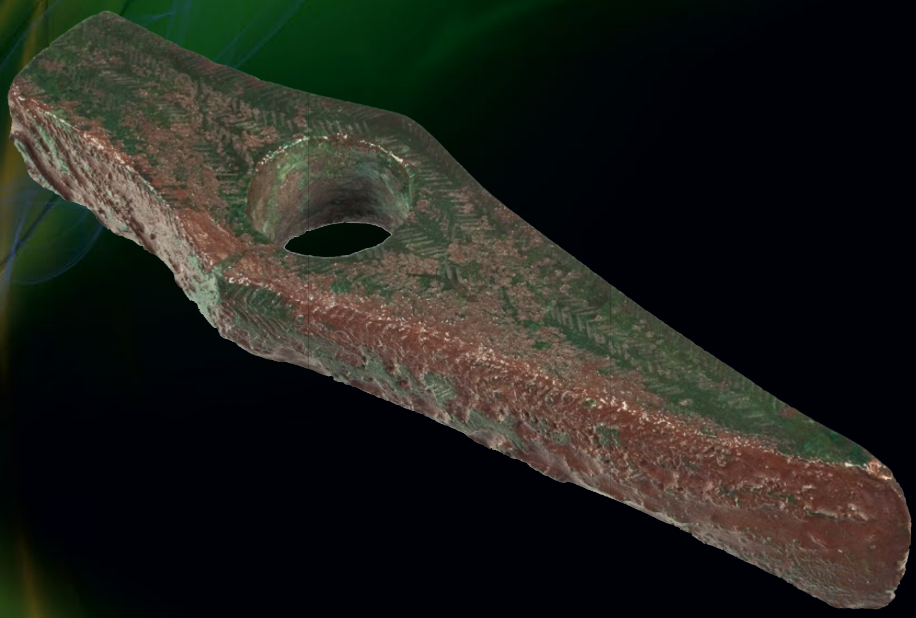
The Rise of Metallurgy in Eurasia

Evolution, Organisation and Consumption of Early Metal in the Balkans



Edited by

Miljana Radivojević, Benjamin W. Roberts, Miroslav Marić, Julka Kuzmanović Cvetković and Thilo Rehren

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Archaeopress Archaeology

Archaeopress Publishing Ltd
Summertown Pavilion
18-24 Middle Way
Summertown
Oxford OX2 7LG

www.archaeopress.com

ISBN 978-1-80327-042-5
ISBN 978-1-80327-043-2 (e-Pdf)

DOI: 10.32028/9781803270425

Cover: Ljiljana Dinić; Copper hammer-axe, type Pločnik, c. 4600 BC
(from Pločnik, Serbia) - Julka Kuzmanović Cvetković.
Inner back cover: Reconstruction of the world's earliest copper smelting. Green flames come from the extraction of metal from malachite. Experiments at Pločnik, Serbia (2013) - Marko Djurica

Copyeditor: Kate Sharpe

To the memory of Borislav Jovanović, our colleague, friend and inspiration

(1930 – 2015)

Contents

Chapter 43

Pottery technology at the dawn of metallurgy in the Vinča culture

Silvia Amicone, Miljana Radivojević, Patrick Quinn and Thilo Rehren

This chapter summarises the macroscopic and microscopic analyses of pottery sherds from the sites of Belovode and Pločnik, presented in Chapters 14 and 31, and provides insight into different technological traits in order to aid reconstruction of pottery making recipes in these two Vinča culture communities. Using a multi-pronged scientific approach, we reconstructed routines of raw material acquisition and processing, techniques of forming and finishing vessels, firing conditions and organisational aspects of pottery production. The possible non-local production identified in this research is also considered in order to understand the dynamics that shaped pottery circulation in these prehistoric communities (e.g. Quinn *et al.* 2010). These results also contribute significantly to the previous technological studies carried out on Neolithic pottery from sites in the central Balkans (Figure 1) (e.g. Dammers *et al.* 2012; Kaiser 1984, 1989, 1990; Kaiser *et al.* 1986; Kreiter *et al.* 2009, 2011, 2013, 2017a, 2017b, 2019; Spataro 2014, 2017, 2018; Szakmány *et al.* 2019).

Combining the results of the pottery technological study together with archaeological information presented in the other chapters of this monograph (Chapters 14 and 29), this synthesis offers a contribution to the understanding of Vinča pottery across different phases of its development. Also, the results of this study help us explore the technological links between the dark-burnished and graphite-painted pottery with extractive metallurgy of copper that emerged in the Vinča culture (Amicone *et al.* 2020a). We test the hypothesis that the ability of potters to exert sufficiently close control

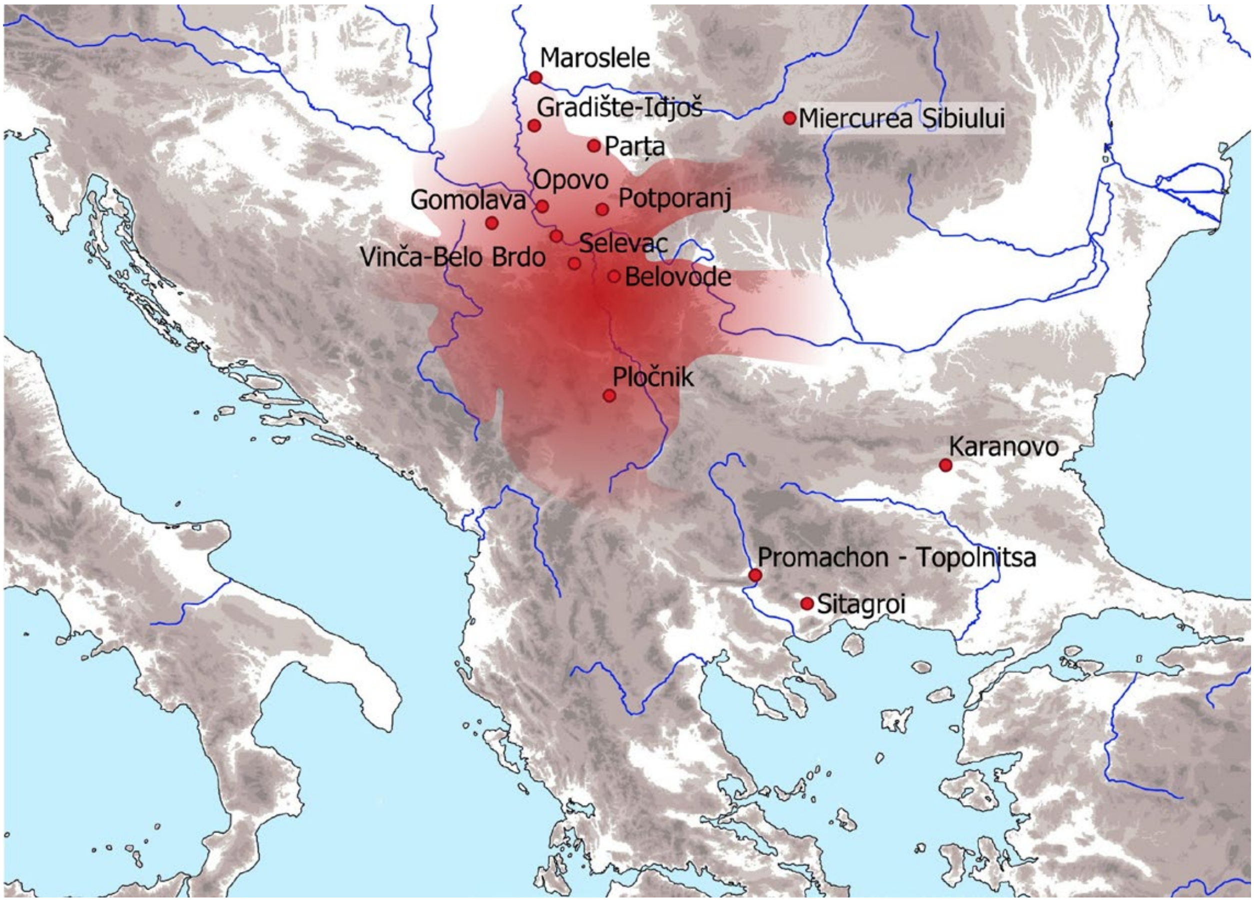

Figure 1. Distribution of the Vinča culture throughout all its periods (shaded) and location of sites mentioned in this study (map by Lars Heinze and Jugoslav Pendić).

over the redox atmosphere in a two-step firing process necessary to produce graphite-painted pottery could indeed provide a long sought-after link between pottery and metal making technologies.

