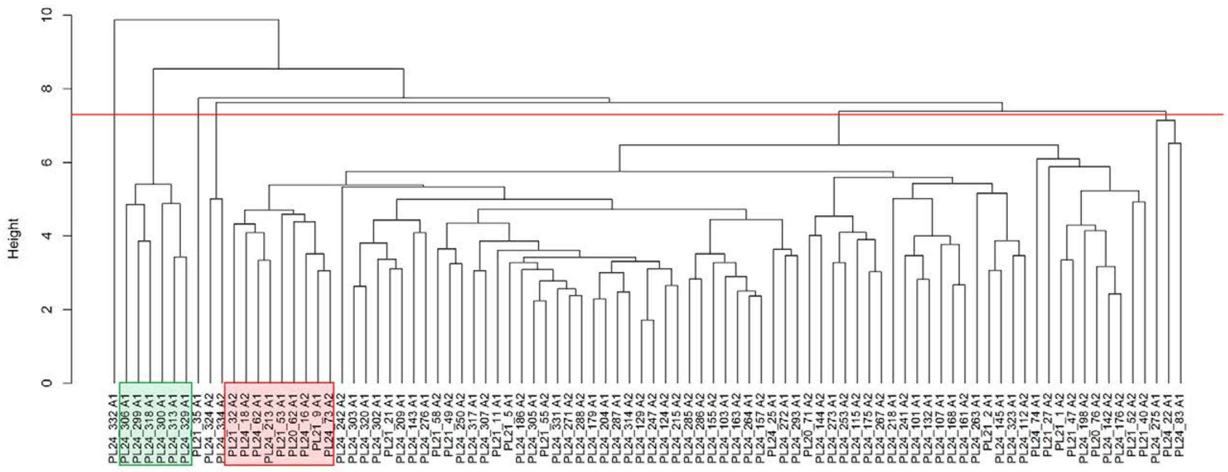


Figure 8.12. Dendrogram obtained by applying hierarchical agglomerative cluster Analysis (average linkage method) on the principal components calculated via the PCA run on the non-normalised Pločnik WD-XRF dataset transformed to logarithmic base -10. The dataset comprises samples of fabric PL-A and 21 variables.

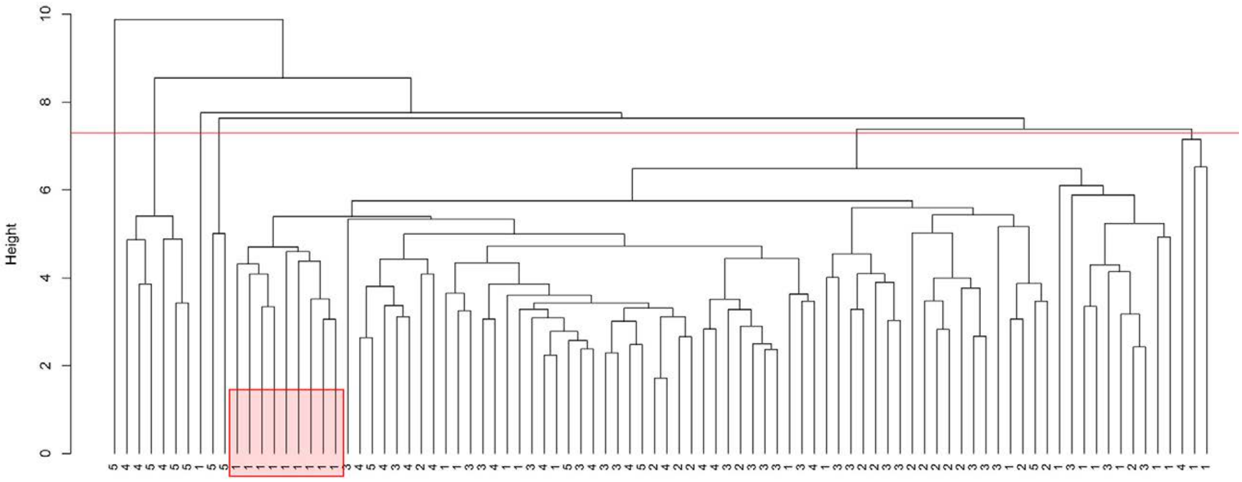


Figure 8.13. Dendrogram obtained by applying hierarchical agglomerative cluster analysis (average linkage method) on the principal components calculated via the PCA run on the non-normalised Pločnik WD-XRF dataset transformed to logarithmic base -10. The dataset comprises samples of fabric PL-A and 21 variables. Below the tree, the associated building horizons (1-5) of the analysed samples are given.

Results of the XRPD and SEM analyses

The XRPD analysis of 59 samples (see **Table 8.2** and **Figures 8.14–8.16**) showed that most of the samples contain illitic clay, which can be distinguished by a main diffraction peak at 8.82 2θ° (10 Å d spacing) and further peaks at increasing 2θ° intervals with variable intensities (**Deer *et al.* 1992**). Overall, the main mineralogical assemblages detected through XRPD analysis were quartz, feldspars, calcite and illite. Several samples (**Figures 8.14** and **8.15**) exhibit a weak diffraction peak corresponding to a d-value of approximately 14Å, which points to either montmorillonite or, more likely, chlorite. The presence of amphibole was verified in some samples (PL 24-23, PL 24-113, PL 24-211, and PL 24-315) by its main characteristic peak at about d ~ 8Å. In addition, cristobalite (d = 4.08Å) was detected in sample PL 24-23 (**Figure 8.16**). The presence of clay minerals such as illite and illite–chlorite suggests that the maximum firing temperature of most of the samples was below 850–900°C (**Kulbicki 1958; Maggetti 1982**). Only a few samples show the presence of calcite in their diffraction patterns, which either means that these vessels could not have been fired at temperatures above 850°C, or calcite occurs as a secondary mineral (**Maggetti 1982; Maritan 2004**). Overall, the XRPD results suggest that the maximum temperature to which most of the ceramic specimens were fired did not exceed 900°C, and was probably around 750–800°C. This includes all the dark-burnished pottery samples with or without graphite painted decoration. One sample, however, PL 24-23, in which cristobalite was detected, was probably exposed to temperatures over 1000°C. Notably, this same sample, characterised by mineral phases that form at high temperatures, is most likely of non-local production. The original vessel fragment from which the sample derived has a perforated wall. While its function remains uncertain, it could be a fragment of a 'chimney'.

The fresh fractures of 11 samples of pottery from different phases of the settlement were also analysed under scanning electron microscope (SEM) to observe their degree of vitrification **(Maniatis and Tite 1981)**. Five dark-burnished samples were re-fired in reducing conditions at temperatures of set intervals ranging from 700–1100°C. Most of the samples showed an initial vitrification compatible with temperatures between 750°C and 850°C (**Figure 8.17** and **Table 8.3**). In the re-firing experiment (**Figure 8.18**), the degree of vitrification of the five samples started to change within this temperature range. Sample PL 24-247, however, decorated with graphite, shows a microstructure (**Figure 8.17f**) compatible with higher temperatures of around 900°C. This sample also shows the presence of bloating pores, which are normally formed under reducing firing conditions (**Maniatis and Tite 1981: 61**).

Characterisation of the raw materials

As discussed in **Chapter 5**, in the summers of 2012, 2013 and 2014, raw material surveys were carried out in the area around Pločnik. The full list of the samples collected and analysed can be found in **Appendices D1.2** and **D3** together with a brief description and a geological map indicating the exact location of all sampled sites. In the following section, the compositional characteristics

Table 8.2. Summary of the XRPD results (DB = dark-burnished; GP = graphite-painted).

Sample	Chronological Horizon	DB	GP	Optical Activity	Qtz	Fsp	Cc	Am	Ill	Msc	Hem	Cri	Spl	Temp
PL 21-2	1 (Gradac II-III)	X		moderate	X	X			X					< 900°C
PL 21-5	1 (Gradac II-III)			moderate	X	X			X					< 900°C
PL 21-11	1 (Gradac II-III)	X		weak	X	X			X					< 900°C
PL 21-21	3 (Gradac I)	X		weak	X	X			X					< 900°C
PL 21-27	3 (Gradac I)			moderate	X	X			X					< 900°C
PL 21-47	1 (Gradac II-III)	X		moderate	X	X			X					< 900°C
PL 21-49	1 (Gradac II-III)	X		absent	X	X			X					< 900°C
PL 21-55	1 (Gradac II-III)	X		weak	X	X			X					< 900°C
PL 21-56	1 (Gradac II-III)	X		weak	X	X			X					< 900°C
PL 20-63	1 (Gradac II-III)			weak	X	X		X	X	X	X	X?		> 1000°C
PL 20-69	1 (Gradac II-III)			absent	X	X		X	X	X	X	X?		> 1000°C
PL 24-15	1 (Gradac II-III)	X		moderate	X	X			X					< 900°C
PL 24-23	1 (Gradac II-III)			moderate	X	X		X		X		X		> 1000°C
PL 24-32	1 (Gradac II-III)			weak	X	X			X					< 900°C
PL 24-34	1 (Gradac II-III)			moderate	X	X			X?	X?				< 900°C
PL 24-54	1 (Gradac II-III)			absent	X	X			X					< 900°C
PL 24-70	1 (Gradac II-III)	X		weak	X	X			X					< 900°C
PL 24-73	1 (Gradac II-III)			absent	X	X			X					< 900°C
PL 24-74	1 (Gradac II-III)			absent	X	X			X					< 900°C
PL 24-75	1 (Gradac II-III)			absent	X	X			X					< 900°C
PL 24-83	1 (Gradac II-III)			absent	X	X	X		X					< 900°C
PL 24-101	2 (Gradac I)	X		weak	X	X			X					< 900°C
PL 24-103	2 (Gradac I)		X	moderate	X	X			X					< 900°C
PL 24-107	2 (Gradac I)	X		weak	X	X			X					< 900°C
PL 24-113	2 (Gradac I)			high	X	X		X	X					< 900°C
PL 24-124	2 (Gradac I)		X	weak	X	X			X					< 900°C
PL 21-129	2 (Gradac I)		X	weak	X	X			X					< 900°C
PL 24-132	2 (Gradac I)	X		weak	X	X			X					< 900°C
PL 24-145	2 (Gradac I)	X		weak	X	X			X					< 900°C
PL 24-157	3 (Gradac I)	X		weak	X	X	X		X					< 900°C
PL 24-161	3 (Gradac I)	X		weak	X	X			X					< 900°C
PL 24-179	3 (Gradac I)			weak	X	X			X					< 900°C

Sample	Chronological Horizon	DB	GP	Optical Activity	Qtz	Fsp	Cc	Am	Ill	Msc	Hem	Cri	Spl	Temp
PL 24-186	3 (Gradac I)	X		moderate	X	X			X					< 900°C
PL 24-204	3 (Gradac I)	X		weak	X	X			X					< 900°C
PL 24-209	4 (B2)	X		weak	X	X			X					< 900°C
PL 24-211	4 (B2)	X		moderate	X	X		X	X					< 900°C
PL 24-215	2 (Gradac I)		X	weak	X	X			X					< 900°C
PL 24-247	3 (Gradac I)		X	weak	X	X			X					< 900°C
PL 24-263	3 (Gradac I)	X		weak	X	X			X					< 900°C
PL 24-267	3 (Gradac I)	X		high	X	X			X					< 900°C
PL 24-275	4 (B2)	X		absent	X	X	X		X					< 900°C
PL 24-287	4 (B2)			moderate	X	X			X					< 900°C
PL 24-288	4 (B2)	X		high	X	X			X					< 900°C
PL 24-299	4 (B2)			high	X	X			X					< 900°C
PL 24-303	4 (B2)	X		weak	X	X			X					< 900°C
PL 24-307	4 (B2)	X		weak	X	X			X					< 900°C
PL 24-313	5 (A2-B1)			weak	X	X			X					< 900°C
PL 24-314	5 (A2-B1)	X		weak	X	X			X					< 900°C
PL 24-315	5 (A2-B1)	X		weak	X	X		X	X					< 900°C
PL 24-318	5 (A2-B1)			weak	X	X	X		X					< 900°C
PL 24-319	5 (A2-B1)	X		moderate	X	X		X	X					< 900°C
PL 24-320	5 (A2-B1)	X		weak	X	X			X					< 900°C
PL 24-323	5 (A2-B1)			moderate	X	X			X					< 900°C
PL 24-324	5 (A2-B1)			absent	X	X			X					< 900°C
PL 24-328	5 (A2-B1)			moderate	X	X			X?	X?				< 900°C
PL 24-329	5 (A2-B1)	X		moderate	X	X			X					< 900°C
PL 24-331	5 (A2-B1)	X		weak	X	X			X					< 900°C
PL 24-332	5 (A2-B1)	X		weak	X	X			X					< 900°C
PL 24-333	5 (A2-B1)			moderate	X	X			X					< 900°C

Table 8.3. Summary of the results of the SEM analysis (IV = initial vitrification 750–800°C; V= extensive vitrification 900–950°C; C= continuous vitrification 1000–1050°C; DB = dark-burnished; GP = graphite-painted).

Sample	Chronological Horizon	DB	GP	Fabric	Refiring	Degree of Vitrification
PL 21-21	3 (Gradac I)	X		PL-A2		IV
PL 21-47	1 (Gradac II-III)	X		PL-A2	X	IV
PL 21-49	1 (Gradac II-III)	X		PL-A2	X	IV
PL 21-55	1 (Gradac II-III)	X		PL-A2	X	IV
PL 20-69	1 (Gradac II-III)			PL-E		IV
PL 24-23	1 (Gradac II-III)			PL-F		V
PL 24-83	1 (Gradac II-III)			PL-A1		IV
PL 24-103	2 (Gradac I)		X	PL-A1		IV
PL 24-124	2 (Gradac I)		X	PL-A2		IV
PL 24-129	2 (Gradac I)		X	PL-A2		IV
PL 24-157	3 (Gradac I)	X		PL-A2	X	IV
PL 24-161	3 (Gradac I)	X		PL-A2	X	IV
PL 24-215	2 (Gradac I)		X	PL-A2		IV
PL 24-247	3 (Gradac I)		X	PL-A1		IV
PL 24-303	4 (B2)	X		PL-A1		IV
PL 24-313	5 (A2-B1)			PL-A1		IV

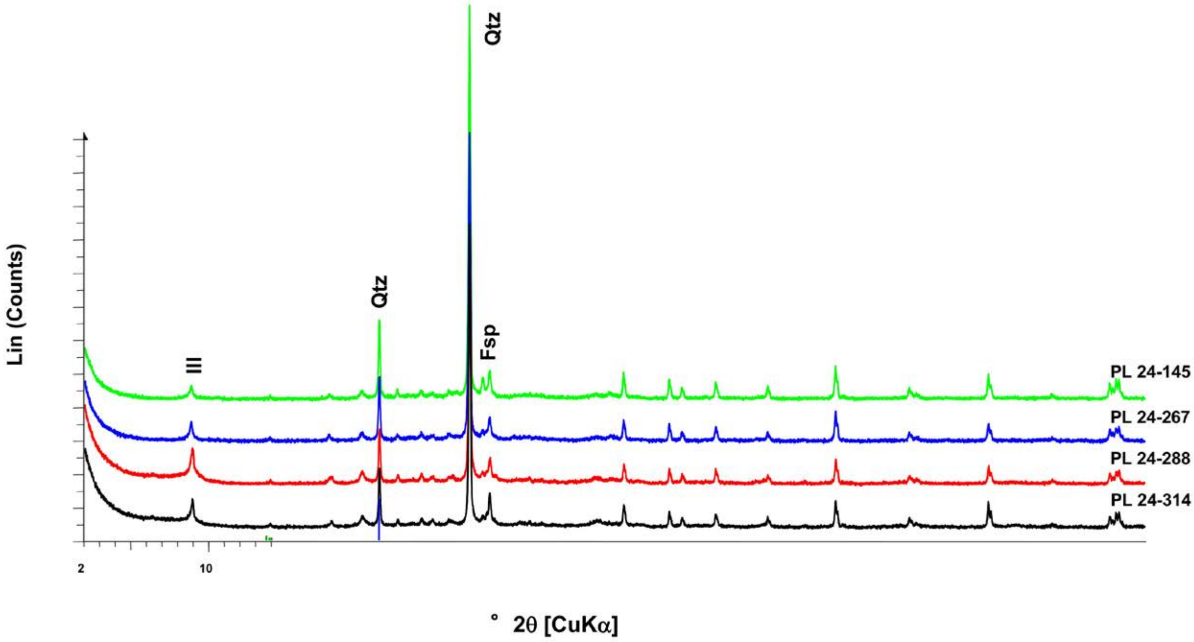


Figure 8.14. Diffractograms of samples PL 24-314, PL 24-288, PL 24-267, and PL 24-145 (dark-burnished pottery). Ill: illite; Qtz: quartz; Fsp: feldspars.

