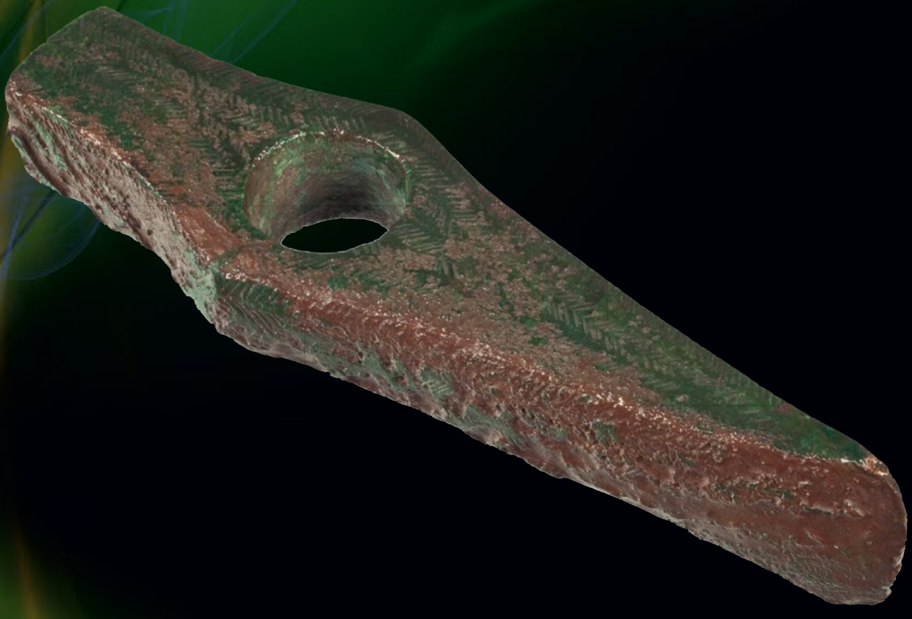
The Rise of Metallurgy in Eurasia

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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(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

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

(1930 – 2015)

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Chapter 3

Balkan metallurgy and society, 6200–3700 BC

Miljana Radivojević and Benjamin W. Roberts

This chapter reviews the pre-existing evidence and interpretations for early mineral use and metallurgy in the Balkans from the earliest use of copper minerals at *c.* 6200 BC (Late Mesolithic-Early Neolithic) to *c.* 3700 BC (end of the Chalcolithic). It presents the empirical and intellectual foundations upon which the data, analyses and interpretations of *The Rise of Metallurgy in Eurasia* project builds. The early metallurgy in this region encompasses the production, distribution and consumption of copper, gold, bronze, lead and silver, all being either pure metals or a natural alloy (tin bronze)[1]. The chapter initially defines the geographical and temporal scope under consideration before evaluating the archaeological and metallurgical evidence in relation to: mineral exploitation; mining; smelting, metals and metal artefacts; and metal circulation. Following each of these sub-sections is a summary of how *The Rise of Metallurgy in Eurasia* project oughtto contribute to this aspect of metallurgical activity, setting this in relation to the project's six research questions as presented in Chapter 2. The chapter concludes by highlighting the dominant interpretative narratives relating to early metallurgy, metallurgists and societies in the Balkans that *The Rise of Metallurgy in Eurasia* project will evaluate, against all the available and relevant archaeological and metallurgical data.

Geographies and chronologies

The cultural, historical and geographical complexities within the widely used term 'Balkans' (Todorova 1997) and the influence of these upon archaeological research (cf. Gori and Ivanova 2017) is acknowledged. For the purposes of this chapter, although we use the geo-political term 'Balkans', defined by the Adriatic Sea to the west, the Ionian and Aegean seas to the south (including southeast and southwest) and the Black Sea to the east, we focus only on those sites that have evidence of mining and metal production and/or use during the indicated time frame. According to the current political divisions of this space, we recognise these sites as located in the states of Serbia, Bulgaria, Romania, Hungary, Bosnia & Herzegovina, Northern Macedonia and Greece, with evidence of the heaviest concentration of metal production and consumption present in the first four of these countries (see Figure 1, Table 1). However, due to the nature of the evidence and the current debates, archaeological and archaeometallurgical research from surrounding geographical regions will also be drawn upon throughout the chapter.