Raw material selection

The first major theme highlighted by the combination of petrographic analysis on the pottery and geological samples from Belovode and Pločnik (Chapters 14 and 29) was raw material selection. The results revealed that potters at both sites selected clay immediately available from their surrounding landscapes. A worldwide study of distances travelled to acquire clays and temper sources (Arnold 2000: 343) suggests that the maximum threshold distance for raw material procurement lies at 7 km from the potter's production place (assuming that their own bodies are used for transport). Nevertheless, most potters did not travel more than 1 km to obtain clays and tempers under these conditions. At both sites, clay sources suitable for pottery making can be found within 1 km of the supposed boundaries of the settlements. These patterns have also been observed at other Vinča settlements (cf. Amicone *et al.* 2020a).

The potters of Belovode selected two different types of clay sources: the first was a non-calcareous Neogene secondary sandy-clay (see Geological Map in Chapter 14, points 2, 12, and 14) whose coarse fraction consists of minerals derived from the weathering of low-grade metamorphic rocks (probably metasedimentary rocks). This was used throughout the period in which the settlement was inhabited (Figure 2). The second type is a Neogene calcareous sandy clay source, rich in calcite and shells (see Geological Map, Chapter 14, point 1), exploited from Horizon 3 onwards (*c.* 5140–4859 cal. BC, 95% probability, Chapter 37). The Neogene formation also includes sandy layers that could have been a suitable source for temper.

Very good primary clay sources were available in Pločnik, deriving from Cretaceous formations rich in conglomerates, sandstones, and mudstone. These types of clay sources originate from the weathering of sedimentary rocks and therefore contain fragments of these types of clasts and related minerals. The geological sample showed that different outcrops of this clay source differ in coarseness, and both calcareous and non-calcareous clays were found. Throughout its occupation (Figure 3), the inhabitants of Pločnik selected non-calcareous clays which have good plasticity and need only minimal processing (e.g. cleaning or tempering). The calcareous clay sources were used only for loom-weights and plastered floors.

Alluvial clay from the Toplica river does not appear to have been used in pottery manufacturing. Given that this source of raw material was immediately available in the vicinity of the site, this is difficult to explain. One argument could be that the course of the river today is not the same as during the Neolithic period, as illustrated by the fact that a substantial portion of the site has been destroyed by its meandering. At the time the site was occupied, however, the river should have been close to the settlement and would have very likely bordered its southeastern extension.

Other factors could lie behind the decision not to use fluvial sediments for producing pottery: the clay sources from the Cretaceous formations may have been perceived to be more suitable or there may have been socio-political reasons that are today impossible to determine or reconstruct. It has been noted, however, that the distribution of resources in a given environment presents people with different possibilities and influences their movement within that environment (Michelaki *et al.* 2014). In this sense, the existence of multiple resources in single area allows people to simultaneously undertake a variety of tasks in the same general place. It is possible, therefore, that the inhabitants of Pločnik oriented themselves towards a specific clay source perhaps, for example, because that location also offered other important resources. Gosselain and Livingstone-Smith (2005) point out several cases in which potters discovered suitable clay sources by undertaking other tasks, especially those which require a close observation of soils (e.g. fetching water, digging foundations). In general, potters often selected raw material from locations that offered opportunities to undertake a variety of tasks at the same time. It is therefore important to note that the hills surrounding Pločnik are also rich in sandstone that was employed in the ground-stone industry. It is likely that the task of collecting raw materials for both pottery making and for the ground-stone industry were somehow merged, or at least linked, and took place in areas that offered opportunities to find suitable raw materials for both crafts. A similar logic could also explain the fact that some sherds are marked by a fabric rich in mica-schist (fabric PL-B, Figure 2f, Chapter 29). Inhabitants most likely exploited outcrops close to mica-schist quarries that were found about 6–7 km from the site (Geological Map in Chapter 29, Point 9). This mica-schist was also employed in the local ground stone industry (Dimić and Antonović Chapter45, this volume). In Horizon 1 (*c.* 4631–4231 cal. BC, 95% probability, Gradac II–III, see Chapter 37, this volume), the latest phase of the settlement, one third of the sherds are characterised by fabric PL-B, whilst previous horizons contain only a few such samples.

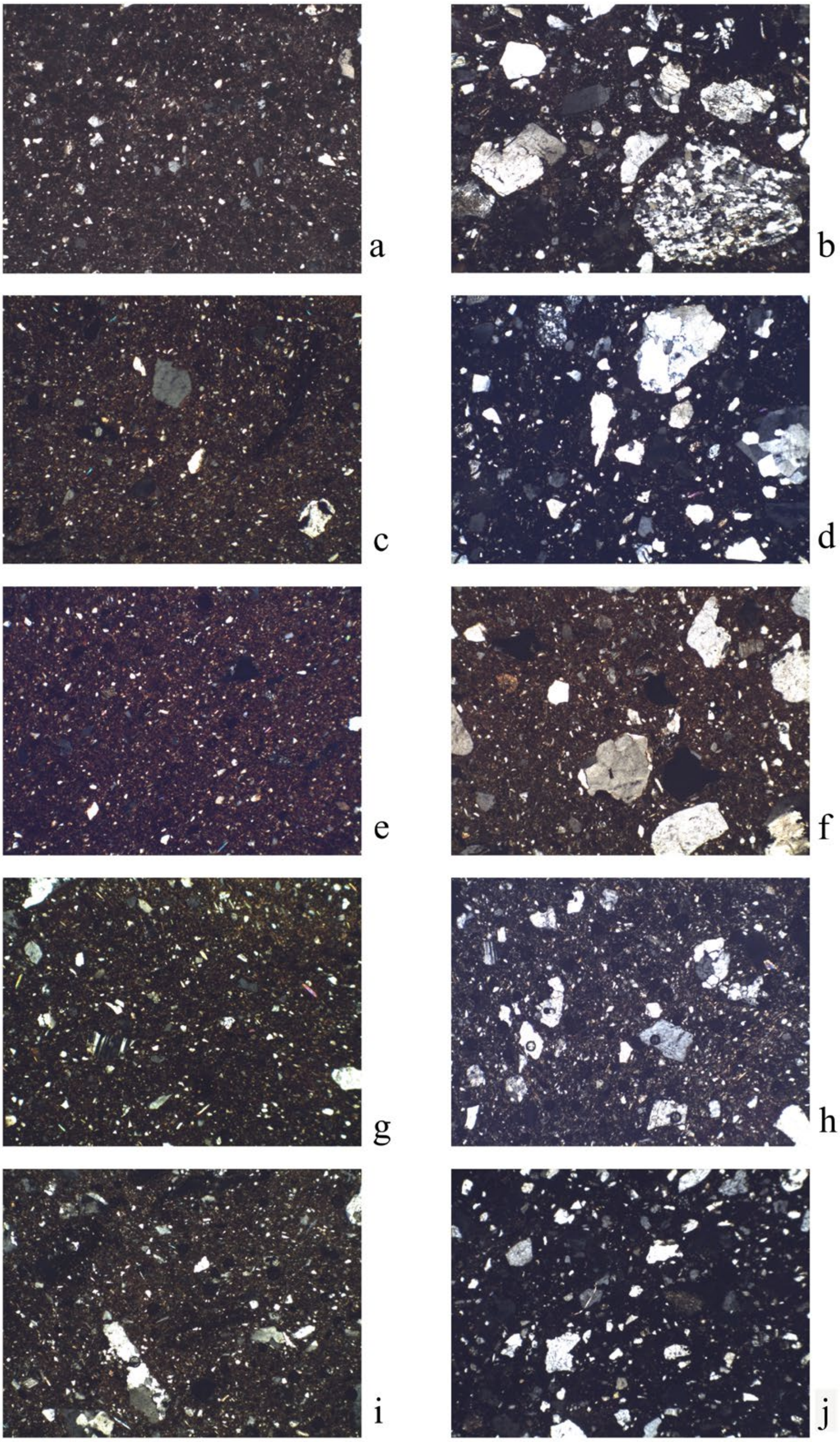

Figure 2. Thin section photomicrographs of fabric BEL-A in different Horizons. a) and b) Horizon 1; c) and d) Horizon 2; e) and f) Horizon 3; g) and h) Horizon 4; i) and j) Horizon 5 (image width = 3 mm).