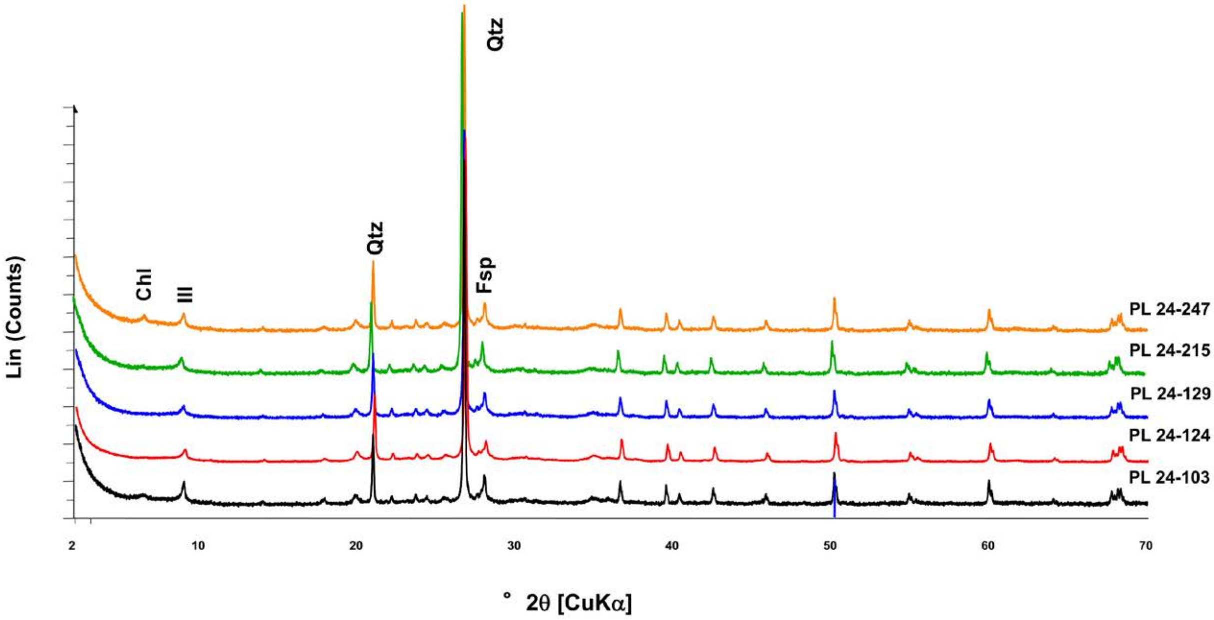


Figure 8.15. Diffractograms of samples PL 24-103, PL 24-124, PL 24-129, PL 24-215 and PL 24-247 (graphite-painted pottery). Chl: Chlorite; Ill: illite; Qtz: quartz; Fsp: feldspars.

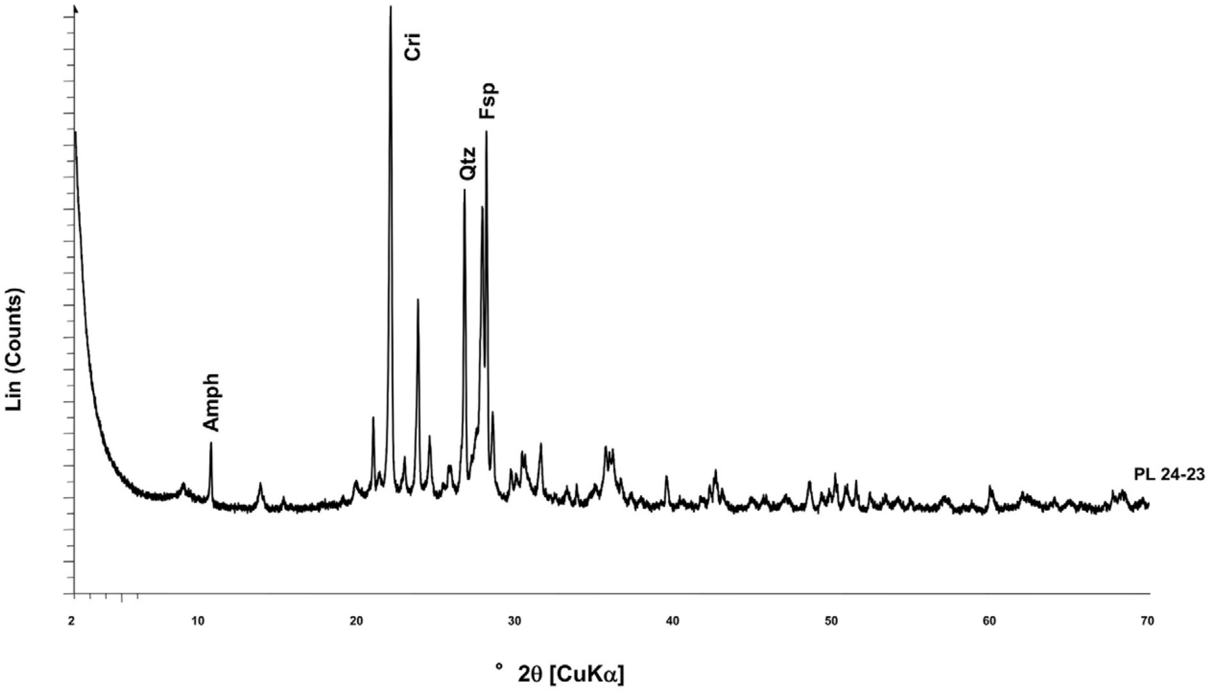


Figure 8.16. Diffractogram of sample PL 24-23 (wall fragment, fabric with volcanic inclusions). Amph: amphibole; Cri: Cristobalite; Qtz: Quartz; Fsp: feldspars.

of the geological samples relevant to the ceramic raw material selection will be briefly considered.

As mentioned in **Chapter 3**, Pločnik is situated on a fertile floodplain characterised by alluvial quaternary deposits related to the activity of the Toplica River (**Figure 8.19**), which flows from the Kopaonik mountain range about 50km away. The surrounding areas are characterised by Cretaceous and Neogene deposits of flysch, sandstone, marl, and olistostrome, overlaying the Precambrian formations of leptinolite and mica schist, fine-grained biotite gneisses and amphibolite. All these formations outcrop to the east of the site (**Figure 8.19**). West of Pločnik, the Kursumlja area comprises Jurassic formations of gabbro, dolerites, rare basaltic pillow lavas, and small isolated outcrops of serpentinite. Jurassic sediments also include diabase rocks, occasionally mixed with Triassic outcrops of sericite schists and limestones. These formations are partially cut through by the Quaternary alluvial valley of the River Toplica and its tributaries.

During the raw material survey, several samples from the Cretaceous formations (e.g. $^2M_{2,3}$, $^3K^3_2$) were collected and analysed via thin section petrography. Clays and sandy clays sourced from these formations are marked by the presence of quartz, and various types of sedimentary rocks (**Figure 8.20a, b**), including quartz arenite, arkosic arenite, lithic arenite and siltstone. These formations also include layers of very calcareous clay, probably marl (**Figure 8.20c**). Sandy clays and sands from Quaternary alluvial sediments (al) were also selected and analysed, revealing their polymictic nature (**Figure 8.20d, e**), being marked by inclusions of varying lithologies (**Maggetti 1994**). For example, sand from the Toplica River (**Figure 8.20e**) includes sedimentary, volcanic, and metamorphic rock fragments. A sample of proluvium (pr) was also collected in the vicinity of Belojin (point 38 in **Figure 8.20f**). This sandy clay sample is characterised by frequent inclusions of amphibole and muscovite.

Ten samples of clay sourced from the Quaternary, Neogene and Cretaceous formations were also analysed via WD-XRF (**Appendix C2.1**). Clay samples from the Cretaceous (sample 36 from point 33, sample 38 from point 35, sample 46 from point 40) and Neogene formations (sample 44 from point 39, sample 45 from point 39), have similar compositions and minor variability in the concentration of some trace elements (V, Cr, Ni, Zn, Sr). Clay samples from Quaternary deposits (sample 2 from point 2, sample 3 from point 2, sample 7 from point 6, sample 32 from point 29, and sample 43 from point 38), have a heterogeneous composition and show considerable differences in their chemical profiles compared to samples from Cretaceous and Neogene formations.

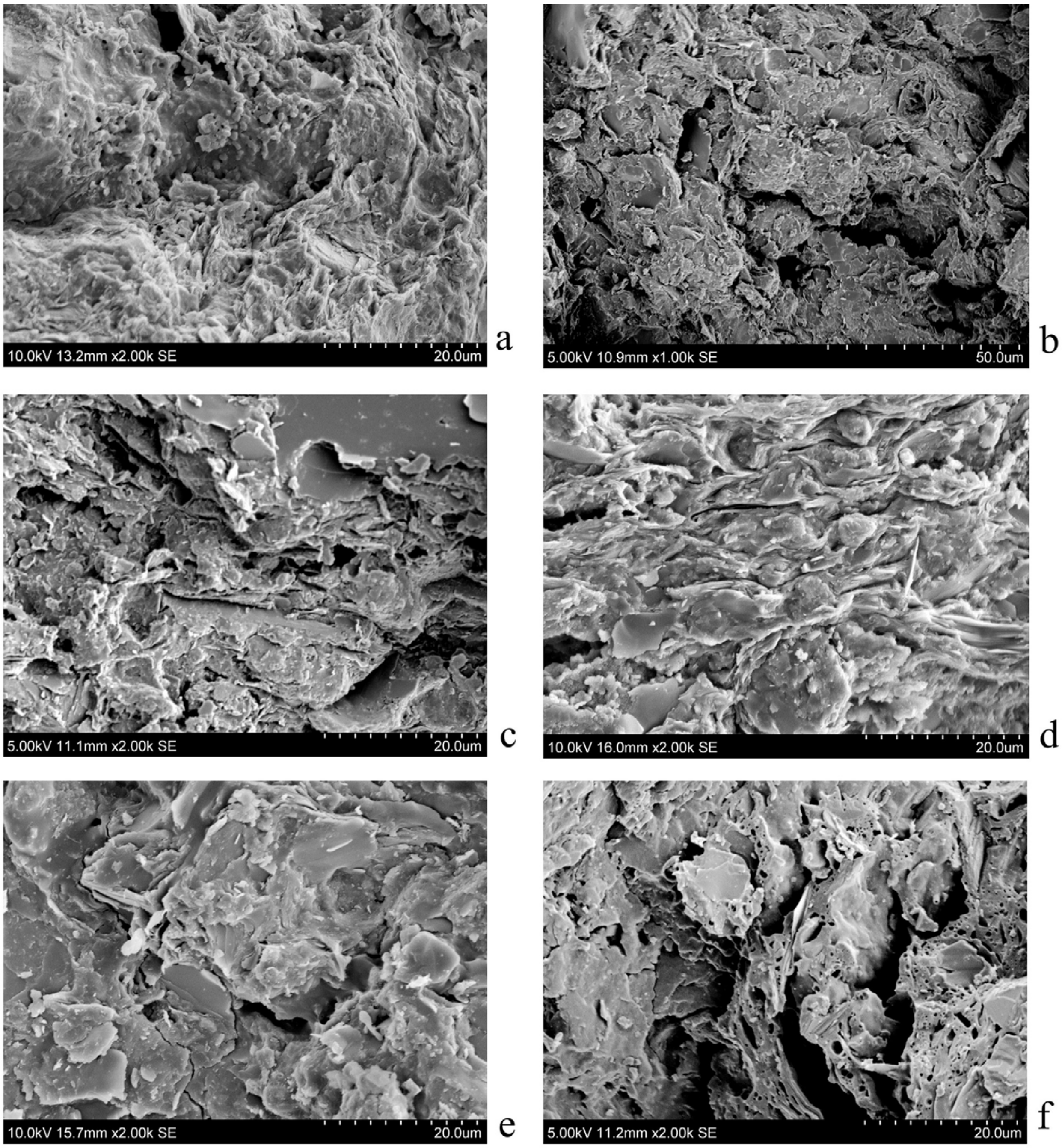


Figure 8.17. SEM photomicrographs of ceramic samples from Pločnik: a) PL 24-83 (bowl); b) PL 24-103 (bowl, dark-burnished ware with graphite decoration); c) PL 24-124 (dark-burnished ware with graphite decoration); d) PL 24-129 (dark-burnished ware with graphite decoration); e) PL 24-215 (dark-burnished ware with graphite decoration); f) PL24-247 (dark-burnished pottery with graphite decoration).

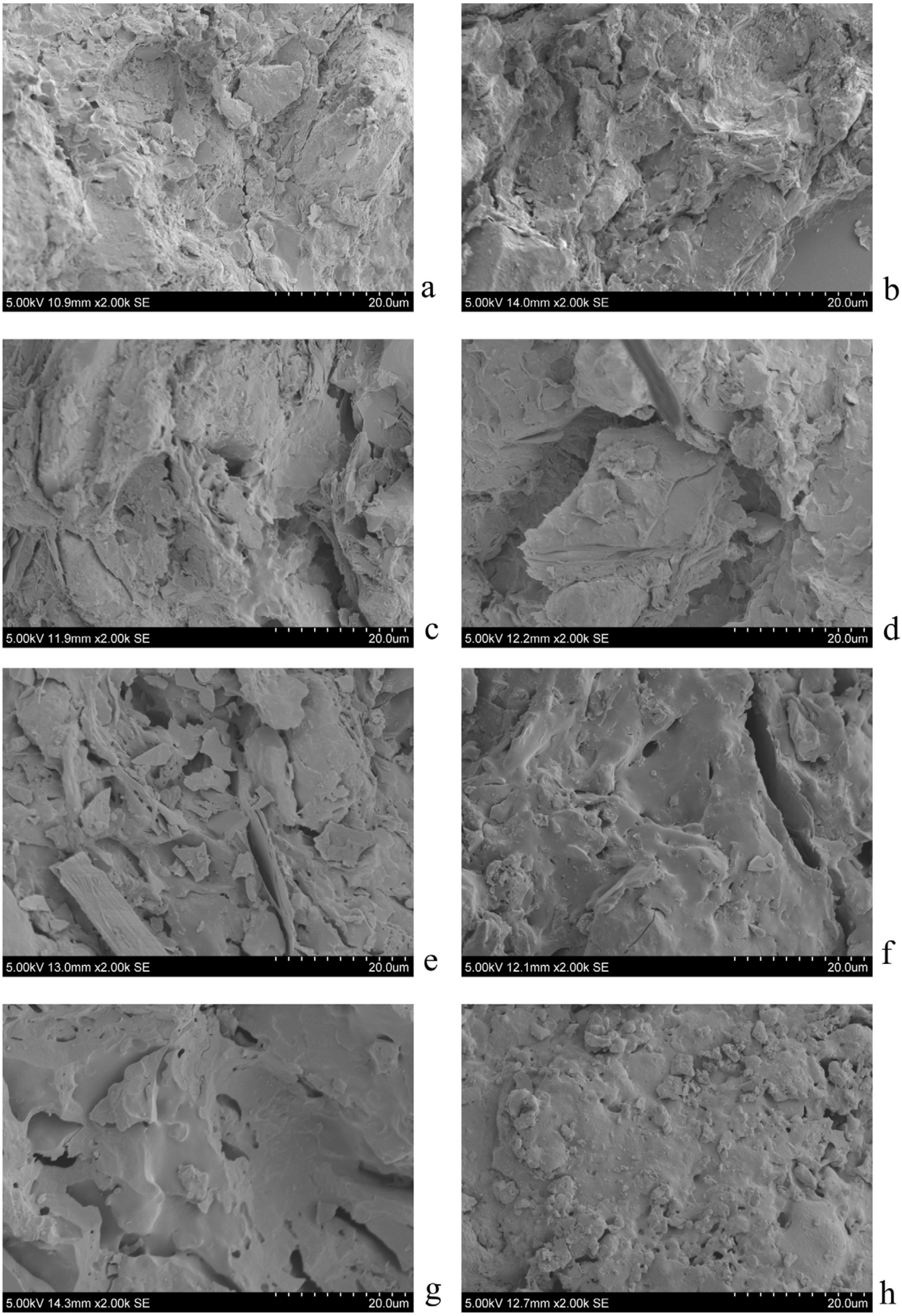


Figure 8.18. SEM photomicrographs of BEL 157 (bowl, dark-burnished pottery, re-fired in reducing atmosphere at different temperatures): a) as received; b) 700°C; c) 750°C; d) 800°C; e) 850°C; f) 900°C; g) 950°C; h) 1000°C.

Discussion

Raw material selection and provenance

The petrographic analysis shows that sherds belonging to fabric PL-A (marked by sedimentary rock fragments) can be associated with clay sources in the area surrounding Pločnik (**Figure 8.19**), suggesting that these were locally produced. In particular, the compositional characteristics of the geological sample 46 (point 40, near Pepeljevac) closely matches those of fabric PL-A (**Figure 8.21a, b**). As discussed above, these sandy clays contain quartz, muscovite, and various sedimentary rocks. A daub sample (**Figure 8.21c, d**) taken from a modern hut close to the archaeological site contained a similar range of inclusions.

It is difficult to locate the exact outcrop of clay exploited by Pločnik inhabitants to produce ceramic material assigned to fabric PL-A, not least because it is very likely that different outcrops in the same geological formations were exploited over time. It is possible, however, to exclude the alluvial clay deposited by the Toplica River, as sand samples from the river were revealed to be polymictic, with fragments of rocks of different origins (e.g. sedimentary, metamorphic and volcanic). This is corroborated by the WD-XRF results, which show that the chemical composition of the river clay is significantly different from the samples attributed to fabric PL-A, which exhibit a narrow range of minerals and sedimentary or metasedimentary rocks. Rather, the raw material employed was most likely derived from the Neogene and Cretaceous formations, outcrops of which contain sandy clays suitable for pottery manufacture.

While the provenance of the samples belonging to fabric PL-A, (most of the analysed sherds from Pločnik) is clear, the samples belonging to the other detected fabrics deserve a separate and more detailed discussion. First, however, it is worth mentioning that a fabric very similar to fabric PL-A was also found in the Late Neolithic survey materials from Merovac ('fabric B'), suggesting shared technological traditions or the circulation of pottery between the two sites (**Appendix E**).