The relative chronological frameworks spanning the Balkans during the absolute date range of this chapter (*c.* 6200–3700 BC) are notoriously complex, largely due to the accumulation of over a century of scholarly traditions that have varied significantly. For instance, in order to avoid confusion, the period related to the emergence of metallurgy throughout southeast Europe is referred to here as the Chalcolithic, replacing the Eneolithic (as used in the former Yugoslavia and Romania) or the Copper Age (as used in Hungary). The potential confusion is especially pertinent with regard to the use of the term Eneolithic by former Yugoslav archaeologists, defined as starting with the beginning of the use of metals from the mid-late 5th millennium BC which, for Bulgarian archaeologists, correlates with the Middle/Late Chalcolithic period, when metals had been widespread for centuries (e.g. Todorova 1995). To facilitate navigation through the various labels used by Balkan archaeologists for the same phenomenon, we will adopt the term 'Chalcolithic' throughout this text, and also the (relative) Chalcolithic periodisation in the Balkans (Early, Middle, Late and Final), as elaborated by Bulgarian scholars.

The application of radiocarbon dating in the past few decades and, more recently, Bayesian statistics, has significantly influenced and strengthened the independent and relative temporal frameworks for Balkan prehistory between *c.* 6200 and 3700 BC (e.g. Bojadžiev 2002; Forenbaher 1993; Georgieva 2012; Görsdorf and Bojadžiev 1996; Higham *et al.* 2007, 2018; Krauss 2008; Krauss *et al.* 2014, 2017; Lazarovici 2006; Luca 1999; Müller 2012; Patay 1974; Pernicka *et al.* 1993, 1997; Orton 2017; Radivojević *et al.* 2010a; Schier 1996, Todorova 1981, 1995; 2014a; Vander Linden *et al.* 2014; Weninger *et al.* 2009; Whittle *et al.* 2016). This is especially true of recent intensive radiocarbon dating and Bayesian modelling of entire stratigraphic sequences at selected, well-excavated sites. Major radiocarbon dating projects

[1] Natural alloy refers to metal alloys produced from smelting complex ores— in this case, copper-tin bearing ores— as opposed to those produced by exposing two or more metallic elements to high temperature treatment through co-smelting, cementation or alloying of metals, ores, or metallic mixtures (i.e. speiss).

across Neolithic Europe led by Alastair Whittle (Whittle *et al.* 2002, 2016; Whittle 2018) have encompassed the sequences of the Balkan Neolithic-Chalcolithic Age sites of Uivar in Romania and Vinča Belo-Brdo in Serbia (Draşovean *et al.* 2017; Draşovean and Schier 2021; Tasić *et al.* 2015, 2016a). A further radiocarbon dating project across Late Neolithic-Early Bronze Age Greece and Bulgaria led by Zoï Tsirtsoni has also recently been completed (Tsirtsoni 2016b). These two major projects are further complemented by a range of smaller radiocarbon dating projects at specific sites such as Okolište in Bosnia (Müller et al. 2013a) and including earlier dating programmes at Belovode and Pločnik in Serbia (Radivojević *et al.* 2010a; Radivojević and Kuzmanović Cvetković 2014). The addition of an extensive number of radiocarbon dates at both Belovode and Pločnik by *The Rise of Metallurgy in Eurasia* project on the newly excavated sequences, enables not only a refinement of the respective site chronologies but also of the broader chronologies of metal and ceramic pyrotechnology and Vinča settlement activity (see Chapters 11, 14, 26, 29).

However, there frequently remains an absence of extensive radiocarbon dating at the majority of late 7th to early 4th millennium BC sites and, invariably, at potential copper mining sites and depositions of metal objects across the Balkans. It is still, therefore, the relative chronological frameworks based on ceramic types and archaeological cultures, frequently identified a century ago, whose absolute date ranges are constantly being refined, as occurred recently with Vinča culture ceramics (cf. Whittle *et al.* 2016). Furthermore, the emergence of rival national traditions of archaeological scholarship in the 20th century across the Balkans has frequently meant that virtually identical archaeological phenomena whose distribution crosses modern national borders have been assigned different nomenclatures, an example being the Starčevo–Körös–Criş cultural complex. Körös and Criş are the names of the same river after which an Early Neolithic cultural phenomenon was named in Hungarian and Romanian respectively whilst Starčevo is the type site in northern Serbia. This results in regional scholarship being

Table 1. Relative and absolute chronology for copper mineral (malachite) and metal-using cultures / archaeological complexes in the 'core' metallurgical zone (Serbia, Bulgaria, parts of Romania) between 6200 BC and 3700 BC. Chronological framework largely based on Schier (1996; 2014), Boyadžiev (1995; 2002) and Whittle et al. (2016). Green font = use of copper minerals (i.e. malachite beads); red = metallurgical materials (i.e. metal artefacts, slags).