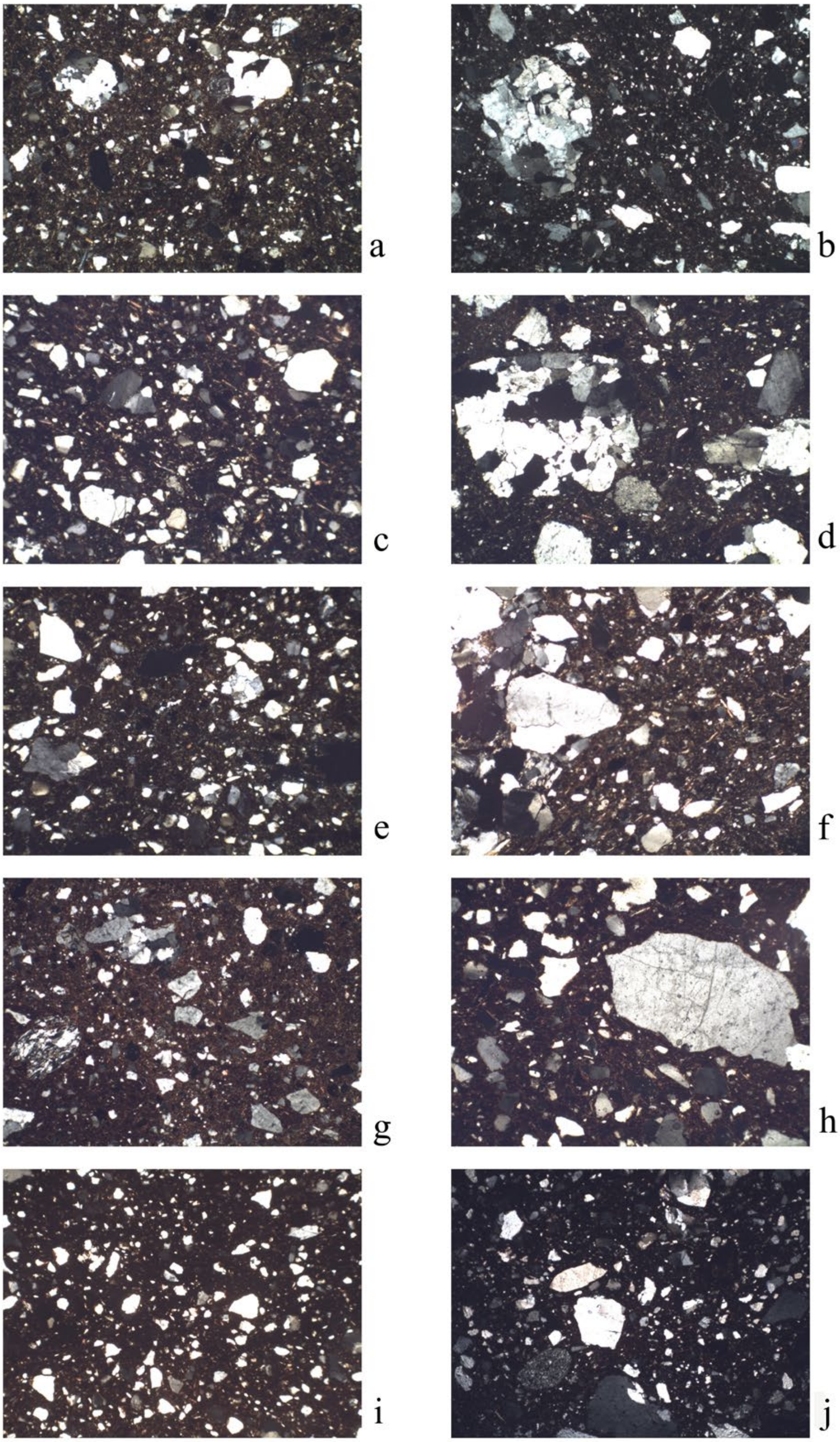

Figure 3. Thin section photomicrographs of fabric PL-A in different horizons. a) and b) Horizon 1; c) and d) Horizon 2; e) and f) Horizon 3; g) and h) Horizon 4; i) and j) Horizon 5 (image width = 3 mm).

Raw material processing

In both Belovode and Pločnik, clay processing seems to have been minimal. Tempering was not a very common practice and often barely recognisable. In Belovode this practice is attested to, especially in the earliest horizons, by the inclusion of rock fragments and minerals or organic tempering (e.g. chaff). In the earliest phases of the settlement, Horizon 5 and 4 (*c.* 5648–5054 cal. BC, 95% probability, Starčevo–Vinča A, Chapter 37, this volume), it is already possible to differentiate three different paste recipes which employ the same type of clay, but differ in terms of tempering: one is defined by mineral tempering, one by plant tempering and one is untempered. Plant tempering is associated with a specific pottery making recipe that is marked by barbotine decoration, oxidising firing conditions and, possibly, slightly lower firing temperatures. This pottery recipe is associated with material of the early/middle Neolithic Starčevo culture. In Belovode this pottery making tradition is only present in the earliest horizon, but probably co-existed and overlapped with other traditions marked by mineral tempering or the absence of tempering, which are associated with more typical Vinča culture pottery. From Horizon 3 onwards (*c.* 5140–4859 cal. BC, 95% probability, Vinča B1–B2, Chapter 37, this volume) mineral tempering is still used, but very sporadically.

In Pločnik, the bimodal grain size distribution noted in some of the coarse clay samples assigned to fabric PL-A (Figure 2, Chapter 29, this volume), from Horizons 5 and 4 (*c.* 5389–4976 cal. BC, 95% probability, Vinča A2–B2, Chapter 37) could be evidence of the intentional addition of aplastic material. Also, coarse samples assigned to fabric PL-B (with mica-schist) could have been tempered. Otherwise, there is no strong tradition for tempering observable at this site. Conversely, the results of the analysis carried out for other Vinča settlements (Amicone *et al.* 2020a) show that tempering is a quite common practice among potters who used a variety of different materials including river sand, plant material, rock fragments and grog.

The two sites also show differences in the relationships between pottery fabric, shape, and function. In the analysis carried out on the sherds from Pločnik it was possible to observe a slight tendency for coarser fabrics to be used for vessels characterised by thicker walls (e.g. amphora and pithoi), however a strict relationship between fabric and vessel type was excluded. Very interestingly, in terms of grain size distribution of the inclusions, the fabric used to produce dark-burnished bowls did not differ significantly from those used to produce other types of pots. At Belovode, however, we can observe a tendency towards a different selection and preparation of the paste according to the type and surface treatment of the vessels. Bowls, for instance, which are in most cases burnished or polished, have a fine fabric (fabric BEL-A2, Figure 2a, Chapter 14, this volume) that could indicate that a finer clay source was used to manufacture these vessels, or that the starting raw material was freed of its coarser fraction through sieving or levigation. By contrast, the majority of the cooking pots were characterised by a paste rich in shell fragments, microfossils and calcite (fabric BEL-B, Figure 4a,b, Chapter 14). The selection of clay sources rich in naturally occurring calcite or calcite tempering in connection with cooking pots is not surprising, since the presence of calcite could have a positive impact on the vessel's thermal shock resistance (Rice 2015: 324).

Similar patterns have been noticed at other Vinča sites (Figure 1) such as Opovo, Selevac, Gomolava (Kaiser 1984, 1990; Tringham *et al.* 1992), Parţa, Miercurea Sibiului Petriş and Vinča-Belo Brdo (Spataro 2014, 2017, 2018). Kaiser, for example, noticed a correlation between pottery fabric, vessel form, and size, because each vessel type tended to be associated with a particular fabric and less strongly with others. In addition, at Potporanj (near Vršac) and Gradište-Iđoš (near Kikinda), which are both located in Banat (northern Serbia), a more systematic correlation between fabric and vessel shapes seems to be present (Amicone *et al.* 2020b). At Belovode, bowls which are normally dark and burnished have a very fine fabric that was probably obtained through cleaning (e.g. by levigation) of clay. Storage and cooking vessels (pots and pans), however, have a very coarse-tempered fabric.

Forming techniques, surface finishing and decoration

The combination of macro and micro analysis revealed that coiling was widely applied for the manufacturing of vessels at Belovode and Pločnik (Roux 2017). The use of this technique was recognised macroscopically by the presence of vessels with fractures preferentially aligned parallel to the rim plane and via the identification of joins between coils visible on the surface of numerous vessels. This was also confirmed by the distribution of inclusions and voids observed in the samples examined via thin section analysis (Quinn 2013: 179). Pinching techniques were employed at both sites, but only in the manufacturing of small vessels and sometimes in the forming of the bottoms of bowls. There is no evidence of the use of moulds, while the slab technique seems to be employed—at least at Pločnik—when producing vessels with a squared mouth or to produce the base of vessels. Forming techniques seem to be evenly employed across different horizons at Belovode and Pločnik. Similar patterns were also noticed at the sites of Selevac and Gomolava by Kaiser (1984: 208–217).

Different techniques of decoration were used at both sites including barbotine, incising (often filled with calcite and cinnabar), impressing, channelling, painting, and applied decorations. These were very common techniques of pottery decoration at that time in the Balkans (Bonga 2013). The development of decorative techniques follows similar trajectories at both sites, with an increasing presence of channelling corresponding with the emergence of the Gradac Phase (*c.* 5000 BC) and the gradual disappearance of barbotine decoration over time. Pločnik, however, shows some differences in the presence of graphite-painted pottery from Horizons 3 and 2 (*c.* 5036–4621 cal. BC, 95% probability, Gradac I, cf. Chapter 37, this volume).