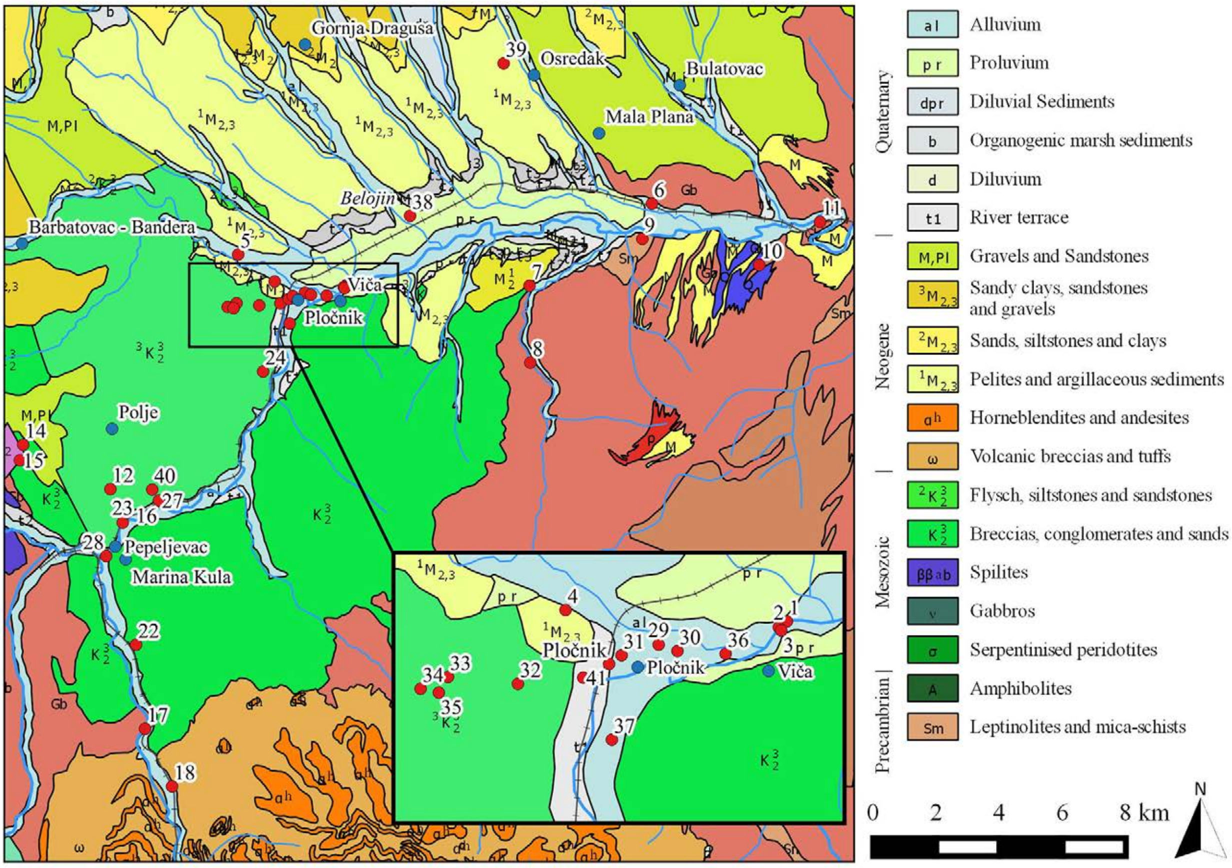


Figure 8.19. Geological map of the area surrounding Pločnik (based on Yugoslavia Geological Map issued by the Federal Geological Institute. Sheets L34-31; L34-32 - 1: 100 000, prepared by Enrico Croce). Sample locations are indicated by red dots, Neolithic archaeological sites by blue dots. Black dots correspond to relevant modern topographic locations.

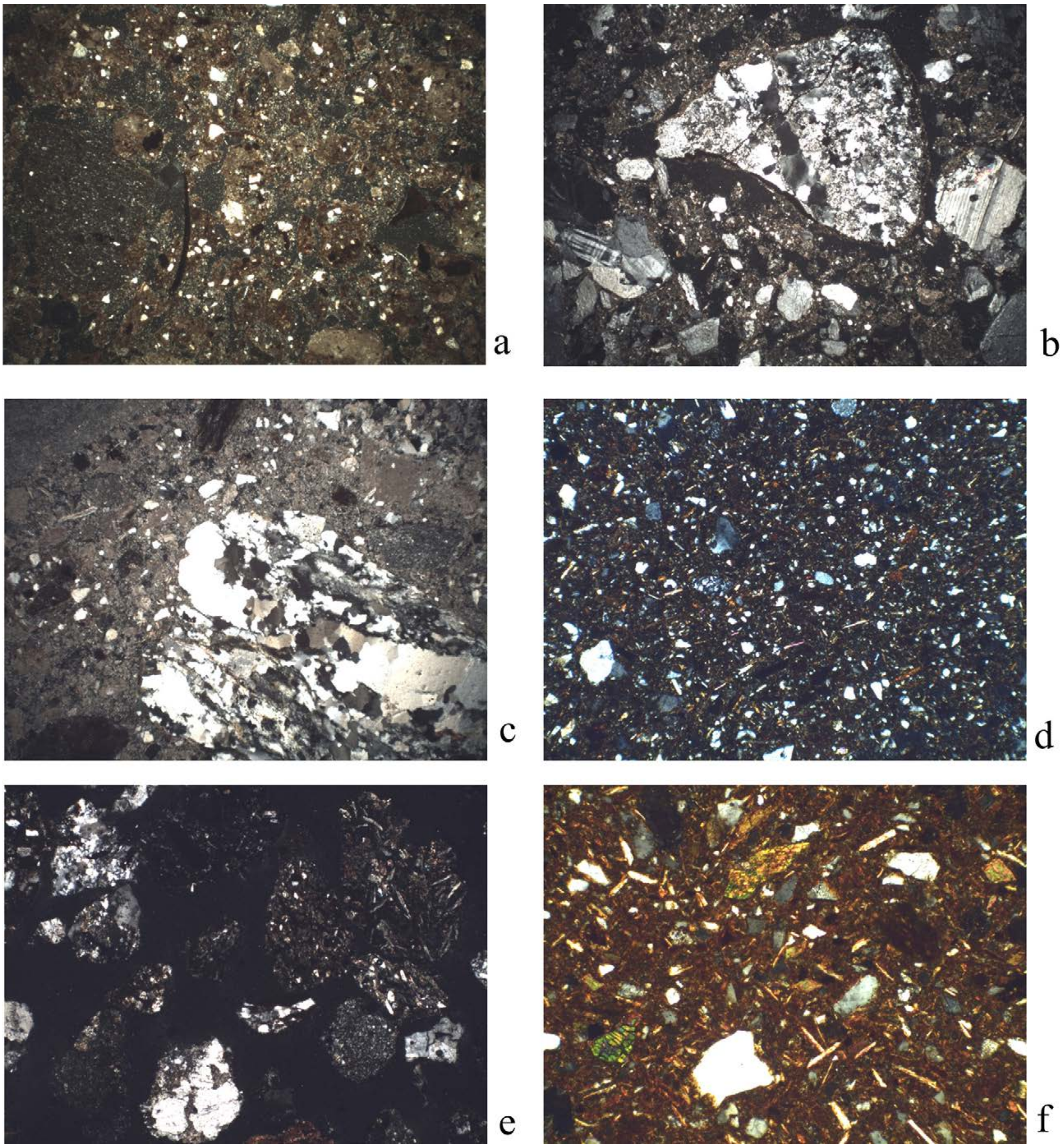


Figure 8.20. Thin section photomicrographs of selected geological samples from Plocnik: a) clay (point 35, sample 38, near Pločnik), XP; b) sandy clay (point 40, sample 46, near Pepeljevac), XP; c) marl and sand (point 4, sample 5, close to Pločnik), XP; d) sandy clay from Viča, (point 36, sample 39), XP; e) sand from Toplica River (sample 48), XP; f) sandy clay from Belojin, (point 38, sample 43), XP. Field of view = 6 mm (a–d); 3 mm (e); 1.5 mm (f).

Specimens of fabric PL-B are characterised by their abundance of muscovite and metamorphic rock inclusions in addition to fragments of sedimentary rocks (e.g. PL 21-10, PL 21-19, PL 21-29, PL 21-31 and PL 24-54). The statistical analysis performed on the chemical dataset showed that this group does not distinguish clearly from fabric group PL-A. It is possible that another source of raw material, geochemically similar and available in the vicinity of the site, was exploited by the inhabitants of Pločnik or that the same clay used for producing fabric A was tempered with mica-schist. Suitable formations with mica-schist/gneiss outcrops would be available around 6–7km east of the site (points 8–9, sample 10–11; **Figure 8.22a, b**). It is interesting to note that this fabric shows a broad comparison with other metamorphic fabrics, such as

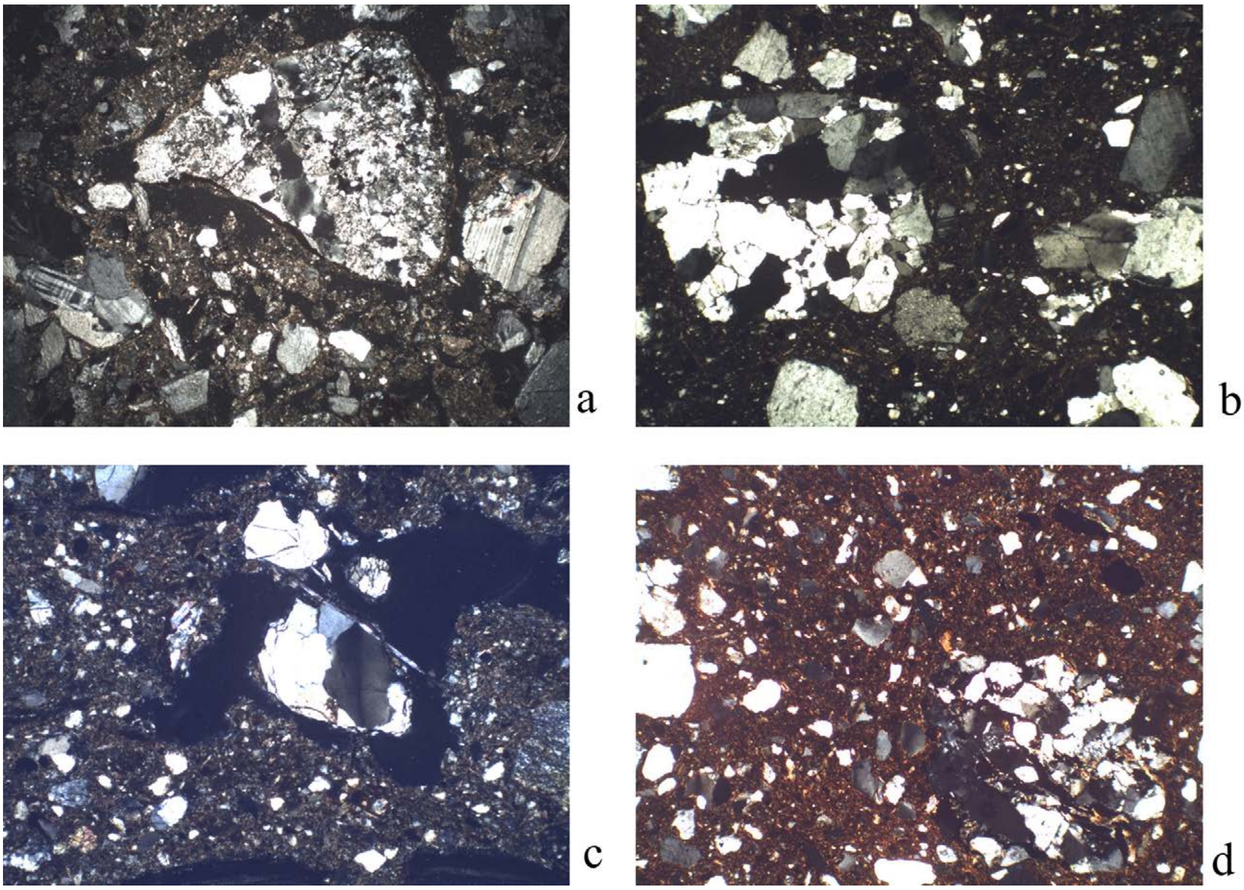


Figure 8.21. Thin section photomicrographs of selected geological and pottery samples from Pločnik: a) sandy clay rich in fragments of sedimentary rocks (point 40, sample 46, near Pepeljevac), XP; b) Fabric PL-A (PL 24-132) with quartz arenite, XP; c) modern daub with sedimentary rock fragments (from Pločnik), XP; d) Fabric PL-A (PL 20-78) with arkosic arenite, XP. Field of view = 3 mm (b–d); 6 mm (a).

those found in Late Neolithic survey materials from Bulatovac, Marina Kula, and Merovac (**Appendix E**).

The compositions of samples assigned to fabric PL-C (PL 21-6, PL 21-66, PL 20-68 and PL 20-72), marked by abundant amphibole and muscovite, is compatible with clay sources found around Belojin (**Figure 8.22c, d**). Of course, it is not clear whether these samples were produced with a clay source collected from Belojin and brought to Pločnik or were made in a village local to the source, but there is currently no evidence of Neolithic occupation in the area of Belojin.

Samples representative of fabric PL-D (PL 24-82 and PL 24-315) seem to match with an area characterised by phyllite which outcrops to the west of the site (formation D, see **Appendix D1.2**). However, the phyllite rock fragments that mark this fabric are well rounded, which may suggest that they were transported from elsewhere.

For fabric PL-E, which is rich in epidote, a sedimentary clay source is suggested. This was probably formed from the weathering of metamorphic rocks, but it is not possible to give a precise location of the origin of this raw material source based solely on the characteristics of this group.

Compositional characteristics of the samples of fabric PL-F (PL 24-23, PL 24-211), marked by volcanic rock fragments, indicate that these specimens were made from a residual clay rich in andesite. They may originate from a region extending from Rudare to the border of Kosovo (Niševac), which is characterised by volcanic breccia, tuff and andesite formations (**Figure 8.22e, f**). This fabric was found to be similar to that identified in the samples collected in Degerman (**Appendix E**).

Two of the analysed loom weights (PL 24-202 and PL 24-258) assigned to fabric PL-G and one oven fragment (PL 24-336, fabric PL-H) were produced with a very calcareous clay, probably a marl. As mentioned above, the geosurvey identified a marly clay source in the vicinity of the site (**Figure 8.22g, h**). Additionally, the clay source used to produce the loom weight PL 24-256, fabric PL-A2 has very different chemical profile

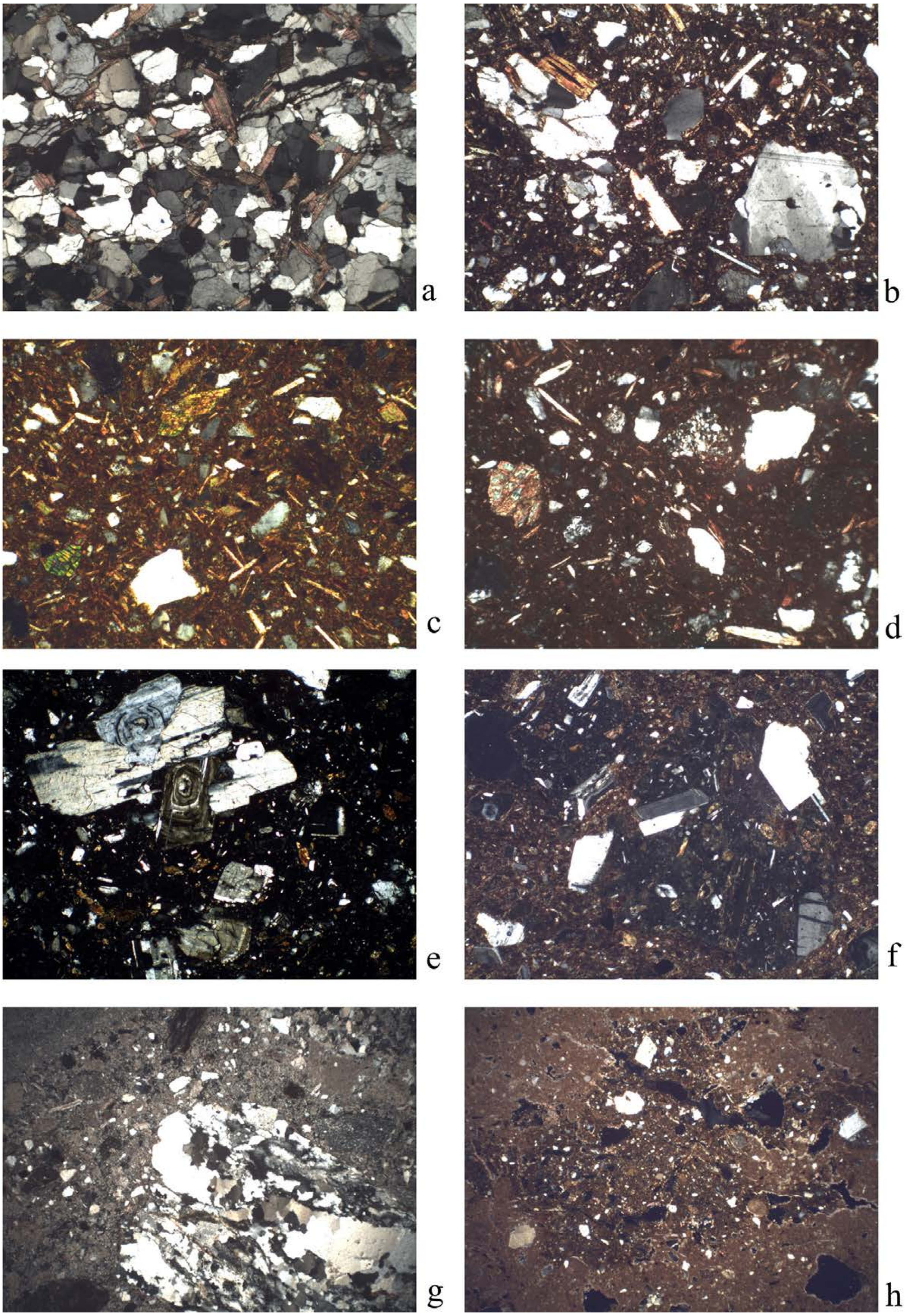


Figure 8.22. Thin section photomicrographs of selected geological and pottery samples from Pločnik: a) fragment of a metamorphic foliated rock (point 8, sample 10), XP ; b) Fabric PL-B (PL 21-19) with mica schist, XP; c) sandy clay from Belojin (point 38, sample 43), rich in muscovite and amphibole, XP; d) PL-C (PL-21-6) with abundant muscovite and amphibole, XP; e) volcanic rock fragment (point 18, sample 21), XP; f) Fabric PL-F (PL 24-211) with volcanic rocks, XP; g) marl and sand (point 4, sample 5, close to Pločnik), XP; h) Fabric PL-H (PL 24-336) made from calcareous clay, XP.
Field of view = 3 mm (a, b, d, f, h); 1.5 mm (c); 6 mm (e, g).

to that of the main production group (fabric PL-A) and was probably produced with a raw material different to that available near the site; further analysis will be necessary to establish whether the loom weight was imported.