Period	C14 dates	Vojvodina	Central Balkans	West Bulgaria	South Bulgaria	Muntenia	North-east Bulgaria	Black Sea Coast (west)
Proto Bronze Age	3200	Boleráz	Cernavoda III	**Galatin**	**Yagodina**	Cernavoda III	**Usatovo**	
Final Chalcolithic	3700	**Salcuţa IV** **Bodrogkeresztúr** **KSBh**				Cernavoda I	**Cernavoda I/Pevets**	Cernavoda I
Late Chalcolithic	4100	**Tiszapolgár / KSBh**		**Krivodol-Salcuţa-Bubanj hum (KSBh)**	**Karanovo VI**	**Kodžadermen-Gumelniţa-Karanovo VI**	**Kodžadermen-Gumelniţa-Karanovo VI**	**Varna III**
Middle Chalcolithic	4450	**Vinča D**			Marica IV	**Boian-Spanţov**		**Varna I** **Varna II** **Hamangia IV**
Early Chalcolithic	4600	**Vinča D** **Vinča C**		**Gradešnica** **Dikilitash-Slatino**	**Marica III- Karanovo V**	Boian-Vidra	Poljanica	**Sava / Hamangia III**
Late Neolithic	5000	**Vinča B** **Vinča A**		Kurilo/Akropotamos Topolnica	Karanovo IV Karanovo III	Boian III	Hotnica	**Hamangia II** **Hamangia I**
Early Neolithic	5500 6200	**Starčevo** **Lepenski Vir III**						

subsequently tasked with identifying the connections between these culture-historical sequences and then proposing new nomenclatures that integrate the pre-existing terms.

It is therefore not uncommon to see debates on the connections between the emergence of metallurgy and the Gradac Phase of Vinča culture ceramic sequence, or the relationship between the development of metallurgy and the widespread graphite painted decoration on the ceramics of the Kodžadermen-Gumelniţa-Karanovo IV (KGK IV) cultural complex (e.g. Amicone *et al.* 2019, 2020b; Garašanin 1994/1995; Jovanović 1971, 1994, 2006; Radivojević *et al.* 2010a; Radivojević and Kuzmanović Cvetković 2014; Renfrew 1969; Spataro *et al.* 2019; Spataro and Furholt 2020; Todorova 1995; Todorova and Vajsov 1993). As is now widely acknowledged in Balkan and world prehistory, the creation of spatial and temporal frameworks through the identification of similarities and differences in materials and practices continues to evade researchers; straightforward explanations are unlikely (cf. Gori and Ivanova 2017; Roberts and Vander Linden 2011; Shennan 2013). It would seem inevitable that, despite well-argued proposals for abandoning relative typologies and cultures in the Balkans due to improved and increased independent scientific dating techniques (Tsirtsoni 2016a), they will very likely endure into future generations of archaeological scholarship.

For the purpose of *The Rise of Metallurgy in Eurasia* project, we use the available relative and absolute dating spanning *c.* 6200–3700 BC throughout the Balkans. We identify six periods reflecting the changing characteristics in the metallurgical evidence that enable questions surrounding metallurgical origins, development and societal inter-relationships to be addressed. These are: *Early Neolithic* (*c.* 6200–5500 BC), *Late Neolithic* (*c.* 5500–5000 BC), *Early Chalcolithic* (*c.* 5000–4600 BC), *Middle Chalcolithic* (c. 4600–4450 BC), *Late Chalcolithic* (*c.* 4450–4100 BC) and *Final Chalcolithic* (*c.* 4100–3700 BC). It should be stressed, however, that in certain areas there are insufficient modern, published excavations, archaeometallurgical analyses and/or resolution of radiocarbon dating for the framework to be evaluated. Our strongest focus remains, therefore, on the modern-day territories of Serbia, Bulgaria, Romania and Hungary (see Figures 1–3), as the core area of activities related to mineral use and metallurgy. The majority of the periods used in the chronological scheme for this article have been employed in earlier frameworks. The identification of a new 150 year long period, spanning the mid-5th millennium BC (*c.* 4600–4450 BC, Middle Chalcolithic), reflects recent dating and current interpretations centred on the iconic—and still currently unparalleled—site of Varna, Bulgaria and the possibility that the site is a reflection of a relatively short regional phenomenon encompassing distinctive metal production and consumption evidenced by a growth in wealth, amongst other observations (e.g. Biehl and Marciniak 2000; Chapman 2013; Schier 2014a).