Surface treatments such as smoothing, burnishing and polishing (Martineau 2010) occur at both Belovode and Pločnik. Burnishing and polishing are applied to different types of vessels, but they are predominant in the production of dark-burnished bowls. This surface treatment is very common and became widespread during the Middle and Late Neolithic of southern Europe, and in other material cultures such as Danilo, Hvar, Vinča and Karanovo (Spataro 2017). It is interesting to note that Pločnik Horizon 1 (*c.* 4631–4231 cal. BC, 95% probability, Gradac II–III, see Chapter 37, this volume) is marked by a significant decrease in burnishing, polishing and decoration techniques.

Pyrotechnology and colour

The reconstruction of aspects of pottery pyrotechnology at the studied sites is challenging since there is no clear evidence for the firing installations used. There is generally no conclusive evidence for pottery kilns in Vinča culture settlements. Features that could be compatible with these types of pyrotechnological installations were found, for example, in Trench 6 at Belovode (Šljivar *et al.* 2011), represented by three round firing structures, a fireplace and an assemblage of clay figurines (bulls), all of which the excavator ascribed to ritual-cult function. Yet, it is not common in Vinča households to find groups of round structures for firing next to each other, and these indeed could indicate the presence of kilns. Similar clusters of round structures were also identified from anomalies detected during the geophysical survey of Pločnik (see Rassmann *et al.*, Chapter 24, this volume); future excavations may show whether these are dwelling debris or, indeed, are much sought-after examples of kilns on a Vinča site.

In the absence of more secure evidence, it might be plausible that pots were simply (or additionally) fired in pits dug in the ground. As shown in a firing experiment carried out in Serbia (Svoboda *et al.* 2004/2005; Vuković 2018b), it is possible to produce the entire range of pottery found in Vinča sites without using a proper kiln. Despite the lack of clear evidence for firing installations in the archaeological record, it is still possible to reach preliminary conclusions based on results presented in Chapters 14 and 29, especially based on the colour of the vessels and the results of XRD and SEM analyses.

Most of the pottery from Belovode has a pale yellow to reddish yellow surface colour, indicating firing under oxidising conditions. Only the vessels with burnished or polished surfaces appear to be fired differently (in reducing conditions). By contrast, 60% of the sherds from all five horizons at Pločnik exhibit grey and black shades associated with burnishing or polishing and, more rarely, with graphite decoration (Amicone 2017: 190). This preference for dark pottery persists into Horizon 1 (Gradac II–III), although there is only occasional evidence for burnishing at this point. Some black-topped sherds occur at both sites, for example in Horizons 5 and 4 (Vinča A2–B2).

The colour of most of the examined sherds varies in cross-section (Figure 4) indicating variable atmospheric conditions during firing and/or a short firing duration. The fabric of dark-burnished vessels is never homogeneously grey. Rather, it is usually characterised by a reddish core and a darker grey matrix towards the surface; the boundary between them is not sharply delineated. Vessels fired completely in an oxidised atmosphere are also attested, with the cooking pots at Belovode being a good example. However, reddish sherds often come from the interiors of burned features and might therefore have turned red during destruction events. Vessels from other Vinča sites are more often grey in colour, and larger preserved fragments frequently display a range of shades from pale to dark grey (Chapman 2006; Kaiser 1984). Fragments from Pločnik decorated with graphite derived from building Horizon 3 (*c.* 5036–4951 cal. BC, 95% probability) and 2 (*c.* 4927–4621 cal. BC, 95% probability)(see Chapter 37), corresponding to the Gradac Phase I of the Vinča culture, exhibit a relatively homogeneous dark to light grey fabric in cross-section (Amicone *et al.* 2020b).

There are two common ways to achieve a grey or black colouration of pot surfaces during the firing process: iron reduction and carbon black (also called the smoking and smudging technique). In the first case, the black colour is connected with the nucleation of dark coloured iron-oxides (e.g. magnetite). In the second, the black colour derives from carbon particles that cover the vessel surface during firing and penetrate the pores (Jones 1986: 762–763). However, the XRD analysis carried out on samples from both sites (Table 2 in Chapters 14 and 29 respectively) did not reveal the presence of magnetite on the surface of black coloured pots, thus ruling out the iron reduction methods. However, carbon was detected on the surface of several dark-burnished sherds from both Pločnik and Belovode via μ-Raman analysis, suggesting that their lustrous black surfaces were the result of the carbon black smudging technique (Amicone *et al*. 2020b).

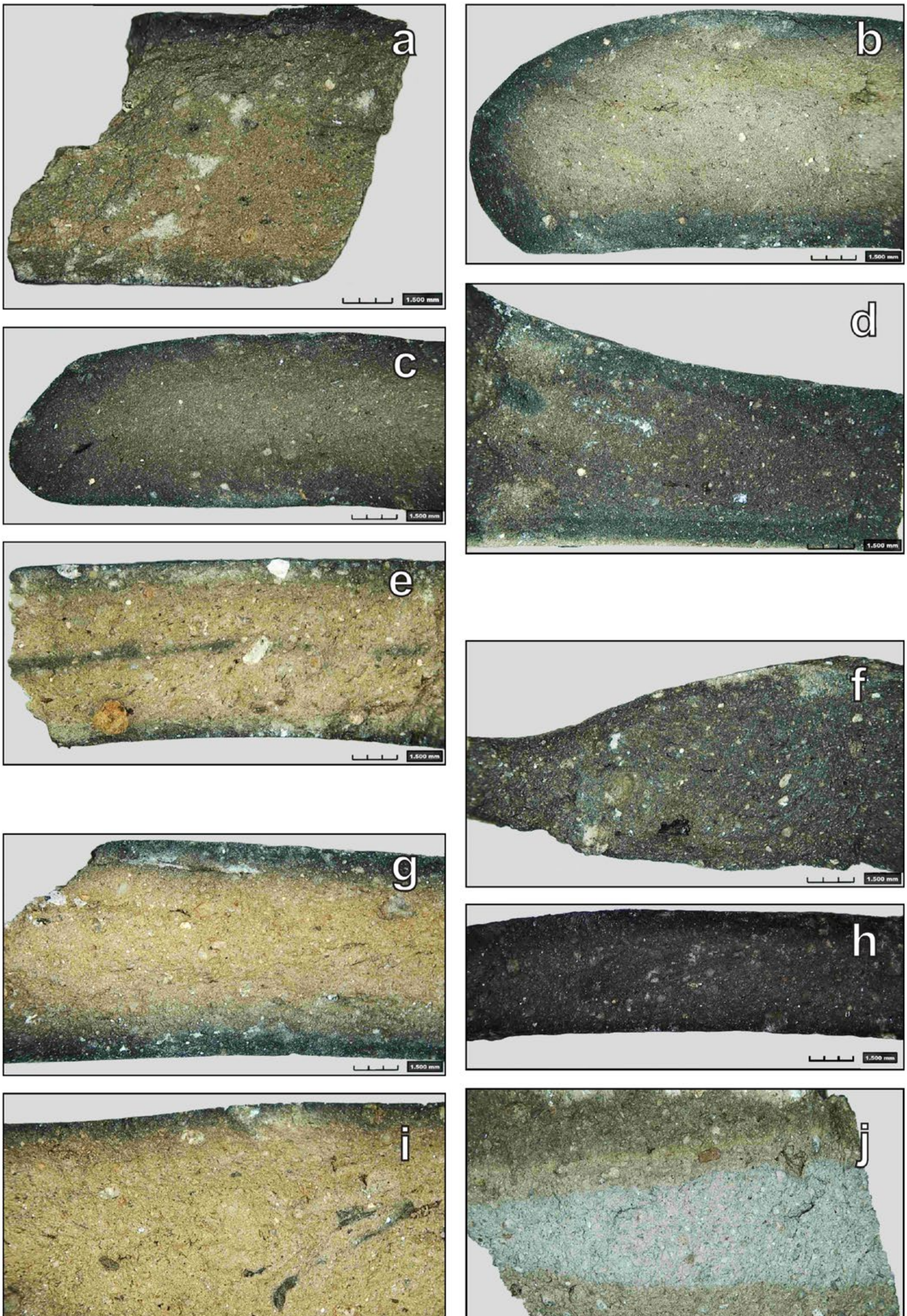

Figure 4. Selected dark-burnished and graphite-painted pottery sherds from the Vinča culture sites of Belovode and Pločnik seen in fresh break, revealing the fired colour of their fabric and the presence of firing horizons: a) BEL 289; b) BEL 94; c) BEL162; d) BEL 219; e) BEL 299; f) PL 24-129 (graphite-painted); g) PL 24-107; h) PL 24-124 (graphite-painted); i) PL 24-288; j) PL 24-145.