Sample PL 24-32 (fabric PL-I) is marked by the presence of serpentinite, which is characteristic for the area surrounding Kuršumlija, a likely candidate for the origin of this vessel. Some fragments of serpentinite have, however, been found in conglomerate and breccia formations north of Pločnik, and in clay samples collected from the banks of the Toplica River. Samples PL 20-63 (fabric PL-J) and Pl 24-113 (fabric PL-K) show an abundance of amphibole and amphibolite and are therefore compatible with an area south of Prokuplje characterised by the presence of amphibolite (formation A; see **Appendix D1.2**). This fabric also compares with the one found in the Late Neolithic survey materials from Mačina (**Appendix E**).

Sample PL 24-208, characterised by gneiss fragments, could also be attributed to this area.

Paste preparation

The evidence provided above indicates that the main ceramic production group in Pločnik is represented by samples assigned to fabric PL-A. Although some differences were observed in the grain size, the sorting and the distribution of the inclusions within this fabric, it does not appear that this variability is the result of intentional modification according to the vessel typologies to be produced. It was possible to recognise only a general tendency towards more abundant and coarser inclusions in vessels with thicker walls and a generally finer fabric amongst samples with thin walls. In addition, it is not clear whether the analysed ceramics were tempered or not, although this was more likely for some specimens than for others (**Appendices A2.2** and **A2.3**). It seems, for example, that tempered pottery was more common in the earliest horizons of the settlement: a small group of samples from horizons 5 and 4 (Vinča A2/B2) is characterised by bimodal grain size distribution that could be evidence of intentional addition of aplastic material (**Figure 8.23**). These samples are also marked by a higher concentration of SiO_2 (the result of the presence of abundant quartz inclusions) in comparison to other specimens of fabric PL-A. In general, it seems that once the suitable raw material for pottery making was collected, this was only minimally processed, and any tradition of tempering was limited largely to the earliest phases of the settlement. It is very interesting that the fabric of dark-burnished vessels is not fine, nor is it possible to associate it with any specific paste recipe. Evidence of clay processing is also minimal among the other productions that can be attributed to the site (e.g. fabric PL-C) but there are a few coarse samples assigned to fabric B in which fragments of mica schist could have been intentionally added as temper. Finally, grog tempering seems to characterise the local production of loom weights represented by fabric PL-G.

Estimation of firing temperatures

The results of petrographic analysis, XRPD and SEM show that the potters at Pločnik must have been able to achieve relatively high firing temperatures (at least *c.* 750°C) but tended not to exceed temperatures of *c.* 850°C. The variations in colour of many of the surfaces and fabrics indicate that they were not always able to perfectly control the firing atmospheres. This observation also applies to the dark-burnished pottery; however the five sherds characterised by graphite-painted decoration were probably fired in more controlled, reducing firing temperatures. Graphite burns off at relatively low temperatures in oxidising conditions (**Kreiter *et al.* 2014**), so it is possible that the potters were aware of this, having a relatively advanced pyrotechnology that enabled them to adequately control redox conditions in order to produce this type of decoration.

The firing temperatures estimated for Pločnik match the results of the analysis carried out on the material from Belovode. The only sample that could have been fired to temperatures exceeding 1000°C is of non-local production and is probably a fragment of a 'chimney' (PL 24-23).

Summary

The analysis of ceramic sherds from trenches 20, 21 and 24 from Pločnik provides important information about the nature of pottery technology at the site across different chronological horizons. The results show that there was consistency in pottery recipe traditions whilst routines connected to raw material procurement/processing and forming techniques remained unchanged over the complete occupation of the site. This points to a scenario of strong continuity in the transmission of knowledge of pottery making traditions, surprisingly not even influenced by the appearance of metallurgy in the Gradac I phase (*c.* 5000 BC). Despite this, some changes were observed in the final horizon, such as the possible exploitation of new clay sources. In addition, the range of surface treatments and decorations in this last horizon became significantly simplified. This building horizon seems to correspond to the Gradac phase III (*c.* 4446–4231 cal BC), a period that saw an increase in the presence of metal artefacts in Pločnik.

The range of analyses conducted provides important information about the provenance of the studied

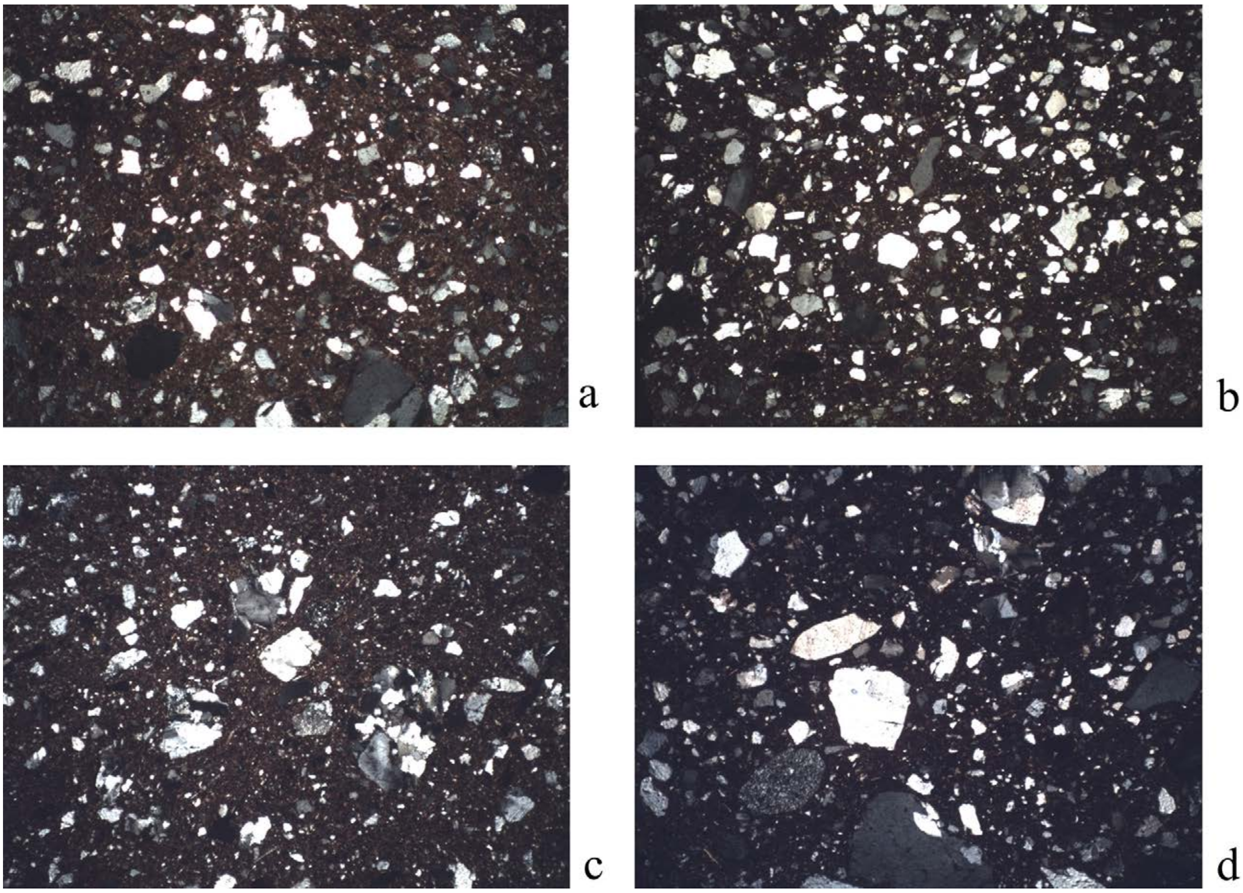


Figure 8.23. Thin section photomicrographs of samples of fabric PL-A from Pločnik that show possible evidence of tempering: a) PL 24-318, XP; b) PL 24-313, XP; c) PL 24-323, XP; d) PL 24-326, XP. Field of view = 6mm.

samples, allowing the identification of several possible non-local productions, the numbers of which seem to increase in the final building horizon of the site. These specimens provide insights into the networks that must have existed between the Pločnik settlement and contemporary sites in its vicinity. This contributes significantly to the broader panorama we are now able to provide for pottery technology in this region of the Vinča material culture.

Finally, the results of XRPD and SEM analysis further stimulate the discussion on the pyrotechnological link between pottery and metallurgy. The applied methods demonstrate that, at Pločnik, the dark-burnished ware—and examples of this decorated with graphite—were fired at around 750–800°C, a temperature not even close to that necessary to smelt copper (1083°C). However, the increased presence of graphite-painted wares can be seen as evidence that potters had advanced pyrotechnological skills that gave them good control of atmospheric conditions during the firing process.

All these themes will be further expanded upon in **Chapter 9**, where the results obtained from Belovode and Pločnik will be directly compared.

Chapter 9
Discussion of the Results

Integration of the macroscopic and microscopic analyses on samples from Belovode and Pločnik highlights distinct technological characteristics that contribute to the reconstruction of the pottery production methods within these two significant Vinča culture communities. This chapter will discuss various aspects of pottery technology, setting the results from Belovode and Pločnik in the context of similar studies in South East Europe and the Central Balkans mentioned in **Chapter 1** and **2** The organisation of pottery production will also be examined, along with the evidence of potentially non-local production identified in **Chapters 7** and **8**, in order to explore the dynamics of pottery circulation amongst these prehistoric communities.

Ceramic production technology

In the following section, various aspects of pottery production at Belovode and Pločnik are explored, with comparisons to other contemporary sites (**Figure 9.1**).

Raw material selection

The first significant theme highlighted by the analyses is raw material selection, with potters at both sites exploiting resources readily available in their immediate surroundings, a behaviour consistent with global patterns. Studies suggest that the maximum distance travelled to acquire clays and temper sources is typically 7km from the production location, with most potters preferring sources within 1km (**Arnold 2000: 343**). Both Belovode and Pločnik had suitable clay sources within 1km of the settlement boundary, a situation also observed at other Vinča sites (**Amicone *et al.* 2020b**).

At Belovode, two distinct types of clay sources were utilised. A non-calcareous Neogene sedimentary sandy clay, characterised by fragments of medium-grade metamorphic rocks and their derived minerals (**Appendix D1.1**, points 2, 12, 14) was used throughout the settlement's occupation (**Figure 9.2**). A Neogene

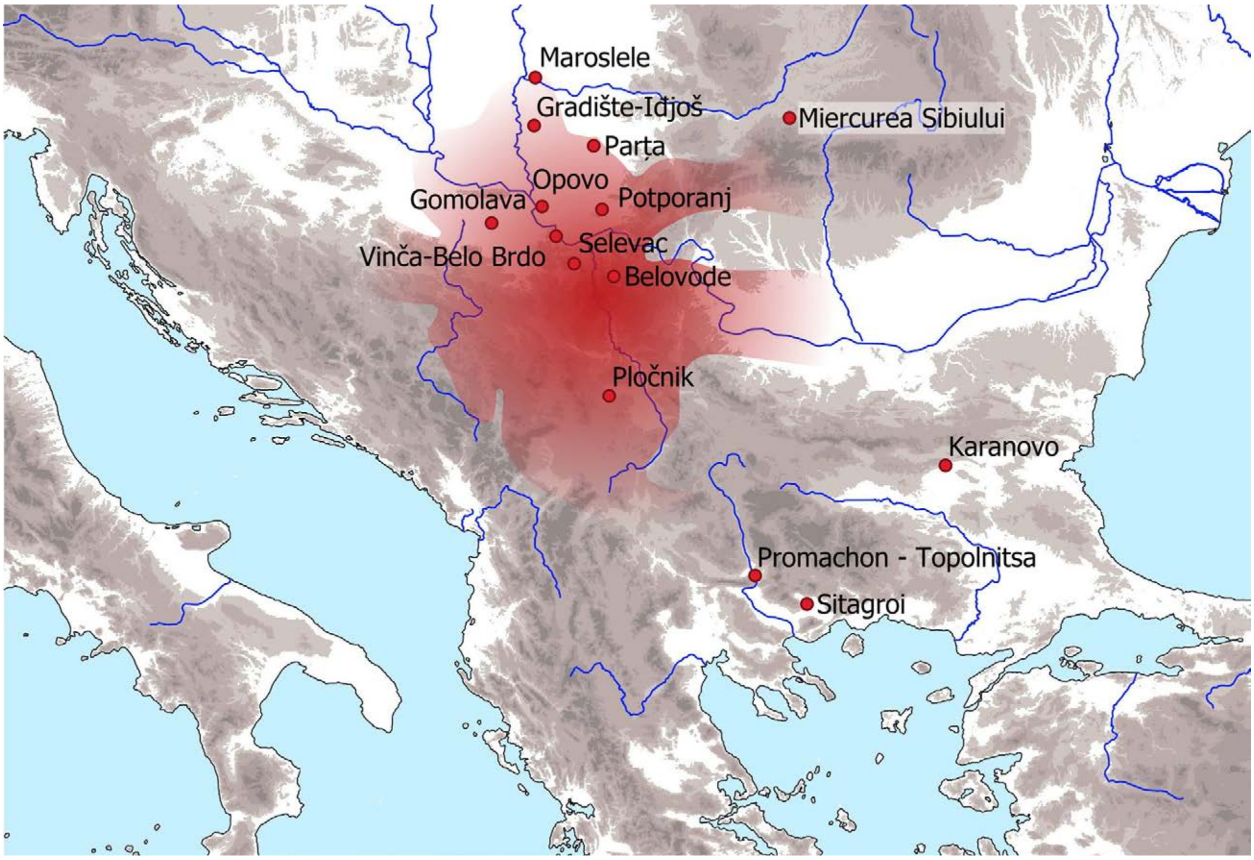


Figure 9.1. Distribution of the Vinča culture throughout all its periods (shaded) and location of sites mentioned in this study (map by Lars Heinze and Jugoslav Pendić).

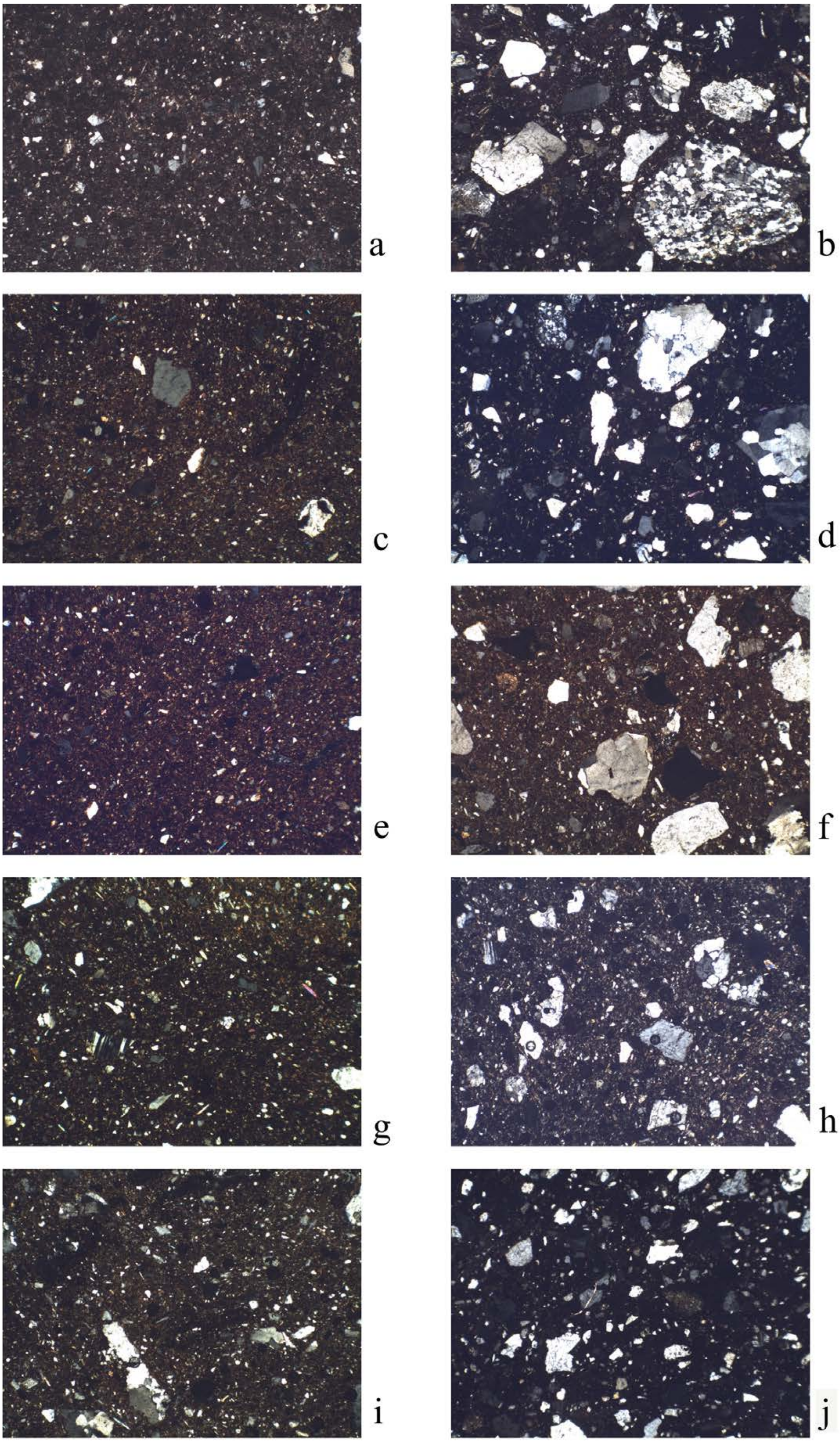


Figure 9.2. Thin section photomicrographs of fabric BEL-A in different horizons: a) and b) horizon 1; c) and d) horizon 2; e) and f) horizon 3; g) and h) horizon 4; i) and j) horizon 5 (field of view = 3mm).

calcareous sandy clay, rich in calcite and shells (**Appendix D1.1, point 1**), was introduced from horizon 3 onwards (*c.* 5140–4859 cal. BC), marking the start of the Gradac phase at the site. Sandy layers within the Neogene formation could also have served as a suitable temper source.