Mineral exploitation

Copper *minerals* in the archaeological record potentially represent only copper *ores.* Ore is a culturally defined term referring to agglomerations of minerals from which the extraction of one or more metals is seen as a profitable action, largely in pre-industrial times (e.g. Radivojević and Rehren 2016; Rapp 2009; Rehren 1997). In other words, what the modern mining industry considers the economically feasible exploitation of mineral resources today differs from what prehistoric miners saw as an acceptable investment of labour. The significance of this distinction in the context of metallurgical activities has been raised by Muhly (1989), who compared the relationship of malachite (copper carbonate) and copper metallurgy at an archaeological site to that of haematite (iron oxide) in a cave painting with iron metallurgy.

Evidence suggests that use of copper mineral and native copper in neighbouring Anatolia and the Near East occurred much earlier than in the Balkans. The earliest example dates back to the 11th millennium BC Epipalaeolithic burial site of Shanidar Cave, where a malachite bead was deposited as a grave offering (Bar-Yosef and Deborah 2008; Solecki *et al.* 2004: 96). By the 9th millennium BC, native copper and copper minerals were increasingly worked, as at the settlement of Çayönü Tepesi in eastern Turkey, a site which also yielded evidence for the annealing of native copper (Maddin *et al.* 1999; Özdoğan and Özdoğan 1999). This settlement was conveniently located near the rich copper mineralisation Ergani Maden but the exploitation of this source has not yet been demonstrated. By 6000 BC, the use of copper minerals had spread beyond its 'core' zone in Anatolia and northern Mesopotamia to the Levant (Golden 2010), Transcaucasia (Kavtaradze 1999; Courcier 2014), the Balkans (Glumac and Tringham 1990; Thornton 2001; see below), Iran (Pigott 1999; Thornton 2009; Helwing 2013) and Pakistan (Kenoyer and Miller 1999; Hoffmann and Miller 2014). The strong association of intensive copper mineral use and agriculture is apparent and has been advocated as inherently related to the strong symbolism of its green colour in relation to crop fertility (Bar-Yosef Mayer and Porat 2008). The study by Bar-Yosef Mayer and Porat (2008: 8549, Table 1) also showed that copper minerals were not the only 'green' option for the Near Eastern (Pre)Neolithic communities, since ornaments made of apatite, turquoise, amazonite or serpentinite were also sought for their visual properties.