The nucleation of dark iron oxide with a lower oxidation state (e.g. magnetite) happens at temperatures above 700 °C in non-calcareous clays and above 800 °C in calcareous clays (Maritan 2004). Firing temperatures are not, however, of particular relevance in smudging, which is normally done towards the end of an oxidising firing process (when temperatures are lower) by smothering the burning fuel and pottery with substances that produce smoke, such as dry manure, green branches, or leaves. The lustre of the smudging process is less bright if temperatures are too high, so this technique is usually carried out at low temperatures (Shepard 1980: 88–90). However, the technique requires careful control of the presence of oxygen in the firing in order to avoid burning off carbon particles.

The results of thin section analyses, XRPD, and SEM on the selection of samples from Belovode and Pločnik all showed that pottery tended to be fired at temperatures between 750 °C and 900 °C, with most samples having been fired at around 750–800 °C. The only samples which were exposed to temperatures around and above 1000 °C are three possible fragments of the so-called 'chimneys' (BEL 18-124, BEL 18-224, and PL 24-23). Only one other fragment (BEL 18-46) showed microstructural and mineralogical characteristics compatible with very high temperatures, however this sample was retrieved from a destruction layer and could easily have been re-fired to a very high degree during this event.

Given these observations, it is possible to formulate some hypotheses about the firing procedures followed to produce dark-burnished pottery at Belovode and Pločnik. As most of the samples have a reddish core and dark margins, we can propose a two-step procedure in which vessels were initially fired in an oxygen-rich atmosphere during which the maximum firing temperature was achieved and sintering started to take place, giving the ceramics their rigidity. Then, with the temperature decreasing, a reducing phase was obtained by covering up the pit, possibly after organic material was added in order to increase the production of smoke. At the beginning of this reducing phase, the temperature was probably not high enough or sustained for long enough to allow the nucleation of magnetite. Only a few sherds of the analysed assemblages display a homogeneous black colour across their surface; the majority show surface colours that vary between light and medium grey to light red. This suggests that, even if potters had a certain awareness and ability in manipulating fire and obtaining reducing conditions, this knowledge was not completely mastered. This is probably only due to the lack of adequate firing installations that could have enabled more absolute control.

Graphite-painted pottery was probably fired in a similar two-step procedure but with a longer reducing process given the relatively homogeneous dark to light grey colour of most of these sherds in thin section. The reducing phase would have started earlier in the process than in the production of dark-burnished pottery, certainly before the initial oxidising phase had reached a temperature of about 700 °C, at which point the graphite would have begun to burn off relatively quickly (Kreiter *et al.* 2013: 176, 2014). It is possible that the maximum temperature was reached under reducing conditions, because the estimated firing temperature of the samples analysed is between 750 and 800 °C, a temperature at which graphite decoration would already have been severely damaged under oxidising conditions. Furthermore, the small bloating pores that characterise one of the analysed samples are normally formed under reducing conditions when vitrification starts (Maniatis and Tite 1975).

Analysis of the 'graphite' painted decoration of one out of five selected samples using µ-XRD[2] and µ-Raman revealed that it was actually coated with a type of artificial carbon black pigment which achieved a very similar metallic lustre to mineral graphite (the 'Glanzkohlenstoff' of Letsch and Noll 1978, 1983), and the distinction is difficult to make with the naked eye. This finding suggests that the same 'graphite' decorative effect on Vinča pottery could have been produced using several alternative processes, demonstrating the technological advancements achieved by the potters (Amicone *et al.* 2020b). Equally, it demonstrates an innovative means to decorate the pottery with metallic lustre, making the distinctive metal-like appearance that is one of the linking components between metal and pottery technologies.

All the evidence presented above seems to suggest that potters were able to exert a relatively close control over the atmosphere of the firing process. This is clearly demonstrated by the presence of vessels that are intentionally bi-coloured (the so-called black topped vessels), the dark-burnished pottery and, especially, the graphite-painted decorations. However, the results of the analyses conducted on samples from Belovode and Pločnik also show that the ability of potters to reach high temperatures was overemphasised in some early studies (e.g. Kaiser *et al.* 1986), while our results are in line with those of other studies (Maniatis and Tite 1981; Perišić *et al.* 2016; Spataro 2014, 2017, 2018). Perhaps too much attention has been paid to using firing temperatures to illustrate the Vinča potters' mastery of the pyrotechnological skills, rather than to their control over firing atmosphere conditions.

In order to produce a functional pot, temperatures of around 600–700 °C are more than enough. The common argument that the potters wanted a hard-fired vessel does not appear to be valid, since this would also have been achievable with a less sophisticated and more resource-efficient firing procedure. The question that remains, therefore, is not whether the potters were able to achieve and to control temperatures above 1000 °C, but rather why they would have preferred to do so in the first place. The impression is that this over-estimation of firing temperatures could have been influenced by the fact that these results matched too well with pre-existing models concerning the connections between pottery and copper pyrotechnology in the Balkans, such as that developed by Renfrew (1969) on the basis of the archaeometric analysis of Frierman (1969) on a sherd from Karanovo. Detailed study of copper smelting shows that this pyrotechnology is fundamentally different to that employed in dark-burnished production, because the sequence of redox conditions is reversed. In metallurgy, the process starts with relatively low temperatures in conjunction with a reducing atmosphere to form copper metal from the ore, followed by higher temperatures in less reducing conditions to melt and allow the metal to form larger prills. Yet, even if we conclude that pottery at Belovode and Pločnik—and more generally within the Vinča culture—was not fired in exactly the same conditions as those necessary for copper smelting, this would not exclude the possibility that certain advances in pottery pyrotechnology, such as the ability to manipulate firing conditions, could have laid the groundwork for further technological progress that was necessary for the smelting of copper. On the other hand, with regard to graphite-painted pottery we cannot exclude a reverse trajectory of transmission, or a parallel development, as this type of decoration was broadly contemporaneous with the emergence of metallurgy. It might be that the pyrotechnology of copper smelting could have evolved together with advanced pottery technology or may even have triggered the development of the graphite decoration technique (Amicone *et al.* 2020b).

Organisation of production

Vinča culture pottery has often been considered the product of specialised labour (for a discussion see Kaiser 1984: 282–287). It is worth remembering, however, that archaeologists and museum curators tend to select only the finest and most beautiful vessels for display and publication, frequently creating a bias in the material record.

Specialisation has been defined in different ways (e.g. Costin 1991: 4; Kaiser 1984: 280; Rice 1981, 1991: 259), but it may be said that it is the organisation of production in such a way that the number of the people involved in the manufacture of a commodity is smaller than the number of consumers. Archaeologists often use direct evidence such as production loci and debris to identify context, concentration, scale, and intensity of production (Costin 1991: 8) to describe the organisation of production. As previously mentioned, there is currently a lack of evidence for pottery production installations in Vinča culture settlements. This makes the task of defining the level of craft specialisation and organisation for the production of pottery in these settlements challenging. There is, however, indirect evidence that could give insights into this issue without knowledge of the exact location of the production areas.

The first is standardisation, which is considered to be positively correlated with specialisation because it is assumed that production with fewer producers will display less variability. An increase in routine activities connected with specialised production can also result in standardisation (Costin 1991: 34). Theoretically, the characteristics of the artefacts could therefore indicate the level of standardisation, efficiency and skill of production, and hence the level of specialisation. In practical terms, however, several problems arise when we try to define a strategy to assess these parameters.

Standardisation has often been measured by considering the metric variability of vessels (e.g. Roux 2003). Within the study of Vinča pottery, an attempt has been made by Vuković (2011; Vuković and Miloglav 2018) who studied the assemblages from Vinča and Montel Slatina. The statistical analysis of metric parameters of ceramic vessels from the two Late Neolithic sites identified some evidence of standardisation in the assemblages considered, despite the exceptional material fragmentation and the difficulties of distinguishing a relevant sample. According to the results of this study, Vinča pottery exhibits a relatively high level of standardisation that can be recognised through the values of the coefficients of variation for metric parameters (Vuković 2011). However, Vuković (2011: 97) also noted a different degree of standardisation between certain functional classes and within each individual class (e.g. carinated bowls versus bowls with incurved rims). This posed many questions that, as the author herself stated, required a more complex comparative investigation into the pottery from several additional sites.