In contrast, the area around Pločnik offered excellent secondary clay sources derived from Cretaceous formations rich in conglomerates, sandstones, and mudstone. These sources, marked by fragments of sedimentary rocks and associated minerals, were consistently used by the inhabitants of Pločnik throughout the settlement's occupation. Notably, the use of non-calcareous clays, which are highly plastic and require minimal processing, became a stable technological tradition over time (**Figure 9.3**), whilst calcareous clays were reserved for loom-weights and plastered floors.

It is notable that alluvial clay from the nearby Toplica River was not employed in pottery production, despite its proximity. While it is challenging to explain this, one possibility is that during the Neolithic, the river's course differed from its current path, as indicated by the significant destruction of the site caused by its meandering. However, during the period of occupation, the river probably bordered the settlement's south-eastern extension.

Several factors may have influenced the decision not to use fluvial sediments, including a preference for Cretaceous clay sources, which were perhaps perceived as more suitable for pottery production. Socio-political factors, though difficult to reconstruct today, may also have played a role. The distribution of resources in the environment offers a range of possibilities, each influencing movement within the landscape (**Michelaki *et al.* 2014**). Potters have been shown to select raw materials from locations where the presence of multiple resources facilitates multiple tasks. Gosselain and Livingstone Smith (**2005**) document cases where potters discovered suitable clay sources while engaging in other tasks, such as fetching water or digging foundations. It is conceivable that the inhabitants of Pločnik favoured their particular clay source because its location also provided other essential resources.

The hills surrounding Pločnik are rich in sandstone that was used in the ground-stone industry. It is plausible that the tasks of collecting raw materials for pottery and for the ground-stone industry were interconnected, taking place in areas offering materials suitable for both activities. This could also explain the selection of clay rich in mica-schist or clay tempered with this type of rock (fabric PL-B). The inhabitants most likely exploited outcrops near mica-schist quarries located approximately 6–7km from the site (**Appendix D1.2, point 9**), where this material was also used in the local ground stone industry (**Dimić and Antonović 2021**). Interestingly, while one-third of the sherds in horizon 1 (*c.* 4631–4231 cal. BC) are characterised by this fabric, only a few samples of fabric PL-B are present in earlier horizons.

Raw material processing

At both Belovode and Pločnik, clay processing appears to have been minimal. The practice of tempering, though present, was not widespread or easily recognisable. For Belovode, tempering was observed primarily in the earliest horizons and included the addition of rock fragments, minerals, or organic materials such as chaff. During the initial phases of the settlement (horizons 5 and 4, *c.* 5648–5054 cal. BC), three distinct paste recipes were used, all based on the same clay source but with either mineral tempering, organic tempering, or no temper. Organic tempering is associated with a specific pottery-making recipe, with vessels characterised by barbotine decoration, fired in oxidising conditions, and possibly with lower firing temperatures, all reflecting an Early Neolithic Starčevo material cultural tradition. This tradition is present only in the earliest horizon at Belovode, most likely coexisting and overlapping with other traditions marked by either mineral tempering or no tempering, both being more typical of Vinča pottery. From horizon 3 onwards (*c.* 5036 cal. BC), mineral tempering continued but was used only sporadically.

For Pločnik, the bimodal grain size distribution noted in some coarse clay samples assigned to fabric PL-A from horizons 5 and 4 (*c.* 5389–4976 cal. BC) may indicate the intentional addition of aplastic material. Coarse samples assigned to fabric PL-B, containing mica-schist, could also have been tempered. However, unlike at Belovode, no strong tradition of tempering was observable at Pločnik. Other Vinča settlements show more consistent use of tempering with various raw materials, including rocks, minerals, river sand, organic materials, and grog (**Amicone *et al.* 2020b**).

The relationship between pottery fabric, shape, and function also varies between the two sites. For Pločnik, coarser fabrics are slightly more common in vessels with thicker walls, such as amphorae and pithoi, but there is no strict correlation between fabric and vessel type. Interestingly, the grain size distribution of inclusions in dark-burnished bowls does not differ significantly from that in other types of pots. Conversely, for Belovode there is evidence of a tendency to select and prepare paste according to the type and surface treatment of vessels. For instance, bowls, which are often burnished or polished, have a fine fabric (fabric BEL-A2), indicating either the use of a finer clay source or the sieving/

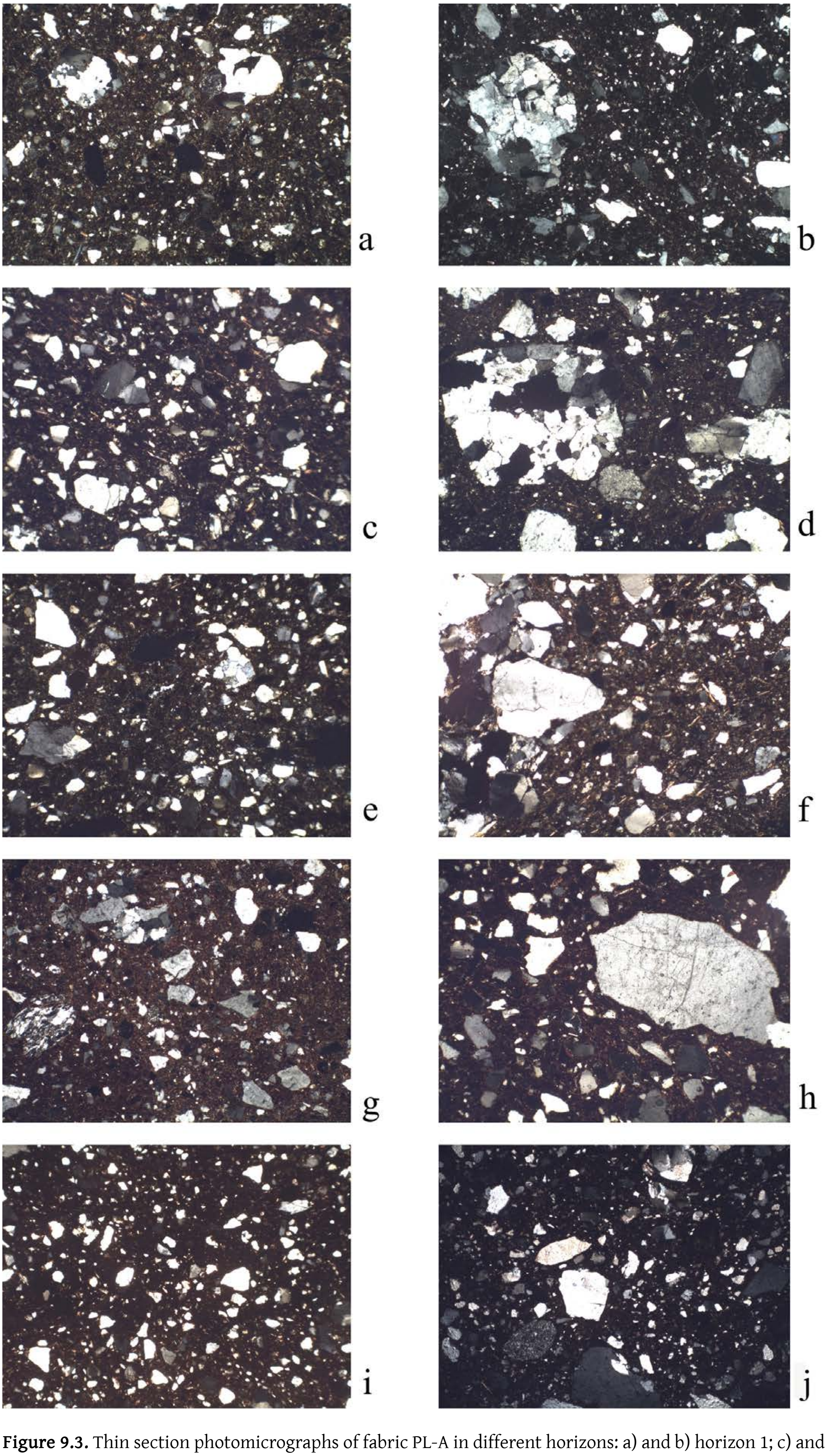


Figure 9.3. Thin section photomicrographs of fabric PL-A in different horizons: a) and b) horizon 1; c) and d) horizon 2; e) and f) horizon 3; g) and h) horizon 4; i) and j) horizon 5 (field of view = 3mm).

levigation of raw material to remove coarser fractions. On the other hand, cooking pots typically have a paste rich in shell fragments, microfossils, and calcite (fabric BEL-B), which is not surprising since the presence of calcite may enhance the vessel's resistance to thermal shock (**Rice 2015**).

Comparisons with other Vinča sites reveal a complex scenario where different technological practices may reflect regional variations in pottery-making traditions. For example, pottery from Opovo, Selevac, and Gomolava shows evidence for the use of various tempers, including grog and rock fragments, with some correlation between pottery fabric, vessel form, and size (**Kaiser 1984, 1990; Tringham *et al.* 1992**). In contrast, pottery from Parța and Miercurea Sibiului Petriş in Romania is mostly untempered, with only a few cases of tempering using rock fragments and minerals, and no clear correlation between fabric and shape (**Spataro 2014**). Northern Serbian sites such as Potporanj and Iđoš display a more systematic correlation between fabric and vessel shapes, with fine fabrics used for bowls and coarser fabrics for storage and cooking vessels (**Amicone *et al.* 2020b**). This suggests that, within Vinča material culture, there were diverse regional patterns in pottery-making practices.

Forming techniques, surface finishing, and decoration

The combination of macro and micro analyses revealed that the coiling technique was widely employed in the manufacturing of vessels at both Belovode and Pločnik. This technique was recognised macroscopically by the presence of vessels with fractures aligned parallel to the rim plane and through the identification of joins between coils visible on the surface of many vessels (**Roux 2019**). This was further confirmed by the distribution of inclusions and voids observed in thin section analyses (**Quinn 2013**). Pinching techniques were used at both sites, but only for making small vessels and sometimes for forming the bases of bowls. There is no evidence of mould usage, although the slab technique seems to have been employed at Pločnik, particularly for producing vessels with squared mouths. Forming techniques appear to be consistent across different horizons for both Belovode and Pločnik.

Various decorative techniques were used at both sites, including barbotine, incisions (often filled with calcite and cinnabar), impressing, channelling, and applied decorations. The development of these decorative techniques follows similar trajectories at all sites, with an increasing presence of channelling during the Gradac phase (*c.* 5000 BC) and a gradual disappearance of barbotine decoration over time. However, Pločnik differs in the presence of graphite-painted pottery in horizons 3 and 2 (*c.* 5036–4621 cal. BC).

Surface finishing and decoration patterns also exhibit similarities between the two sites. Smoothing, burnishing, and polishing of surfaces were common practices at both Belovode and Pločnik, with burnishing and polishing predominantly applied to bowls. These surface treatments became widespread during the Middle and Late Neolithic in southern Europe and in other material cultures such as Danilo, Hvar, Vinča, and Karanovo (**Spataro 2017**). It is noteworthy that horizon 1 at Pločnik (*c.* 4631–4231 cal. BC) shows a significant decline in burnishing, polishing, and decorative techniques.

Pyrotechnology

Reconstructing aspects of pottery pyrotechnology at the studied sites is particularly challenging due to the lack of clear evidence for firing installations, and there is no strong evidence for pottery kilns more generally in Vinča culture settlements. It is therefore likely that pots were fired in pits dug into the ground. As demonstrated by firing experiments in Serbia (**Amicone *et al.* 2021b; Svoboda *et al.* 2004/2005**), it is possible to produce the range of pottery found in Vinča sites without the use of a proper kiln. Clusters of round structures identified during the geophysical survey of Pločnik (see **Rassmann *et al.* 2021b**) may, however, upon future excavation, provide evidence of kilns at this site.

Despite the lack of secure evidence for pottery firing installations in the archaeological record, some conclusions can still be drawn based on the analysis of the ceramic assemblages studied. Both sites exhibit a preference for dark shades, typically associated with burnished or polished surface treatments. The fabric of these vessels is rarely uniformly grey (**Figure 9.4**); instead, it is usually characterised by a reddish core with a darker grey matrix towards the surface. The boundary between the reddish core and the darker outer parts is not sharply defined. Vessels fired in an oxidised atmosphere are also present, with cooking pots at Belovode being a prime example. However, reddish sherds often originate from the interiors of burned features and thus may have turned red during destruction events. Grey-coloured vessels are more common at other Vinča sites, with larger preserved fragments often displaying a range of shades from pale to dark grey (**Chapman 2006; Kaiser 1984**). Bi-coloured pots, such as black-topped vessels, are present in small numbers at both studied sites and are discussed further below in relation to their contribution to the study of pyrotechnology in the Vinča culture.

There are two main techniques for achieving grey or black pot surfaces during firing: iron reduction and carbon black (also known as smoking or smudging). In

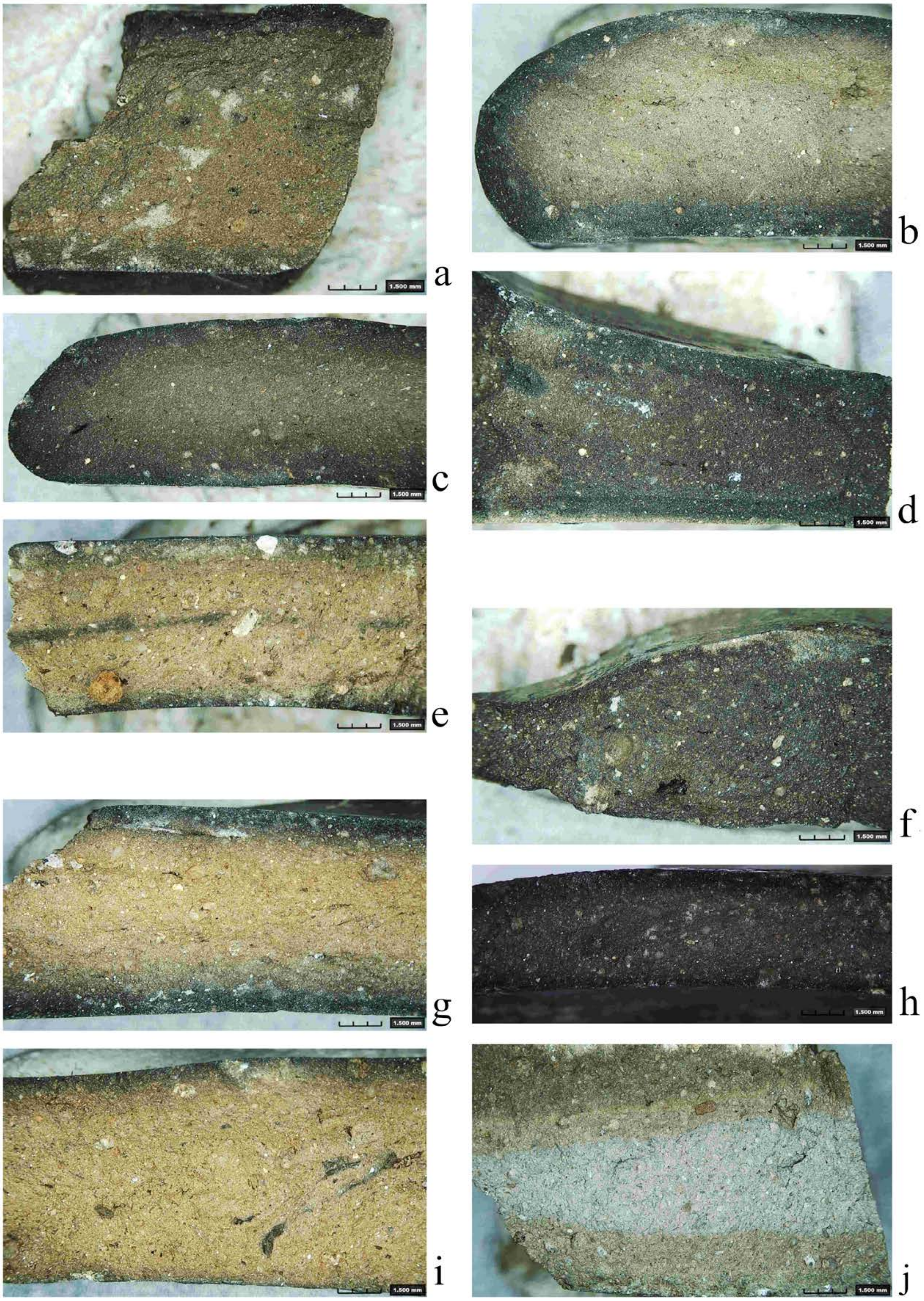


Figure 9.4. Selected dark-burnished and graphite-painted pottery sherds from the Vinča culture sites of Belovode and Pločnik seen in fresh break, revealing the fired colour of their fabric and the presence of firing horizons: a) BEL 18-289; b) BEL 18-94; c) BEL18-162; d) BEL 18-219; e) BEL 18-299; f) PL 24-129 (graphite-painted); g) PL 24-107; h) PL 24-124 (graphite-painted); i) PL 24-288; j) PL 24-145.

the former, the black colour results from the nucleation of dark-coloured iron oxides (e.g. magnetite), while in the latter, the black colour derives from carbon particles that coat the vessel surface and penetrate its pores during firing (**Jones 1986**). XRPD analysis of samples from both sites did not identify magnetite in black-coloured pots. Conversely, Raman analysis (**Amicone *et al.* 2020a**) revealed the presence of carbon on the surface of black vessels, indicating that the black colour was achieved through smudging.

Thin section analyses, XRPD, and SEM of samples from Belovode and Pločnik show that pottery was generally fired at temperatures between 750°C and 900°C, with most samples fired around 750–800°C. Only three possible fragments of 'chimneys' (BEL 18-124, BEL 18-224, and PL 24-23) were exposed to temperatures around or above 1000°C. Another fragment (BEL 18-46) exhibited microstructural and mineralogical characteristics consistent with very high temperatures, though it was retrieved from a destruction layer and may have been refired during that event.

Based on these observations, it is likely that the firing process for dark-burnished ware at Belovode and Pločnik was a two-step procedure. Vessels were initially fired in an oxidising atmosphere, reaching the maximum firing temperature. Then, as the temperature decreased, a reducing phase was achieved by covering the firing installation, possibly adding organic material to increase smoke production. The deep penetration of carbon into the body of dark-burnished vessels, indicated by the fabric's colour and the diffuse boundaries between the core and the sub-surface zone, suggests that the reducing/cooling phase was somewhat extended. Only a few sherds display a uniform black colour, while most show surface colours ranging from light to medium grey or light red. This suggests that, while potters had some awareness and ability to manipulate fire and achieve reducing conditions, their mastery was not absolute, most likely due to the lack of adequate firing installations that could have provided complete control.

Graphite-painted pottery was probably fired similarly, although it was crucial to keep the temperature below 700°C during the oxidising phase to prevent the graphite from burning off. The maximum temperature was most likely reached under reducing conditions, as the estimated firing temperature for the analysed samples was found to be between 750 and 800°C, a range at which graphite decoration would be severely damaged under oxidising conditions. Additionally, the presence of bloating pores in one analysed sample suggests that vitrification occurred under reducing conditions (**Maniatis and Tite 1975**). The fabric colour of graphite-painted sherds is predominantly grey, with only a thin, lighter reddish zone occasionally visible in the core, indicating that the reducing phase was longer than that used for plain, dark-burnished ware.

Black-topped vessels were widely used in the central Balkans between 5200 and 4800 cal. BC. There are two main hypotheses regarding the production of this bichromatic effect. Some researchers (e.g. **Grębska-Kulow 2011**) suggest it was achieved by coating separate parts of the vessels with different pigments that turned red or black during firing, but no evidence of special slip or coating was found on the analysed samples from Pločnik and Belovode. Instead, most scholars (**Kaiser 1990; Kalogirou 1994; Tsirtsoni 2000; Vajsov 2007; Yiouni 1995**) believe that the effect was achieved by controlling the redox conditions during firing without additional pigmentation. If this is correct, vessels were most likely first fired in a reducing atmosphere. Then, during cooling, a selected part was exposed to the air while still hot, causing it to re-oxidise and turn red. This would explain why some black-topped sherds have a black core with only the surfaces showing a reddish hue. An alternative method could involve surrounding a still-hot part of the pot with a smudging agent, such as ash, after the initial oxidising phase.

The evidence suggests that potters had a relatively high level of control over the firing atmosphere, as demonstrated by the intentional production of bi-coloured vessels, dark-burnished ware and, especially, graphite-painted decorations. However, the analyses also indicate that the ability to achieve high temperatures has been over-emphasised in previous studies (e.g. **Kaiser *et al.* 1986**). Too much focus has been placed on firing temperatures as evidence of Vinča potters' mastery of pyrotechnology, rather than on the conditions of the firing atmosphere itself. The issue remains open to discussion, and it is possible that potters from different communities employed varying firing procedures. Nonetheless, it is worth questioning the necessity of firing pottery at temperatures above 800°C when producing functional pottery, since temperatures between 600°C and 700°C are sufficient. The argument that potters aimed to create hard-fired vessels is not compelling, as this could have been achieved with a less sophisticated and more resource-efficient firing process. The question is not, therefore, whether Vinča potters were capable of reaching and controlling temperatures above 1000°C, but rather why they would have chosen to do so. This overestimation of firing temperatures may have been influenced by pre-existing models linking pottery and copper pyrotechnology.

Detailed studies of copper smelting (**Radivojević *et al.* 2010**) indicate that this pyrotechnology differs fundamentally from that used in dark-burnished pottery production, with reversed redox conditions: copper smelting begins with low temperatures and a reducing atmosphere, followed by higher temperatures under less reducing conditions. Even if pottery at Belovode and Pločnik was not fired under the same conditions as those required for copper smelting, the advances in pottery pyrotechnology, such as the ability to manipulate fire conditions, may have laid the groundwork for further technological progress necessary for copper smelting. In the case of graphite-painted pottery, it is possible that a reverse trajectory of technological transmission occurred, or that the development of graphite decoration and copper metallurgy evolved in parallel. It is conceivable that the pyrotechnology of copper smelting could have evolved alongside advanced pottery technology, potentially even triggering the development of graphite decoration techniques (**Amicone *et al.* 2020a**).

Organisation of production

In prehistoric societies, the two most common modes of production are 'domestic' and 'craft specialisation' (**Rice 1981**). Many archaeologists suggest a direct link between craft specialisation and the emergence of social complexity, implying a strong correlation between product specialisation and political administration (**Brumfiel and Earle 1987**). Vinča culture pottery has often been considered the product of specialised labour (see discussion in **Kaiser 1984**). However, it is important to remember that archaeologists and museum curators tend to select only the finest and most aesthetically pleasing vessels for display and publication, which can create a bias in the material record.

Specialisation has been defined in various ways. Kaiser (**1984**) describes it as a division of labour where individuals or groups focus on producing a limited range of goods. Rice (**1991**) defines it as 'the regular and repeated provision of some commodity or service in exchange for some other'. Costin (**1991**) further elaborates that specialisation is a differentiated, regularised, permanent, and possibly institutionalised production system in which producers depend on extra-household exchange relationships for at least part of their livelihood, while consumers rely on them for acquiring goods that they do not produce themselves.

More simply, specialisation can be described as the organisation of production such that the number of people involved in manufacturing a commodity is smaller than the number of consumers. The main characteristics that distinguish non-specialised from specialised production include the amount of time invested in the activity, the proportion of subsistence gained from the occupation, the presence of a recognised name, title, or office defining the person conducting the activity, and the payment in kind or money for the product made by the specialist. Specialisation is not, however, a single organisational state, nor is it a binary condition; rather, it may be present to varying degrees and largely relates to the ratio of producers to consumers (**Costin 1991**).

Archaeologists often use direct evidence such as production loci and debris to identify the context, concentration, scale, and intensity of production (**Costin 1991**), thereby attempting to describe the organisation of production. The current lack of evidence for pottery production installations in Vinča culture settlements makes it challenging to define the level of craft specialisation and organisation for pottery production at these sites. Nonetheless, there is indirect evidence that can provide insights, even without the exact locations of production areas.

A useful indicator to consider is standardisation, defined as 'the relative degree of homogeneity and reduction in variability in the characteristics of the pottery or the processes of achieving such relative homogeneity' (**Rice 1991**). Standardisation is considered positively correlated with specialisation, as it is assumed that production by fewer producers will display less variability. The increase in routine activities associated with specialised production can also result in standardisation (**Costin 1991**). According to Rice (**1981**), non-specialised production should not be standardised, and random variations should be observed in technological and morphological attributes throughout the pottery assemblage. A second parameter is efficiency, as the more efficient a production process, the more specialised it is likely to be (**Costin 1991**). Finally, a third measure is the skill level of the producers, which is, again, positively correlated with the intensity of specialisation (**Costin 1991**). In theory, the characteristics of artefacts could indicate the levels of standardisation, efficiency, and skill involved in production, thus providing insight into the level of specialisation. However, several challenges arise when defining a strategy to assess these parameters.

Standardisation is often measured by examining the metric variability of vessels (e.g. **Roux 2003b**). In a study of Vinča pottery, Vuković attempted this approach by analysing the assemblages from Vinča and Motel Slatina (**Vuković 2011; Vuković and Miloglav 2018**). The statistical analysis of metric parameters from these Late Neolithic sites identified some evidence of standardisation, despite the high fragmentation of the material and the difficulty in distinguishing a significant sample. Vuković's study suggests that Vinča pottery exhibits a relatively high level of standardisation, as reflected in the coefficients of variation for metric parameters. However, Vuković also noted variations in standardisation between different functional classes and within each class (e.g. carinated bowls versus bowls with incurved rims), raising questions that require further comparative investigation across more sites (**Vuković 2011**).

The high fragmentation of the assemblages examined in the present research, combined with the long deposition period and the fact that the sample represents the work of multiple potters, complicates the evaluation of standardisation. Despite these challenges, an attempt was made to explore standardisation through a different approach, focusing on the selection and processing of raw materials at both sites.

At Pločnik, potters consistently used sandy clays characterised by the presence of quartz and various types of sedimentary rocks, accompanied by different mineral suites. Occasionally, inclusions of muscovite, amphibole, and epidote are present. Textural variations were noted in grain size distribution and sorting of inclusions. However, there was a general tendency towards larger inclusions in thick-walled and large vessels and smaller inclusions in thin-walled and small vessels. Coarse fabrics typically show no clear evidence of tempering, suggesting that sandy clays of varying coarseness were employed according to the size and wall thickness of the vessel produced.

At Belovode, two main types of raw material sources were identified: a non-calcareous clay source marked by metasedimentary rocks and a clay source rich in shells and microfossils. A weak association between fabric and shape was observed, with dark-burnished bowls seemingly produced using a clay that may have been well cleaned before use. Conversely, the clay source rich in shells and microfossils is associated mostly with pots likely used in cooking activities.

The narrow variability in paste recipes used in local production is reflected in the low total variance of the chemical dataset, suggesting a degree of standardised behaviour in the selection and processing of raw materials. However, the geological variability of the surrounding area is not high, so it would be unreasonable to expect locally made pots to contain a wide variety of rocks and minerals (**Arnold 2000**). Additionally, technological knowledge tends to be broadly distributed among household producers (**Foster 1965**). When other technological parameters are considered, the forming techniques at both sites appear relatively stable. However, the high fragmentation of the pottery studied limited a detailed reconstruction of the potters' movements during vessel shaping, preventing a thorough evaluation of the standardisation of their motor habits.

In general, this technological overview suggests that, despite the assemblages displaying a relatively high degree of homogeneity, this could result from a widespread and strong technological tradition rooted in the tight learning networks characteristic of this material culture, rather than from specialisation. On the other hand, the technological study carried out by Kaiser (**1984)** on assemblages from Selevac and Opovo shows that while similar notions of appropriate pottery existed and certain aspects of pottery knowledge were shared at these sites, there were differences in the specific procedures followed in various production steps. Thus, it has been suggested that a large number of potters were active at Selevac and Opovo, leading Kaiser to conclude that Vinča ceramics were not made by specialists.

The next consideration is efficiency – a relative measure of the time, energy, and raw materials expended per unit of output. At both Pločnik and Belovode, raw materials used in pottery manufacturing required minimal processing, which could indicate a production process oriented towards cost-efficient behaviour. However, this contrasts with the time and energy invested in other production steps. For example, more than 50% of the pottery from the studied trenches is burnished or polished, surface treatments that offer no direct practical advantage and probably served only to satisfy the aesthetic preferences of the site's inhabitants (**Chapman 2007; Radivojević and Rehren 2016**). Additionally, firing pottery in reducing conditions does not offer practical benefits and may even reduce cost efficiency in terms of fuel resources compared to firing pottery solely in oxidising conditions. There is therefore no clear evidence of particular efficiencies within the pottery production process.

This leads to the final parameter to be considered: skill. Skill refers to the 'proficiency with which activities are executed' (**Bleed 2008**). Skilfully produced objects are expected to be well-made, meaning they are regularly shaped and complex in both form and decoration. Ethnoarchaeological research has explored this topic (e.g. **Roux and Corbetta 1989; Wallaert-Pêtre 2001**), and a few archaeological studies have also examined the production sequence in terms of skill, with interesting results (**Budden 2008; Forte 2019; Michelaki 2008**).

Despite the limitations, some conclusions about 'skill' can be drawn from what we know about the use of pyrotechnics in Vinča culture. The results of this study indicate that potters had some ability to control the variables of atmosphere and temperatures, although variations in the colour of vessel surfaces suggest that they were not always able to control firing conditions completely. While the potters at both sites were aware of how to manipulate fire to produce different colours, this knowledge was not fully mastered. This is most likely due to the lack of proper kiln installations, as conditions in a pit fire can never be entirely controlled, even by a highly skilled artisan.

The presence of graphite-decorated pottery at Pločnik also deserves further consideration. Graphite-painted pottery is often associated with craft specialisation, due to the high degree of control required in firing such decoration (**Evans 1973**). While dark-burnished ware is abundant in all phases at Pločnik, graphite-decorated pottery is rare. Only eleven small sherds of graphite-decorated pots were found, all from building horizons 3 (*c*. 5036–4951 cal. BC) and 2 (*c*. 4927–4621 cal. BC), corresponding to the Gradac phase I of the Vinča culture. These samples come from a single trench and may not fully represent the entire settlement (*c*. 30ha, see **Rassmann *et al.* 2021b**) or the area assumed before erosion by the shifting Toplica River. The fragments belong to vessels that were locally produced, as shown by petrographic and chemical analysis.

Graphite could have been immediately available to the Pločnik communities. In Serbia, graphite deposits are found in locations such as Donja Ljubata, Ibarski Rudnici, Jaram, Pasjača, Ušće, Veta, and Vrška Čuka (Republic of Serbia Ministry of Mining and Energy). Although there is no reference in the literature regarding the exploitation of these deposits during the Neolithic and Chalcolithic, it is likely that some were used. The deposit at Pasjača, about 34km from Pločnik, is easily accessible via the Toplica River valley, and there is no reason to assume that access to this deposit was restricted. Graphite could also have been acquired through specialist trade networks from Bulgaria, in a similar way to the metal obtained from Bulgarian ore deposits for the copper implements found in horizon 1 at Pločnik (**Pernicka *et al.* 1997; Radivojević and Grujić 2018**).

As we have seen, producing graphite-painted decoration required considerable mastery of redox conditions, and this skill may not have been shared by all potters at Pločnik. Perhaps only a few could produce this decoration at any given time, potentially indicating a degree of specialisation, but the current evidence is insufficient to build a solid model. In conclusion, the ceramic record examined here does not reveal clear signs of craft specialisation, as defined above. Given the natural availability of clay sources around Pločnik and Belovode, the ceramic assemblages seem to display relatively high homogeneity in paste recipes and other technological attributes. However, this could result from tight learning networks and strong technological traditions, both of which require further discussion. Additionally, different functional shapes (serving vessels, storage vessels, and cooking pots) show strong technological similarities in raw material selection, procurement, and forming techniques, suggesting an absence of specialist production units making particular pots. Moreover, pottery circulation (discussed below) points to a similar scenario.

On the other hand, no evidence is available regarding the ratio of producers to consumers and it is possible that a small number of potters made a large number of vessels, indicating some degree of specialisation, perhaps at the household level. Graphite-painted vessels could be seen as products of specialised production, as their creation required skills unlikely to have been shared by all potters.

Pottery circulation

Recent analyses of Neolithic pottery in the Southern Balkans and the Aegean challenge traditional views of pottery circulation during this period (e.g. **Gabriele *et al.* 2019; Pentedeka 2011; Quinn *et al.* 2010; Schneider *et al.* 1994; Tomkins and Day 2001**). These studies reveal that pottery circulated in the same way as other commodities, such as obsidian, which was distributed up to 200–300km from its source. This contrasts sharply with the conventional view that ceramics were typically made locally or at least not transported over significant distances (e.g. **Arnold 2000; Vitelli 1993a, 1993b; Wijnen 1994**). These new findings prompt a reconsideration of previous models of craft production and circulation in the Neolithic, which must be incorporated into the present discussion.

The results of the thin section petrography and chemical analyses conducted on samples from Belovode and Pločnik allow for the possible presence of non-local production at these sites; the phenomena of pottery importation and exchange on a regional and interregional scale can be addressed for the first time. However, the low geological variability in the area surrounding Belovode, combined with the stylistic homogeneity characteristic of Vinča material culture, imposes certain limitations on identifying non-local production.

At Pločnik, several samples exhibit petrographic and chemical profiles incompatible with clay sources available in the vicinity of the site or within the 7km threshold suggested by ethnographic studies (**Arnold 1985, 1993, 2000**). In some cases, comparisons between geological maps and collected geological samples indicate possible areas of origin for certain samples.

Preliminary analysis (**Appendix E**) of ceramics from final Neolithic surveys carried out in the region (**Kuzmanović-Cvetković 1998**) indicates some parallels between the possible non-local fabric groups or outliers identified in the ceramics from Pločnik (**Chapter 8**). However, the results also indicate that some of the fabrics identified as ‘local’ at Pločnik exhibit similarities with those found at these other sites (e.g. Merovac), suggesting that either pottery from Pločnik was circulating at these sites or that they were exploiting similar clay sources and employing comparable technological practices. This would, of course, make identification more challenging. In any case, the limited information about the settlement pattern in the area makes it difficult to formulate solid hypotheses regarding the provenance of these samples. Despite this, preliminary results suggest an intriguing network of exchange between Pločnik, surrounding sites, and beyond, which appears to intensify toward horizon 1 (*c.* 4631–4231 cal. BC).

Evidence for non-local production at Belovode is less clear. In **Chapter 6,** we noted that within fabric BEL-A, interpreted as a Belovode production, there is some technological variability in tempering techniques. This variability could be attributed to different tempering traditions, but given the geological homogeneity around Belovode, it is possible that these fabrics originate from nearby sites that exploited similar raw material sources but had different tempering traditions. On the other hand, a few samples show petrographic and chemical profiles that undoubtedly indicate a non-local source, and for some, a presumed area of origin has been proposed.