The high fragmentation of the assemblages examined in the present research, together with the long period of deposition and the fact that the sample contains the products of a number of potters, makes an evaluation of standardisation very difficult. Despite this, an attempt was made using a different approach. Instead of considering metric variables, the focus was shifted towards aspects related to selection and processing of raw materials at both sites. At Pločnik, throughout the period considered, potters were using sandy clays characterised by the presence of quartz and different type of sedimentary rocks, accompanied by different mineral suites. Sometimes a few inclusions of muscovite are present and with others there is the rare inclusion of amphibole and epidote. Textural variation was noted in the grain size distribution and sorting of the inclusions. However, it was possible to observe a general tendency toward larger inclusions within thick-walled and large vessels, and smaller inclusions in thin-walled and small vessels. In most cases, coarse fabrics do not show clear evidence of tempering and it can be assumed that sandy clays of different coarseness were employed according to the size and wall thickness of the vessel produced. At Belovode, two main types of raw material sources were exploited: 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 in that the dark-burnished bowls seem to have been produced with a clay that may have been well cleaned prior to its use; the clay source rich in shells and microfossils is mostly associated with pots that could have been used in cooking activities. However, at both sites the geological variability of the surrounding area is not very high, and it would therefore be unreasonable to expect locally made pots to contain a large variety of rocks and minerals (Arnold 2000). In addition, technological knowledge tends to be broadly distributed and shared among household producers (Foster 1965: 58). If other technological parameters are taken into consideration it is possible to observe that forming techniques at both sites seemed to be rather stable. However, the high fragmentation of the studied pottery did not allow for a full and detailed reconstruction of the *chaîne opératoire* of forming techniques.

More generally, this technological overview reveals that despite the fact that these assemblages show a relatively high degree of homogeneity, this could be the result of a strong and widespread technological tradition rooted in the tight learning networks that seem to characterise this material culture, rather than due to specialisation. However, the results of the technological study carried out by Kaiser (1984) on assemblages from Selevac and Opovo show that although there were similar notions of what constituted an appropriate pot and that certain aspects of pottery knowledge were shared across these sites, differences existed regarding the specific procedures followed in various steps of the production. For these reasons it is suggested that a large number of potters were active at these sites, which ultimately led Kaiser (1984) to conclude that Vinča ceramics were not made by highly specialised potters.

The discourse on firing techniques leads us to the final parameter to be considered, that of 'skill', a concept that refers to the 'proficiency with which activities are executed' (Bleed 2008: 156). Skilfully produced objects are expected to be well made, e.g. regularly shaped and complex in both form and decoration. Ethnoarchaeological research has focused on this topic (e.g. Roux and Corbetta 1989; Wallaert-Pêtre 2001). A few studies in archaeology have also considered the production sequence in term of skills (Budden 2008; Forte 2019; Michelaki 2008), with interesting results.

It is possible to draw some conclusions regarding 'skill' from what we have learned about the employment of pyrotechnics in Vinča culture. Our results have shown that potters were able to control, to an extent, the variables of atmosphere and temperature. However, differences in the colour of vessel surfaces show that potters were not always able to control firing conditions completely. The conclusion is that, even though people who were producing pottery at both sites show an awareness of how to manipulate fire in order to produce different colours, this knowledge is still not completely mastered. In practice, this is very likely because no conclusive kiln installations were employed and that conditions in a pit fire can never be fully controlled, even by highly skilled potters.

The presence of graphite-painted pottery at Pločnik deserves further consideration. Graphite-painted pottery has often been associated with the presence of craft specialisation (Evans 1973), as the unusually high degree of control that was necessary to exercise the firing of such decoration has been attributed to the skills of specialists. While dark-burnished pottery is abundant in pottery from all phases at Pločnik, examples decorated with graphite are rarely found. Only eleven small sherds of graphite-painted pots were found in Trench 24 at Pločnik, all derived from building Horizon 3 (*c.* 5036–4951 cal. BC, 95% probability) and Horizon 2 (*c.* 4927–4621 cal. BC, 95% probability), corresponding to the Gradac Phase I of the Vinča culture. These samples come from a single trench and therefore may not be fully representative given the current size of the settlement (*c.* 30 ha, see Rassman *et al.*, Chapter 24, this volume) or that assumed (possibly double the area) prior to erosion from the shifting Toplica river. The fragments belong to vessels that were all locally produced, as shown by the petrographic analysis of five of them.

Graphite could have been immediately available to the Pločnik communities. In Serbia, graphite deposits (Republic of Serbia Ministry of Mining and Energy n.d.). can be found in Donja Ljubata, Ibarski Rudnici, Jaram, Pasjača, Ušće, Veta and Vrška Čuka (Figure 5). It was not possible to find any reference in the literature for the exploitation of these deposits during the Neolithic and Chalcolithic, but it is very likely that some of these sources were used at the time. The deposit in Pasjača is about 34 km from the site of Pločnik and is easily accessible via the Toplica river valley, and there is no reason to assume that the access to this deposit was restricted. Equally, graphite could have been acquired through specialist trade networks from Bulgaria, via the same connections that brought metal from ore deposits in Bulgaria for the copper implements found in Horizon 1 at Pločnik (Pernicka *et al.* 1997; Radivojević and Grujić 2018).

As mentioned above, the manufacture of graphite-painted decoration required considerable mastery of

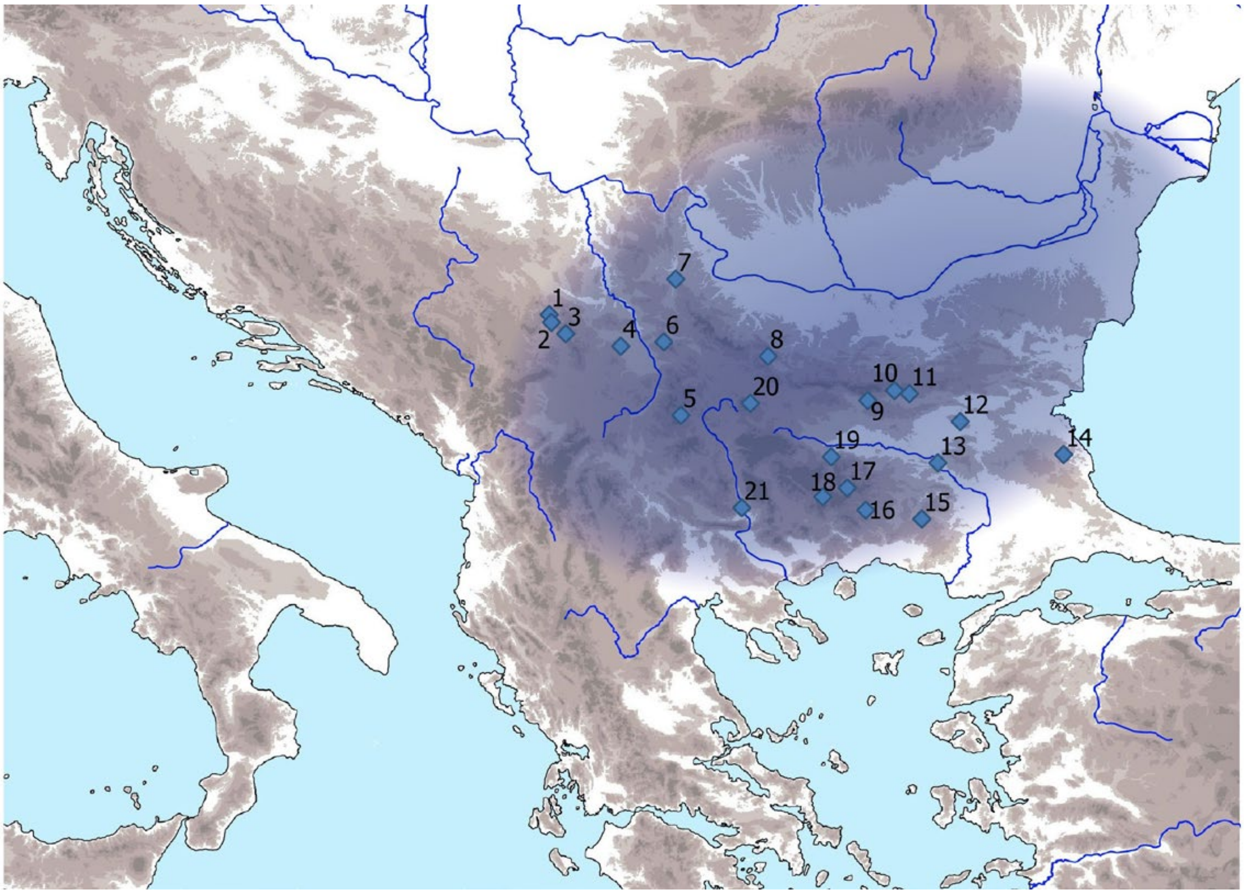

Figure 5. Map showing the main areas of distribution of graphite-painted pottery and deposits of graphite in Serbia and Bulgaria: 1 Ušće; 2 Ibarski Rudnici; 3 Jaram; 4 Pasjača; 5 Donja Ljubata; 6 Veta; 7 Vrška Čuka; 8 Ignatitsa, Vratsa District; 9 Kalofer-Samodivska chukara; 10 Shipka, Kazanlak District; 11 Seltse, Kazanlak District; 12 Sveti Ilija hills (Svetiiliyski Vuzvisheniya); 13 Shishmanovo, Harmanli District; 14 Gramatikovo, Burgas District; 15 Golyamo Kamenyane, Krumovgrad District; 16 Madan; 17 Chepelare; 18 Yagodina, Smolyan District; 19 Krichim; 20 Bistritsa, Dupnitsa District; 21 Lebnitsa, Sandanski District. (Map by Lars Heinze and Silvia Amicone).

redox conditions and this skill may not have been shared by all the potters at a site like Pločnik. Perhaps only a small number were able to produce this decoration at a given time, potentially marking the emergence of a degree of specialisation in pottery production but the overall evidence for this is currently insufficient to build a solid model.