Kaiser (**1984, 1990**) mentions the possible presence of non-local productions when reporting the results of the petrographic analysis conducted by Robert Mason (Royal Ontario Museum, Toronto) on samples from Selevac and Gomolava. Similarly, thin section analyses of ceramics from Opovo (near Pančevo in the middle Danube Valley) reveal the presence of fabrics containing volcanic rock fragments and agate, materials incompatible with the local area (**Tringham *et al.* 1992**). Kaiser does not, however, speculate on the possible provenance of these non-local materials. Finally, Spataro (**2014**), in her work on Starčevo/Vinča sites at Parța and Miercurea Sibiului Ptriş, does not report any samples that could be considered non-local.

Overall, the current evidence is insufficient to draw a comprehensive picture of pottery circulation within the Vinča culture during the Neolithic and Chalcolithic periods, but recent projects are beginning to suggest a more complex scenario than previously thought, opening up the possibility of long-distance pottery exchanges. One likely scenario is that objects were regularly transported via supra-regional marriages, where women brought vessels and other ceramic items (e.g. loom weights) to their new homes (see discussions on the mobility of women versus more stationary men in prehistoric times by **Bentley *et al.* 2002; Knipper *et al.* 2017; Mittnik *et al.* 2019; Morell-Rovira *et al.* 2024**). It is also possible that certain vessels were exchanged for their contents rather than simply as pots. So far, the (presumably imported) vessel repertoire from Pločnik and Belovode does not clearly support either model and could result from both (or other) scenarios.

Summary

Despite identifiable changes, both Pločnik and Belovode exhibit a general pattern of continuity in their pottery-making recipes over the observed periods. Similar observations were made by Kaiser at Selevac and Opovo (**Kaiser 1984**). Even more intriguingly, no significant technological variation in pottery production is associated with horizon 3, which marks the beginning of the Gradac phase and the advent of metallurgy in Vinča culture at both sites. Certain changes do appear, however, in the very last horizon at Pločnik (*c.* 4631–4231 cal. BC), coinciding with an increased presence of metal artefacts.

In the next chapter, concepts of cultural transmission deriving from both communities of practice and evolutionary theory will be used to explore continuity and change in different elements of pottery-making recipes in order to examine the evolution of pottery production at these sites and in Vinča culture as a whole. Additionally, by examining the trajectories of pottery technology, the nature of the impact of metallurgy on the communities at Belovode and Pločnik will be considered, along with the conventional theory that links pottery and copper metallurgy.

Chapter 10
Conclusions

Cultural Transmission in Vinča material culture

The technological study presented in the previous chapters identified various elements of the pottery-making recipes used at Belovode and Pločnik. These new insights have allowed us to address the evolution of pottery-making practices over almost 1000 years, practices that encompass the formation and fragmentation of this significant material culture phenomenon. In this final chapter, the study's findings will be interpreted through the concept of cultural transmission, tracing the trajectories of technological knowledge transfer both within the studied sites and beyond them. This approach provides a framework within which to explore the mechanisms through which knowledge is disseminated and allows us to address the question of how continuity and change in material culture are generated through the ongoing processes of homogenisation and fragmentation within learning networks. The analysis is primarily contextual, focusing on the two study sites to elucidate the development of pottery technology across the pre-metallurgical and metallurgical phases; the trajectories of technological exchange between pottery and metallurgy are also examined. The scope of the analysis is then broadened to consider the wider networks within the world of Vinča material culture, to address the mechanisms that generate both similarity and diversity across time and space.

Pottery-making recipes: continuity in change

The technological analysis revealed a general continuity in pottery-making recipes throughout all phases at both Belovode and Pločnik. This was particularly evident in the compositional analysis, where the low overall variance in the chemical dataset suggests consistent local production at both sites. Essentially, technological traditions remained stable for about 1000 years, a pattern that also seems to characterise other Vinča sites (**Kaiser 1984**). This indicates strong conservatism within pottery traditions and the existence of highly stable learning networks.

Overall, the evidence could point to the presence of direct and vertical transmission of pottery-making knowledge within Vinča culture. In direct transmission, apprentices learnt through verbal and technical guidance via demonstration (**Roux 2015**), implying interaction between teacher and learner. Ethnographic studies have shown that such technical guidance is typically shared among individuals within the same social communities (**Roux 2015: 6**). Vertical transmission, by contrast, refers to a conservative form of cultural transmission, occurring from one generation to the next, specifically from parent to offspring (**Cavalli-Sforza 2001; Hewlett and Cavalli-Sforza 1986**). This type of transmission is often linked to household production (e.g. **Manem 2012: 141**), where households function as the fundamental social units of production, consumption, and reproduction.

Given the overall continuity observed in the sample, it is plausible to assume that context biases, which inhibit widespread change in pottery-making recipes, were among the mechanisms influencing knowledge transmission at the studied sites. More precisely, it appears that the social learning context within these communities fostered conformist behaviour ('conformist bias') that, ultimately, could have led to the stable reproduction of pottery traditions. Conformist transmission is known to reduce the likelihood of the adoption of practices from other social groups (**Eerkens and Lipo 2005**), as individuals tend to imitate behaviours prevalent amongst the majority rather than traits expressed by a minority (**Boyd and Richerson 1985; Henrich 2001: 997; Henrich and Boyd 1998; Shennan 2008**). This suggests that some technological traits at Belovode and Pločnik may initially have been selected because they were perceived as superior to others. Over time, however, the potential adoption of different traits could have been influenced (or inhibited) by their social context or prevalence.

While a general persistence in technological traditions was observed at both Belovode and Pločnik, variations were also noted within this broader pattern of technological continuity. For Belovode, the most notable phenomenon is the disappearance of a pottery-making recipe characterised by abundant chaff tempering and firing in an oxidising atmosphere, traditionally associated with Starčevo material culture. Generally, the practice of adding chaff to the paste was widespread in the Carpathian Basin and the Balkans during the Early and Middle Neolithic, as seen in material cultures such as Körös, Criş, and Starčevo (**Manson 1995; Spataro 2014; Szakmány *et al.* 2006**). This phenomenon resulted from the uninterrupted transmission of this technical trait for most of the 6th millennium, facilitated by channels of interaction that extended beyond local communities and resonated on a broader temporal and geographical scale.

The near-complete disappearance of the practice of adding chaff to pottery pastes during the Late Neolithic has traditionally been viewed as part of a broader phenomenon linked to the transition from the Early/Middle Neolithic to the Late Neolithic in southeastern Europe.

For the central Balkans, the traditional assumption of a violent encounter between newcomers characterised by 'Vinča material culture' and groups marked by 'Starčevo material culture' (**Dimitrijević 1974: 91**) has been challenged by a theory focusing on the possibility of internal development (e.g. **Chapman 1981**). This alternative hypothesis relies heavily on the fact that many elements marking Starčevo ceramic vessels, such as biconical shapes, pedestalled bowls, and barbotine decoration, are also found in Vinča pottery. However, technological studies of pottery addressing the specific problem of the Vinča/Starčevo transition remain limited (**Spataro 2014; Vuković 2015**). Despite this, the few available studies address one of the key points in understanding the nature of this significant material culture change, which is also associated with a reconfiguration of technological learning networks. Given the complexity of the evolutionary trajectories shaping such a wide-scale phenomenon, the limited evidence analysed here permits only preliminary considerations.

One possible hypothesis is that the widespread use of a chaff-tempered pottery recipe across the Körös, Criş, and Starčevo phenomenon may be linked to mobile social groups, particularly in the context of migration-driven mobility. Mobility facilitates the transmission of technological traditions, as suggested by **Doumani Dupuy *et al.*** (2025). On the other hand, the selection of a temper material that is readily available across different regions may simply reflect a practical adaptation, enabling potters to develop a versatile recipe that could be easily replicated in diverse environmental settings. This would suggest that, as societies gradually transitioned towards more sedentary ways of life, ceramic traditions became increasingly diverse. Communities of practice very likely began to adapt pottery production to their specific environmental and cultural contexts, leading to greater regional variation in technological traditions.

If we consider the evidence provided by Belovode and Pločnik, it is notable that at both sites, pottery characterised by the 'Starčevo' recipe appears in the same horizons as pottery typical of Vinča material culture. This phenomenon is also recorded at other sites, such as Pavlovac in South Serbia (e.g. **Vuković 2015: 659**). Further, the present analysis revealed that some technological traits are shared by both Starčevo and Vinča traditions, including the use of barbotine decoration and similar clay sources. While limited, this evidence points to an intriguing scenario of both continuity and change during the Starčevo/Vinča transition. The implications of such a mixed scenario warrant further investigation of a wider array of samples. In the absence of broader evidence, it is impossible to provide a definitive explanation of the mechanisms that led to, or at least contributed to, the evolution of Vinča material culture during this transitional phase.

While the technological discontinuities at Belovode offer some insight into the Starčevo/Vinča transition and thus the earliest phase of Vinča material culture, Pločnik provides interesting evidence regarding its final developments. For Pločnik, significant technological discontinuity in pottery-making techniques can be traced only within horizon 1 (*c.* 4446–4231 cal BC Gradac III phase). Nevertheless, this could be considered a continuous development, as there is no complete cessation of cultural transmission even within horizon 1 (**Roux and Country 2013: 189**). Technological change can be traced in relation to three main features of the pottery recipes: (a) the use of burnishing and polishing decreases significantly; (b) the employment of decorative techniques declines substantially; and (c) a paste technique characterised by mica-schist becomes increasingly common. Cultural transmission did not, however, cease completely, and significant continuities can be seen, for example, in the use of the traditional paste technique with sedimentary rock fragments, here defined as fabric PL-A.

The decline in the use of time-consuming surface finishing and decoration at Pločnik is paralleled by a simplification in the repertoire of pottery shapes, with horizon 1 becoming dominated by turned-in bowls (type 117, representing 68% of the vessels in the whole horizon), which are easier and faster to manufacture than other vessel shapes, such as biconical bowls with carinations and necks. It seems that certain technological traits started to be favoured during this period, possibly due to their advantages in the overall social context of production and use; in this specific case, a reduction in the labour investment required.

The increasing use of a clay source rich in mica-schist or tempered with this type of rock (fabric PL-B) is also difficult to account for, but clues may be found by considering the material culture of the time. The abundant muscovite inclusions in fabric PL-B create a dramatic, glittering effect on the surface of vessels made from this type of clay. As already noted, a preference for striking colours and brilliance characterises the material culture of the Late Neolithic/Chalcolithic in the Balkans (**Chapman 2007; Radivojević and Rehren 2016: 203**), so the increased use of clay that produced glittering vessels could be coupled to the decrease in time-consuming surface treatments that enhanced the reflective appearance of surfaces. As noted in **Chapter 7**, mica-schist formations and clay sources rich in muscovite are located close to Pločnik (6–7km), so this clay source could easily have been collected alongside raw materials for the ground stone industry, minimising labour, evidently a concern during this period. Ultimately, conformist bias may again have played an important role in determining the growing selection of this clay source as potters aimed to produce shiny vessels to satisfy the community's aesthetic preferences.

On a broader level, other changes are evident in Pločnik's horizon 1 that perhaps reflect a reconfiguration of social structures at the site that, in turn, affected the transmission of technical behaviours and caused the discontinuities observed in pottery-making recipes. For instance, this period saw developments in the lithic industry, with the use of a greater variety of flint and non-flint raw materials from secondary sources (**Ibragimova 2021**), a trend towards increased cattle consumption (**Orton *et al.* 2021**), and a growing presence of non-local pottery productions and metal artefacts. It is important to note that horizon 1 (*c.* 4446–4231 cal. BC) corresponds to Gradac phase III, also known as the final development of Vinča material culture in the South Morava Valley (see **Chapter 3**). Settlements in this area seem to have survived after the 46th century cal. BC, when most late Vinča settlements (including the eponymous site at Belo Brdo) in the Danube and Vojvodina region ceased to exist (**Tasić *et al.* 2015**).

Typological studies of pottery (**Mirković-Marić *et al.* 2021b**) have also revealed interesting developments, such as the increased presence of beakers with two handles and bowls with turned-in rims, which suggest affinities with the Bubanj-Hum material culture that appears to have originated in the east, in Bulgaria. This is strongly paralleled by the reconfiguration of the metal supply network, which also seems to have changed during this period. Before horizon 1, artefacts in Pločnik were mostly made of copper from deposits in eastern Serbia. In horizon 1, however, metal appears to have been sourced from Bulgarian deposits (**Radivojević 2012**), pointing to a significant reconfiguration of networks during this period. In this sense, Gradac phase III could be considered the true expression of the Chalcolithic character of Vinča culture (**Jovanović 1994: 11**), as it is denoted not only by an increased presence of metal artefacts but also by elements that blend into the subsequent Chalcolithic Bubanj-Hum phenomenon. This prompts a reconsideration of the traditional theory of a 'catastrophic' end to Vinča material culture under the pressure of incoming populations (e.g. **Garašanin 1973**). While this discussion falls outside the scope of the research presented here, it is worth noting that several Bubanj-Hum sites, such as Bodnjik near Koceljeva (**Palavestra *et al.* 1993, 1996**), have yielded pottery showing strong similarities with typical Vinča vessels, such as those found at Pločnik in the Gradac III phase. Radiocarbon dating indicates that Bodnjik dates to the mid-45th century cal. BC, making it broadly contemporaneous with Pločnik's final horizon. This suggests that learning networks for pottery-making did not completely disappear during or after what is commonly referred to as the final phase of Vinča material culture. It is likely that this period saw only a reconfiguration of these networks under new social and cultural patterns, suggesting a degree of continuity. Further research, including an extensive radiocarbon dating programme, is needed to investigate this intriguing phenomenon.

Another point worth considering is the impact of the advent of metallurgy on the communities of Pločnik and Belovode. It is widely accepted that the introduction of metallurgy would have had a significant impact on society, argued to imply an increase in social complexity, including the emergence of a more hierarchical organisation and the rise of elites controlling the production and distribution of metal objects (**Porić 2012: 177**). This hypothesis has been challenged (**Bartelheim 2009; Kienlin and Stöllner 2009**). Kienlin (**2010, 2012: 21**) in particular has suggested that it is unnecessary to associate the rise of metallurgy with the existence of elites and that the spread of Eneolithic/Copper Age metallurgy could have occurred along kinship lines alone.

The Gradac phase (*c.* 5000 BC) is commonly associated with the emergence of metallurgy in Vinča communities. According to Jovanović (**1994**), the developments during this phase indicate significant social changes. The period is also distinguished by typological developments in pottery production, with the introduction of new vessel shapes and increasing use of channelled decorations. Indeed, it is due to these typological and stylistic innovations that the Gradac phase is recognisable as such in Vinča culture sites. We have now seen, however, that for Belovode and Pločnik, no dramatic changes in pottery technology are observable with the onset of the Gradac phase. It seems unlikely that such an important social reconfiguration would not have affected the learning networks responsible for the reproduction of pottery traditions and, consequently, pottery-making techniques. Moreover, when the wider archaeological record is considered (**Radivojević *et al.* 2021a**), all evidence indicates that there was no significant change in the lifestyle of the people at either Belovode or Pločnik at the beginning of the Gradac phase, i.e., with the advent of metallurgy. The continuity of pottery-making traditions at these sites does not support the conventional hypothesis of a significant and immediate impact of metallurgy on the life of Vinča culture communities.

On the other hand, as noted earlier, the developments corresponding to horizon 1 at Pločnik (4446–4231 cal. BC Gradac III phase) suggest the occurrence of some form of social change, reflected in various aspects of the archaeological record. This scenario implies that, although the introduction of metallurgy did not have an immediate effect on Vinča communities, the full adoption of this innovation may potentially have driven a reconfiguration within the social structures of this society. However, despite the notable abundance of metal objects during this phase at Pločnik, metallurgy cannot be considered the sole factor contributing to this social change. Unfortunately, the final development of Vinča material culture has not yet been the subject of systematic study, primarily due to the lack of large-scale excavations. Consequently, in the absence of more extensive evidence, these considerations remain speculative.

Connecting pyrotechnologies: new perspectives

The question of the impact of metallurgy on Vinča communities naturally leads to a consideration regarding the invention of metallurgy and the conventional theory that proposes a link between pottery and copper pyrotechnology. As discussed in **Chapter 1**, recent work by Radivojević (**2012, 2015; Radivojević and Rehren 2016; Radivojević *et al.* 2010**) supports the notion of an independent invention of metallurgy in the Balkans. Furthermore, Radivojević hypothesises that the knowledge of metal extraction in this area is closely connected to an awareness of the material properties of green and black minerals, with a history of selection dating back to the late 7th/early 6th millennium BC (**Radivojević 2015: 335**). However, dark-burnished ware and graphite-painted decoration have also often been considered prerequisites for the development of copper smelting pyrotechnology in the Balkans (e.g. **Amicone *et al.* 2020a** and literature therein).

Invention is often defined as the discovery of a new idea, a new material, or a new process (e.g. **Radivojević 2015; Roberts and Radivojević 2015; Renfrew 1978**). The invention could be a completely new product (**Weber *et al.* 1993**), or it could involve the recombination of pre-existing technological components for a new purpose (**Fleming and Sorenson 2004; Henrich 2001**). Therefore, although knowledge of ore properties may have played a major role in the development of metallurgy in the Balkans, other factors could also have contributed significantly to this process.

As discussed in **Chapter 4**, every artefact can be viewed as the outcome of a recipe that can be described and studied on different scales and ordered into subroutines. In pottery-making, firing is one such subroutine and can be further subdivided into other necessary components. Specifically, knowledge about firing would involve, for example, know-how concerning the selection of fuel, the preparation of firing installations, and the management of fuel (e.g. how much to add and how often) to achieve and maintain the intended firing temperatures and atmospheres. All these different elements impact the firing procedure and collectively form a recipe, i.e. behavioural information transmitted from teacher to learner in the pottery apprenticeship process. Crucially, however, elements of this recipe may also be transferred to another technological domain.

Regarding pottery pyrotechnology, it has already been noted (**Chapter 9**) that Vinča potters must have acquired a degree of knowledge regarding the manipulation of fire to produce different colours. The ability to exert at least partial control of fire may have been transferred from pottery to metallurgy, allowing metalworkers to achieve the different firing atmospheres necessary for smelting copper. Moreover, if pottery-making was a household activity, or involved little or no specialisation, as the evidence presented here suggests, it is possible that technological knowledge was not confined to and transmitted solely within specific craft groups, as, in this context, such groups are unlikely to have existed. Instead, a more fluid scenario of knowledge transmission based on kinship rather than craft affiliation is proposed. Certain technological traits could easily have been transferred from pottery-making to other knowledge domains such as copper smelting, thereby contributing to the development of metallurgy. Conversely, it is also possible that the trajectory of transmission was reversed in the case of graphite-painted decoration. While it is well-known that dark-burnished ware developed towards the end of the 6th millennium, the appearance of graphite decoration could have occurred in parallel with the emergence of metallurgy (**Bailey 2000**). It is conceivable that pyrotechnological advances acquired through copper smelting may have led to a heightened awareness of thermal properties, which in turn enabled the development of this decorative technique.

Another aspect of pottery firing that may have played a role in the development of metallurgy is the discovery that charcoal could be used as a reducing agent, a critical factor (considered a technological invention) introduced with the development of metal extraction (**Ottaway 2001**). Unfortunately, there is no evidence regarding the fuel used in Vinča culture communities or how it was acquired and managed. Even more significantly, it remains unclear whether Vinča potters and metalworkers competed or collaborated in the procurement and management of the fuel essential for both activities (see also **Shimada *et al.* 2007**). Indeed, it is uncertain whether these were even separate groups within Vinča communities.

Natural layers of coal occur in the vicinity of Belovode (see **Appendix D.1.1**), but the geological prospection conducted for this research (**Chapters 7 and 8**) detected no visible coal outcrops. It is impossible to determine whether outcrops were once exploited by people from the settlement. It is plausible, however, that the fuel necessary for smelting activities at Belovode was produced through the combustion of woody plant material (**Radivojević *et al.* 2010**). It is also tempting to suggest that charcoal produced during the manufacture of dark-burnished ware could have been recycled for smelting activities. Ceramic experiments by Shimada *et al.* (**2007**) showed that firing a few dozen relatively small vessels in a single kiln under reducing conditions (in the final phase of the firing) produced approximately 15l of charcoal in just one firing process. The possibility that residual charcoal from within pottery firing pits or kilns was removed after firing and used for copper smelting is not unrealistic. Various lines of evidence suggest this scenario at the Sican culture site of Huaca Sialupe in Peru (**Shimada *et al.* 2007**). In this way, ceramic production could have complemented metalworking by providing charcoal. However, in the absence of related archaeological evidence in this specific context, this suggestion remains strictly hypothetical, and it is impossible to establish how closely these crafts interacted in the negotiation of fuel usage.

It is also unclear whether ceramic production in Vinča communities complemented metalworking with the provision of technical ceramics for use in the production process. At Belovode, the recovery of four pottery sherds with metallurgical slag spilled over them could suggest that these fragments were used to line a hole in the ground to insulate a smelting pit (**Radivojević and Rehren 2016: 213**). These sherds were not, however, specifically produced for this purpose but were merely fragments of domestic pottery. Furthermore, the evidence that the so-called 'chimneys' were used in smelting is not unequivocal. These have traditionally been linked to smelting activities (**Šljivar 2006**), and the present analysis shows that they are the only ceramic sherds not recovered in destruction layers that appear to have been exposed to temperatures exceeding 1000°C. On the other hand, no adhering slag or copper contamination has so far been found on them (**Radivojević *et al.* 2010: 2779**).

Similarities and diversity within Vinča material culture

Before concluding, it is worth considering the contribution that this research makes to understanding the processes that generate similarities and diversity in material culture within the area covered by the Vinča phenomenon and beyond. Alongside the evidence provided by other studies focusing on Vinča culture pottery technology through archaeometric analyses (e.g. **Kaiser 1984, 1989, 1990; Kreiter *et al.* 2011; Spataro 2014, 2017, 2018; Tringham *et al.* 1992**), the results from Belovode and Pločnik show that, although several recipe traits are shared by different Vinča communities (e.g. the widespread use of coiling as the primary forming technique, similar finishing and decoration techniques), significant differences do exist, particularly regarding raw material processing and the relationship between fabric and shape (**Amicone *et al.* 2020b**). These differences are also highlighted by studies of pottery typology. Indeed, it is based on typological diversity that several regional variants of the 'Vinča culture' were previously recognised by Garašanin (**1979**). It is therefore highly likely that several communities of practice with varying regional pottery traditions and trajectories of cultural transmission coexisted under the label of 'Vinča culture'. This would also explain the different developments of this material culture phenomenon in different geographical areas.

Livingstone Smith's (**2015**) work on clay processing for pottery in northern Cameroon observed that patterns of technical variation seem to correspond to certain geographically definable areas (e.g. 'people of the west bank of the Faro' or 'people around Poli'). Thus, the level of social interaction and the transmission of technological information appear to be correlated with settlement patterns and population density. It is possible that similar mechanisms based on interactions influenced by spatial proximity, operated within Vinča communities, generating the pattern of regional variability observed in the archaeological record, a process that closely aligns with models of isolation-by-distance and homophily in cultural transmission, as discussed by Shennan *et al.* (**2015**). However, the Vinča knowledge networks may also reflect kinship webs (**Kienlin 2010; Radivojević and Rehren 2016: 233**). On the one hand, relatively large-scale and loose networks would be responsible for the general similarities seen in the pottery-making traditions and, more broadly, in the material cultures of the central Balkans. On the other hand, regional variants could result from smaller, somewhat tighter learning networks that reflect interactions favoured by both spatial proximity and kinship webs.

It has been suggested above that the strong continuity in pottery-making at Belovode and Pločnik could be the result of vertical and direct transmission from parents to offspring. Although comparable studies of nearby sites could be carried out only on a very limited scale, the preliminary petrographic analysis of the pottery collected from sites around Pločnik (**Appendix E**) revealed strong similarities with the technological traits of the recipes characterising pottery from the site itself. Regional learning networks, based on close kinship ties, could explain these shared characteristics.

Overall, aspects of material culture and technical knowledge that do not require direct learning could have spread easily through the movement of individuals, objects, or ideas along various channels of interaction beyond the regional and local level. Other aspects, however, might have required technical guidance, implying interaction between a teacher and learner through direct imitation, verbal instruction, or hands-on demonstration. This form of transmission would be restricted to kinship-related communities of practice, thereby creating corresponding patterns of similarities and differences.

Final remarks

The sites of Belovode and Pločnik have yielded hundreds of thousands of pottery sherds, alongside some of the earliest known evidence of copper metallurgy. The rich material culture at these sites offers significant potential for studying Vinča pottery craft technology during the transition into the Metal Age. The detailed technological study of pottery assemblages from these two sites has enabled the identification of various traits within the pottery-making recipes and the possible ways in which these elements were combined. This revealed strategies for the selection and processing of raw materials, alongside insights into practices of forming and decoration. Additionally, it has been possible to formulate hypotheses regarding the firing procedures employed, enhancing understanding of pottery manufacturing technology at Belovode and Pločnik. By comparing this evidence with that provided by earlier studies (e.g. **Kaiser 1984**), deductions were also possible regarding the organisation of production within Vinča culture.

These results challenge the traditional view of specialisation in pottery manufacturing in this period (**Chapman 1981**). Indeed, this study shows that, while not excluding the possibility that this was present to some degree (e.g. specialised household production), there is no clear evidence for the existence of a group of people solely focused on pottery production and subsisting on this activity alone. The only exception to this general pattern might be the existence of pottery decorated with graphite at Pločnik, which required considerable pyrotechnological skills and the procurement of materials not available in the immediate vicinity, but further evidence is needed to formulate solid hypotheses regarding this phenomenon. The results also suggest possibilities for pottery circulation and exchange on a regional and interregional scale, reshaping the traditional view of such processes in the central Balkans during the Neolithic period. The research demonstrates that pottery did indeed circulate to a certain degree, but the small number of studies undertaken to date on this issue (e.g. **Kaiser 1984; Spataro 2014**) must be supplemented by further analyses if we are to fully understand the scale of the phenomenon.

The study of the trajectories of transmission of pottery-making recipes has contributed to the development of an understanding of the evolution of pottery traditions within these two important communities, across the pre-metallurgical and metallurgical phases. The analysis has provided insights into the mechanisms of cultural transmission that shaped the spread of technological knowledge at Belovode and Pločnik. A general pattern of continuity in the transmission of pottery-making recipes appears to characterise both sites. Even when discontinuities were recorded, there was no complete break in the transmission of technological traits. For Belovode, the most significant technological discontinuity corresponds with the disappearance of pottery-making recipe linked to the Starčevo period, as recorded in horizon 5 (*c.* 5648–5338 cal BC). For Pločnik, however, several significant technological changes mark horizon 1 (*c.* 4446–4231 cal. BC, Gradac III). These include a decrease in the use of surface finishing and decoration, a simplification of the pottery shape repertoire, and an increased use of a clay source rich in mica-schist (fabric PL-B). Nevertheless, several elements of the established pottery tradition continued into horizon 1.

This pattern of continuity amidst change, observed at both sites, suggests the existence of very stable learning networks, most likely operating through direct and vertical transmission of pottery-making knowledge from parents to offspring. The low level of variability observed also suggests that a conformist bias was influencing the transmission of technological knowledge. Studies on cultural transmission (**Eerkens and Lipo 2005; 2008**) demonstrate that variation modelled under unbiased conditions tends to increase over time, whereas under conformist bias, variability is clearly suppressed. The continuity observed in the technological tradition indicates that no significant change in the transmission of pottery-making recipes coincided with the beginning of the Gradac phase (*c.* 5000 BC), which marks the advent of metallurgy in Vinča culture. This evidence of continuity challenges the traditional view of a profound change driven by the introduction of new technology during the Gradac phase (**Jovanović 1994**). Alongside this, it was expected that any significant social reconfiguration would also impact the learning networks responsible for reproducing technological traditions. However, the discontinuities noted in horizon 1 at Pločnik may indeed reflect some dynamics of social change. This horizon appears to correspond to the Gradac III phase, which, according to Jovanović (**1994**), represents the final phase of Vinča culture development in the South Morava Valley. As noted, this period is marked by the increasing presence of a paste recipe characterised by mica-schist, which creates a striking glittering effect on the surface of vessels that seems to counteract the sharp decline in burnished and polished finishes. In this sense, this element perfectly exemplifies the concept of continuity within change. On the one hand, an alternative paste recipe was employed, yet the traditional aesthetic requirement for brilliance, typical of Vinča culture, was retained (**Chapman 2007; Radivojević and Rehren 2016**). This phase is also characterised by an increased presence of metallurgy at the site and a reconfiguration of metal supply networks, accompanied by pottery developments that blend the final stages of Vinča material culture with the Chalcolithic Bubanj-Hum phenomenon. As such, the results challenge the traditional view of a violent end to Vinča material culture through the arrival of newcomers, which might have caused the associated learning networks to cease (**Garašanin 1973**). This intriguing problem requires further study through large-scale excavations, systematic radiocarbon dating programmes, and broader technological studies of the accompanying pottery, to gain a clearer picture of the continuities and discontinuities between Vinča and Bubanj-Hum technological traditions.

This research also contributes significantly to the long-standing theory suggesting a link between pottery and metallurgy pyrotechnology (e.g. **Renfrew 1969**). Here, it has been clearly demonstrated that dark-burnished ware and graphite-decorated pottery were not fired at the same temperatures used in copper smelting (1083°C). These findings align with a series of analyses already conducted on other assemblages that include dark-burnished ware and graphite-decorated pottery from the Neolithic and Chalcolithic periods in the Balkans (e.g. **Gardner 2003; Goleanu *et al.* 2005; Maniatis and Tite 1981; Yiouni 2000**), but they challenge the extensive analysis carried out by Kaiser, which suggested that pottery from Selevac and Gomolava was routinely fired at temperatures around 1000°C and above. Without denying the possibility that different firing routines were employed in other Vinča culture communities, it has been suggested here that previous studies have overemphasised firing temperatures to establish a connection between pottery and copper metallurgy.

By integrating macro observations with thin-section petrography, XRPD, and SEM analyses, this study allowed the formulation of a hypothesis regarding the firing routines employed in producing dark-burnished ware and graphite-decorated pottery (**Chapter 9**). This confirmed that the pyrotechnology used to produce these types of pottery was significantly different from that used to smelt copper. Both required a two-step process, but the redox conditions appear to have been reversed. The study of pottery pyrotechnology has, however, clearly highlighted an awareness of fire manipulation to achieve different surface colours. This general knowledge could easily have been transferred from pottery to other knowledge domains, thus contributing to the development of an independent metallurgy in the Balkans. Conversely, graphite-painted decoration may have followed a reversed transmission trajectory. Advances in pyrotechnology from copper smelting likely enhanced thermal awareness, enabling this pottery decorative technique

Finally, when considered alongside evidence from other research on Vinča pottery technology, the study has provided evidence for regional or local variability in technological traditions. This phenomenon is well supported by typological studies on Vinča pottery and reflects the presence of different levels of networks that shaped interactions within and among Vinča culture communities and beyond. Within this broader context, stronger ties most likely connected communities in the same geographical area, as they shared similar environmental conditions and resources. These spatial ties could, however, have been reinforced by kinship networks, within which craft knowledge would have easily circulated through different forms of direct transmission, including both verbal and technical guidance. Thus, at a broader level, similarities in Vinča material culture could have been shaped by the circulation of ideas, objects, and people. At local and regional levels, however, tighter networks of practice were responsible for creating regional variability, which could also explain the different developments of Vinča material culture. In this context, it is possible to argue that the longer survival of the southern variant may have been due to the specific structure of networks developed within these communities during the Gradac phase. These networks appear to have been oriented towards increasing connections with communities in what is now Bulgaria. This is well illustrated by the presence of graphite decoration, a technique that seems to have developed in the Struma Valley (**Chapter 2**), alongside a shift in metal supply towards sources located in Bulgaria (**Radivojević 2012**). Ultimately, the development of material culture, with a gradual penetration of Chalcolithic Bubanj-Hum elements, reinforces the hypothesis of a strengthening of connections with the east. Further research is necessary to explore the nature and development of these connections. A key area of focus in this regard should be the phenomenon of graphite decoration. Although several studies have been undertaken (**Chapter 2**), the topic has never been systematically approached, and the networks through which this material circulated, along with the channels through which knowledge of the technology spread, remain largely unknown. The GRAPHTEC project (University of Tübingen), financed by the The Ministry of Science, Research and the Arts of Baden-Württemberg, and led by the present author, will focus specifically on addressing these gaps.

To conclude, this study has provided evidence that challenges conventional views on the emergence and fragmentation of the Vinča culture phenomenon, highlighting the need for more nuanced approaches to transitional periods, which cannot be explained solely by focusing on population migration. The results also prompt a re-examination of the traditional narrative regarding pyrotechnological connections, offering new trajectories of interpretation based on a greater understanding of pottery and metal firing routines and a more sophisticated approach to the mechanisms of technological knowledge transmission.

Links to Online Appendices

A1.1. Belovode Catalogue:
https://doi.org/10.32028/9781803278896-A1-1

A1.2. Appendix Belovode sample list:
https://doi.org/10.32028/9781803278896-A1-2

A2.1. Pločnik Catalogue:
https://doi.org/10.32028/9781803278896-A2-1

A2.2. Appendix Pločnik sample list: T20:
https://doi.org/10.32028/9781803278896-A2.2

A2.3. Appendix Pločnik sample list: T24:
https://doi.org/10.32028/9781803278896-A2-3

A3. Table Samples according to features, horizons and chronology:
https://doi.org/10.32028/9781803278896-A3

B1. Appendix Belovode petrography texture:
https://doi.org/10.32028/9781803278896-B1

B2. Appendix Pločnik petrography texture: T20-T21:
https://doi.org/10.32028/9781803278896-B2

B3. Appendix Pločnik petrography texture: T24:
https://doi.org/10.32028/9781803278896-B3

B4. Appendix Petrography description main groups:
https://doi.org/10.32028/9781803278896-B4

C1.1. WD-XRF Belovode:
https://doi.org/10.32028/9781803278896-C1-1

C1.2. Variation Matrix Belovode:
https://doi.org/10.32028/9781803278896-C1-2

C2.1. WD-XRF Pločnik:
https://doi.org/10.32028/9781803278896-C2-1

C2.2. Variation Matrix Pločnik:
https://doi.org/10.32028/9781803278896-C2-2

C3. Appendix Accuracy:
https://doi.org/10.32028/9781803278896-C3

D1.1. Geomap Belovode:
https://doi.org/10.32028/9781803278896-D1-1

D1.2. Geomap Pločnik:
https://doi.org/10.32028/9781803278896-D1-2

D3. Appendix geological sample list:
https://doi.org/10.32028/9781803278896-D3

E. Sites around Plocnick – petrography:
https://doi.org/10.32028/9781803278896-E

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This book investigates the reconstruction and transmission of pottery-making recipes at the Neolithic/Chalcolithic sites of Belovode and Pločnik (*c.* 5350/5300–4500), two key settlements of the Vinča culture located in northeast and south Serbia, respectively. Both sites have recently yielded some of the earliest known copper artefacts in Eurasia, making them exceptional case studies for exploring the evolution of ceramic technology during the transition to the Metal Age. An interdisciplinary methodology—combining macroscopic observations with a suite of analytical techniques including thin section petrography, XRF, XRPD, and SEM—was applied to a wide selection of ceramic samples. These samples span the full typological and technological spectrum of pottery from both sites, enabling the reconstruction and comparison of production recipes across different occupational phases. The study's primary aim was to trace the transmission of technological knowledge in pottery production and to investigate potential pyrotechnological links with the emergence of early metallurgy. The results demonstrate the value of integrating materials science with archaeological inquiry. They reveal distinct technological choices and refined craftsmanship, offering fresh insights into the interplay between ceramic production and metallurgical innovation at the dawn of the Metal Age.

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