In conclusion, the ceramic archaeological record considered here does not exhibit clear signs of high degree of craft specialisation. Within the limits imposed by the natural availability of clay sources in the area surrounding Pločnik and Belovode, the ceramic assemblages seem to be characterised by high homogeneity in paste recipes as well as other technological attributes. This could be the outcome of a tight learning network and strong technological traditions (that need to be discussed further) rather than specialisation. In addition, different functional shapes (serving vessels, storage vessels and cooking pots) show strong technological similarities both at the levels of the selection and procurement of raw material and of forming techniques. This evidence suggests the absence of separate production units specialised in the production of different functional shapes. Moreover, pottery circulation (see below) points to a similar scenario. There is, however, insufficient evidence to counter the hypothesis that the number of pottery producers was smaller than the number of consumers and therefore that a low degree of specialisation (*e.g.* household specialisation) existed. Further, graphite-painted vessels could have required specialised production with skills unlikely to have been shared by all people making pottery.

Pottery circulation

Recent analyses of Neolithic pottery in the Southern Balkans and the Aegean have challenged our view of pottery circulation at that time (see for example Pentedeka 2011; Quinn *et al.* 2010; Schneider *et al.* 1994; Tomkins and Day 2001). These studies have shown that pottery was circulating around routes and (long) distances comparable with those of other materials, such as obsidian and copper. This strongly contrasts with the traditional view that sees ceramics at this time as a commodity that was usually made and consumed locally, or at least was not transported over significant distances (e.g. Arnold 2000: 342; Vitelli 1993a, 1993b; Wijnen 1994). These new discoveries have encouraged us to rethink our previous models of craft production and circulation in the Neolithic. Understanding the circulation of pottery to and from Belovode and Pločnik is therefore key to the present study.

The results of thin section analysis carried out on the samples from Belovode and Pločnik allow us to discuss the possibility of non-local production for the two sites. The phenomena of importation and/or exchange of pottery on a regional and interregional scale can, to a degree, be addressed for the first time for both sites. However, the low geological variability of the area surrounding Belovode and the stylistic homogeneity that generally characterised Vinča material culture somewhat limit the identification of non-local production.

At Pločnik, several samples clearly show a petrographic profile that is not compatible with clay immediately available in the vicinity of the site, or even within the 7 km threshold suggested by ethnographic studies (Arnold 1985, 1993, 2000). In some cases, the comparison between the geological maps and the collected geological samples indicates possible areas of origin for some of the samples. Unfortunately, not enough is known about the settlement pattern of this area to formulate solid hypotheses about the provenance of the studied samples. The results do, however, show a very interesting network of exchange between Pločnik and the surrounding sites and beyond, and this seems to intensify towards Horizon 1 (*c.* 4631–4231 cal. BC, Gradac II–III, 95% probability) (see Chapter 37), the latest phase of occupation. The expansion of these trade networks matches well with the results of complex networks analysis that used the composition of copper artefacts from this and other Balkan sites to indicate supply networks (Radivojević and Grujić 2018). Pločnik changes from being part of a Vinča culture-dominated supply network to developing trading links with cultural complexes in east and central Bulgaria shortly after the massive and hasty abandonment of the northern Vinča culture sites in around 4600/4500 BC.

As mentioned above, the evidence for non-local production in Belovode is less clear. It was noted in Chapter 14 that within fabric BEL-A (Figure 2, Chapter 14), interpreted as being produced locally to Belovode, some technological variability exists in terms of tempering techniques, potentially reflecting different traditions. However, given the homogeneity of the geological environment around this site, it cannot be discounted that they originated from nearby contemporary villages that exploited similar raw material sources, yet had different tempering traditions. As discussed previously however, a few other samples show a petrographic profile that leaves no doubt about their non-local origin, and for some a presumed area of origin has been proposed (Figure 4, Chapter 14).

Kaiser (1984, 1990) mentioned the possible presence of non-local production at Selevac and Gomolava but does not elaborate on their possible provenance. The results of the ceramic thin section analysis (Tringham *et al.* 1992) carried out on specimens from Opovo, also seem to provide evidence of wider pottery circulation: fabrics are characterised by volcanic rock fragments and agate, which are not compatible with the area surrounding this site. Finally, Spataro (2014), in her work on the Starčevo/Vinča sites of Parţa and Miercurea Sibiului Ptriş, does not report the presence of any samples that could be potentially non-local.

In general, we can conclude that current evidence is not sufficient to allow us to draw a broader picture about pottery circulation in the Vinča culture during the Neolithic and Chalcolithic periods. The projects carried out so far are, however, starting to suggest a more complex picture than was previously supposed, also opening the possibility for long distance pottery exchanges. These could be explained in many ways. One likely scenario, for example, is that objects were regularly carried via supra-regional marriages, where women could have brought vessels and other ceramic material (e.g. loom weights) to their new homes (for a discussion on the mobility of women as opposed to more stationary men in prehistoric times, see Bentley *et al.* 2002; Knipper *et al.* 2017; Mittnik *et al.* 2019). But we should not exclude the possibility that certain vessels were exchanged for their contents rather than for the pot itself. So far, the (presumably imported) vessel repertoire from Pločnik and Belovode does not favour either of these models and could well be the result of both (or other) scenarios.

Conclusions

The results of the analyses carried out on samples from Belovode and Pločnik, considered in the context of other contemporary sites from the central Balkans, shed new light on various aspects of pottery manufacturing in the region at this time. Despite recognisable changes, both sites show a general pattern of continuity within their pottery making recipes over the observed periods. Kaiser observed a similar scenario at both Selevac and Opovo (Kaiser 1984: 292–297). This pattern of continuity in the technological tradition indicates that there was no significant change in the transmission of pottery making recipes related to the start of the Gradac Phase (*c.* 5000 BC), which denotes the appearance of metallurgy in Vinča culture. This evidence of continuity challenges the traditional vision of a profound change driven by the appearance of a novel technology in the Gradac Phase (e.g. Jovanović 1994; Garašanin 1994/1995) accompanied by an important social reconfiguration that would have impacted the learning networks responsible for the reproduction of technological traditions.

Despite the discontinuities noted in Horizon 1, this final stage of occupation at Pločnik may indeed reflect some dynamics of social change. The Horizon 1 (*c.* 4631–4231 cal. BC, 95% probability) (see Chapter 37) seems to correspond to the Gradac II-III Phases that, according to Jovanović (1994), is the final stage of development of Vinča culture in the South Morava Valley. The phase is characterised by an increased presence of metallurgy at the site and a reconfiguration of the network of metal supply, as mentioned above. Before Horizon 1, artefacts at Pločnik were made mostly from copper sourced from deposits in eastern Serbia (Radivojević 2012). However, metal from Horizon 1 shows consistency with Bulgarian copper ores (Pernicka *et al.* 1997). This is closely paralleled by the results of a study of pottery typology that blend the final developments of Vinča material culture with the Chalcolithic Bubanj-Hum phenomenon that seems to originate from east Bulgaria (see Mirković-Marić Chapter 42, this volume). As mentioned above, these newly forged links between Pločnik communities and Bubanj Hum (or further, Krivodol-Salcuta-Bubanj Hum I complex) in eastern and central Bulgaria seem to be supported by a sharing of both metal resources and pottery making technologies. Was this the connection that ended life in Pločnik as violently as at other Vinča culture sites? The results are inconclusive, although the arrival of newcomers in Pločnik is argued to represent the beginning of the end for this prehistoric settlement (Garašanin 1973). Based on the pottery technology study we can argue that throughout the occupation of Pločnik there was a general trend of continuation of pottery making recipes, with a diversification of resources in the latest stage, but no disruption of the potters' traditions. Could such gradual change have contributed to the abrupt ending for the Pločnik communities? There is no conclusive evidence to determine the exact cause of the site's ultimate destruction and abandonment.

The present research also provides an important contribution to the long prevailing theory that sees a link between pottery and metallurgy pyrotechnology (e.g. Gimbutas 1976; Kaiser *et al.* 1986; Renfrew 1969). It was clearly shown that dark-burnished pottery and graphite-painted pottery were not fired at the same temperature employed in copper smelting (up to around 1083 °C, the melting point of copper). These results are in agreement with a series of analyses already made on other assemblages of the Neolithic and Chalcolithic periods, that include dark-burnished pottery and graphite-painted pottery from the Balkans (e.g. Gardner 2003; Goleanu *et al.* 2005; Maniatis and Tite 1981; Youni 2000; Perišić *et al.* 2016; Spataro 2018), but they challenge the extensive analysis carried out by Kaiser which showed that pottery from Selevac and Gomolava was routinely fired at temperatures of around 1000 °C and beyond. Without denying the possibility of different firing routines employed in other Vinča culture communities, we suggest that previous studies have placed too much emphasis on the achievement of high firing temperatures as connection between pottery and copper metallurgy. Instead, we would highlight the mastery of fire control as the crucial link between these technologies. Vinča potters were able to achieve various decorative finishes to ceramics by skilled control of the firing conditions. For example, the production of both dark-burnished and graphite-painted pottery would have been achieved by opening and closing the firing installation and hence varying the air to fuel ratio in a two-step process. Potters also seem to have added relatively moist organic matter, such as straw and leaves which combusted quickly and used up free oxygen while depositing soot, as well as perhaps ash. This manipulation of the firing atmosphere, particularly the ability to obtain and sustain reducing conditions, could have been an important precursor to the development of early metallurgy, which also requires a two-step process but in reverse order: first a predominantly reducing atmosphere to extract copper metal from ores before more oxidising conditions are introduced to reach the higher temperatures needed to melt the copper metal (or in other words physical change is followed by chemical during this process). It is possible, even tempting, to envisage the transfer of this expert knowledge of manipulating redox conditions from ceramic production to another technological domain such as metallurgy.

There is no conclusive evidence that pottery making and copper smelting were highly specialist activities. Radivojević (2012) could not identify dwellings occupied by metal smiths in the Vinča culture, and neither could the present excavations at Belovode and Pločnik. Even if pottery were a specialist activity, it could have taken place seasonally, at times that would not require crafts people to engage in other subsistence activities. If the craft knowledge was not segregated within specialist groups, then the cross-fertilisation of pottery and metal making knowledge within the Vinča culture appears feasible.

Looking across the Balkans, the wider appearance of graphite decoration seems to be contemporary with the emergence of metallurgy during the start of the fifth millennium BC (Bailey 2000: 227; Vajsov 2007) and requires the same strongly reducing atmosphere for much of the firing cycle as is essential in copper smelting. Significantly though, given the current dating evidence that sets the early fifth millennium BC for the emergence of both metal making and graphite-painted decoration in Pločnik, it is more plausible to suggest a parallel development—or even reverse trajectory of transmission—in which the production of graphite-painted decoration was influenced by early metallurgy, and both were benefitting from the pre-existing experience with dark-burnished pottery (cf. Amicone *et al.* 2020b).

Yet, while graphite-painted decoration and metallurgy occur in the Balkans at broadly the same period it is important to bear in mind that the current evidence seems to suggest that the earliest emergence of the two are geographically unrelated, with graphite-painted pottery probably first appearing in the Struma Valley at the site of Promachon-Topolnitsa (Vajsov 2007), outside the Vinča culture (Figure 1) which was home to the earliest metallurgy (Radivojević *et al.* 2010). Importantly, the appeal of the black graphite correlates with the wider preference for black lustre in the Chalcolithic Balkan material culture, as well as the sought-after black component in black-and-green copper ores, found to have the most beneficial qualities to facilitate a successful smelt (Radivojević 2015; Radivojević and Rehren 2016). With this in mind, the two crafts are likely to have been generally linked, geographically, technologically and aesthetically, making them 'close cousins' rather than one being the direct precursor to the other.

The bibliographic reference for this chapter is:

Amicone, S., Radivojević, M., Quinn, P. and Rehren, Th. 2021. Pottery technology at the dawn of metallurgy in the Vinča culture, in Radivojević, M., Roberts, B. W., Marić, M., Kuzmanović Cvetković, J., and Rehren, Th. (eds) *The Rise of Metallurgy in Eurasia*: 538–551. Oxford: Archaeopress.

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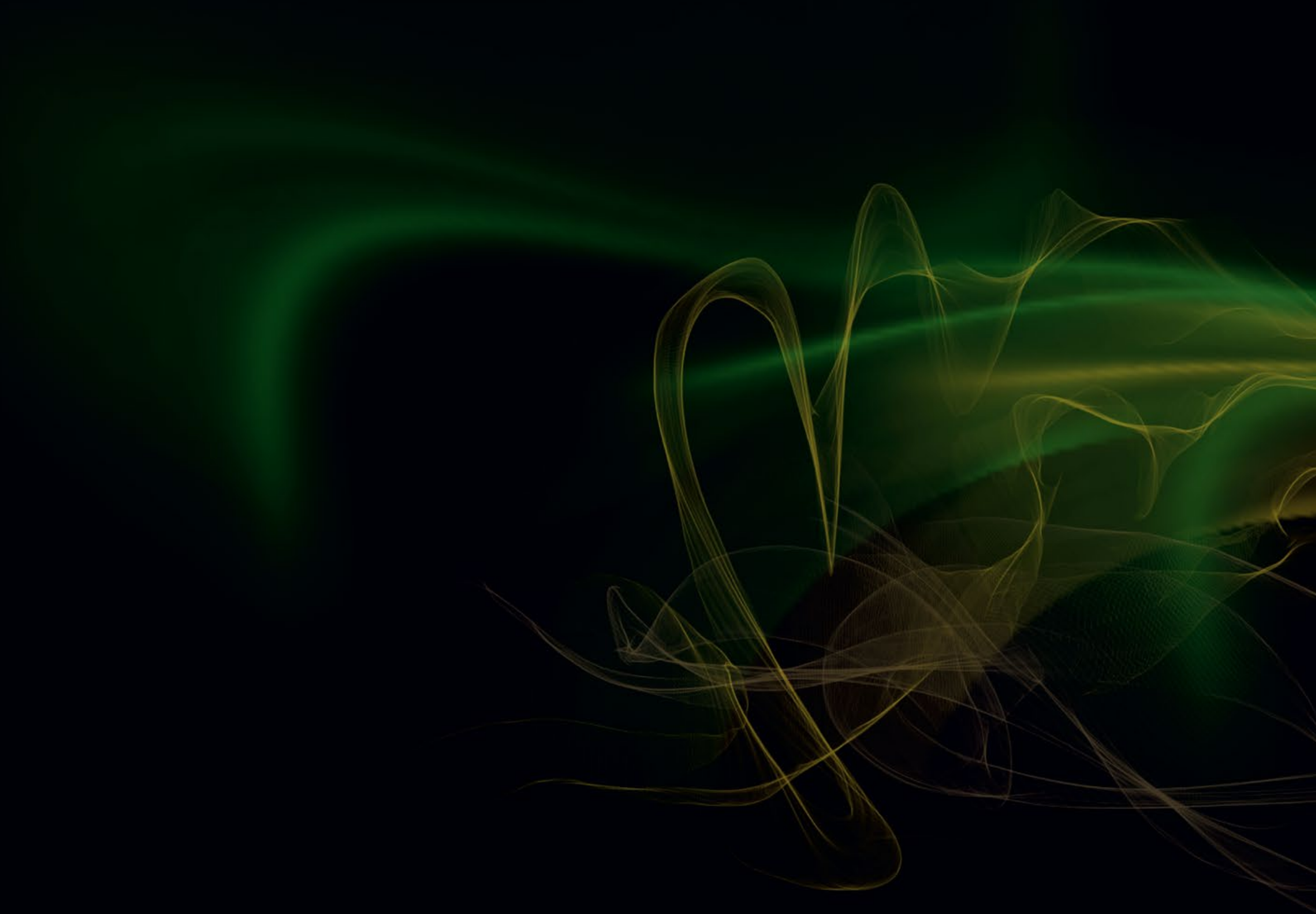

The Rise of Metallurgy in Eurasia is a landmark study in the origins of metallurgy. The project aimed to trace the invention and innovation of metallurgy in the Balkans. It combined targeted excavations and surveys with extensive scientific analyses at two Neolithic-Chalcolithic copper production and consumption sites, Belovode and Pločnik, in Serbia. At Belovode, the project revealed chronologically and contextually secure evidence for copper smelting in the 49th century BC. This confirms the earlier interpretation of c. 7000-year-old metallurgy at the site, making it the earliest record of fully developed metallurgical activity in the world. However, far from being a rare and elite practice, metallurgy at both Belovode and Pločnik is demonstrated to have been a common and communal craft activity.

This monograph reviews the pre-existing scholarship on early metallurgy in the Balkans. It subsequently presents detailed results from the excavations, surveys and scientific analyses conducted at Belovode and Pločnik. These are followed by new and up-to-date regional syntheses by leading specialists on the Neolithic-Chalcolithic material culture, technologies, settlement and subsistence practices in the Central Balkans. Finally, the monograph places the project results in the context of major debates surrounding early metallurgy in Eurasia before proposing a new agenda for global early metallurgy studies.

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