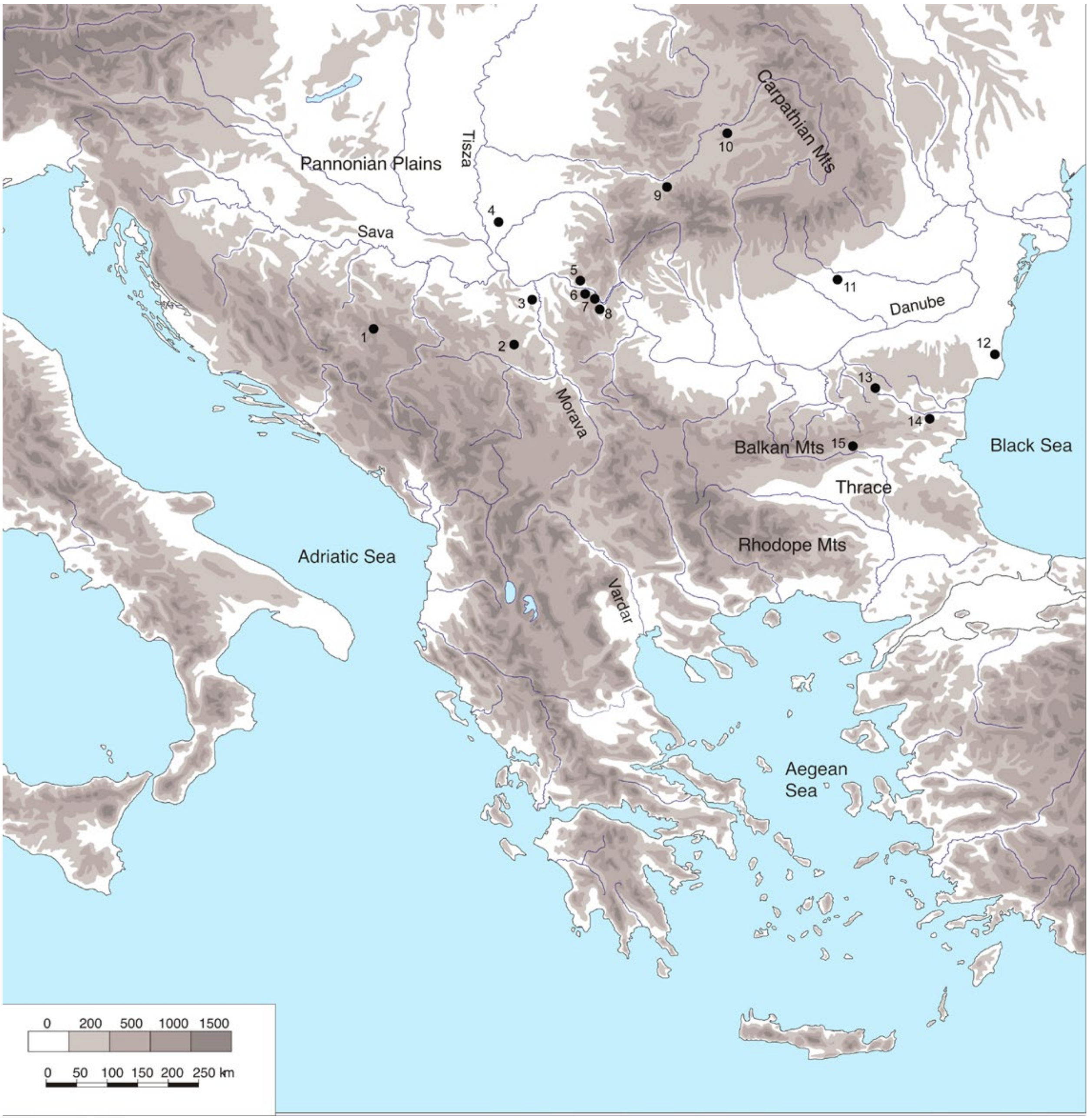

Figure 1. Map of the Early Neolithic sites (*c.* 6200–5500 BCE) mentioned here. 1- Obre I; 2- Divostin; 3- Zmajevac; 4- Szarvas 23; 5- Gornea; 6- Lepenski Vir; 7- Vlasac; 8- Rudna Glava; 9- Balomir; 10- Iernut; 11- Cernica; 12- Durankulak; 13- Ovcharovo I; 14- Usoe I; 15- Karanovo; 16- Kolubara-Jaričište. (map CC BY-NC-ND 4.0 J. Pendić and M. Radivojević)

The earliest evidence for the use of copper minerals in the Balkans occurs during the transition to the Early Neolithic (or the emergence of Starčevo-Criş-Körös culture groups) in *c.* 6200–5500 BC, with evidence spanning the Carpathian Basin, Moldavia, western Ukraine and northern Balkans (Bognár-Kutzián 1976: 70–73). The earliest exploitation of copper minerals was possibly by hunter-fisher-gatherer communities (likely mixed with the early farming population migrating from Anatolia, see for instance Mathieson *et al.* 2018), as indicated by samples discovered at Lepenski Vir, Vlasac and Kolubara-Jaričište (Figure 1), and dated to *c.* 6200 BC (Radivojević 2015: 325; Srejović and Letica 1978: 11–14). The processing of copper minerals and native copper developed within the subsequent Neolithic Starčevo-Criş-Körös culture groups, which mostly produced beads from malachite [$Cu_2CO_3(OH)_2$] or azurite [$Cu_3(CO_3)_2(OH)_2$]. In addition to malachite and azurite beads from Lepenski Vir and Divostin I (Glumac1988: 460; Radivojević 2012; Srejović 1969: 173; Srejović 1972: 146), similar items were found in the cemeteries of Cernica in southern Romania and Durankulak in northeastern Bulgaria, and settlements of Obre I in Bosnia, and Ovcharovo I and Usoe I in Bulgaria (Figure 1) (Cantacuzino and Morintz 1963: 72–75, Figure 28, 18, 19; Pernicka *et al.* 1997: 44; Sterud and

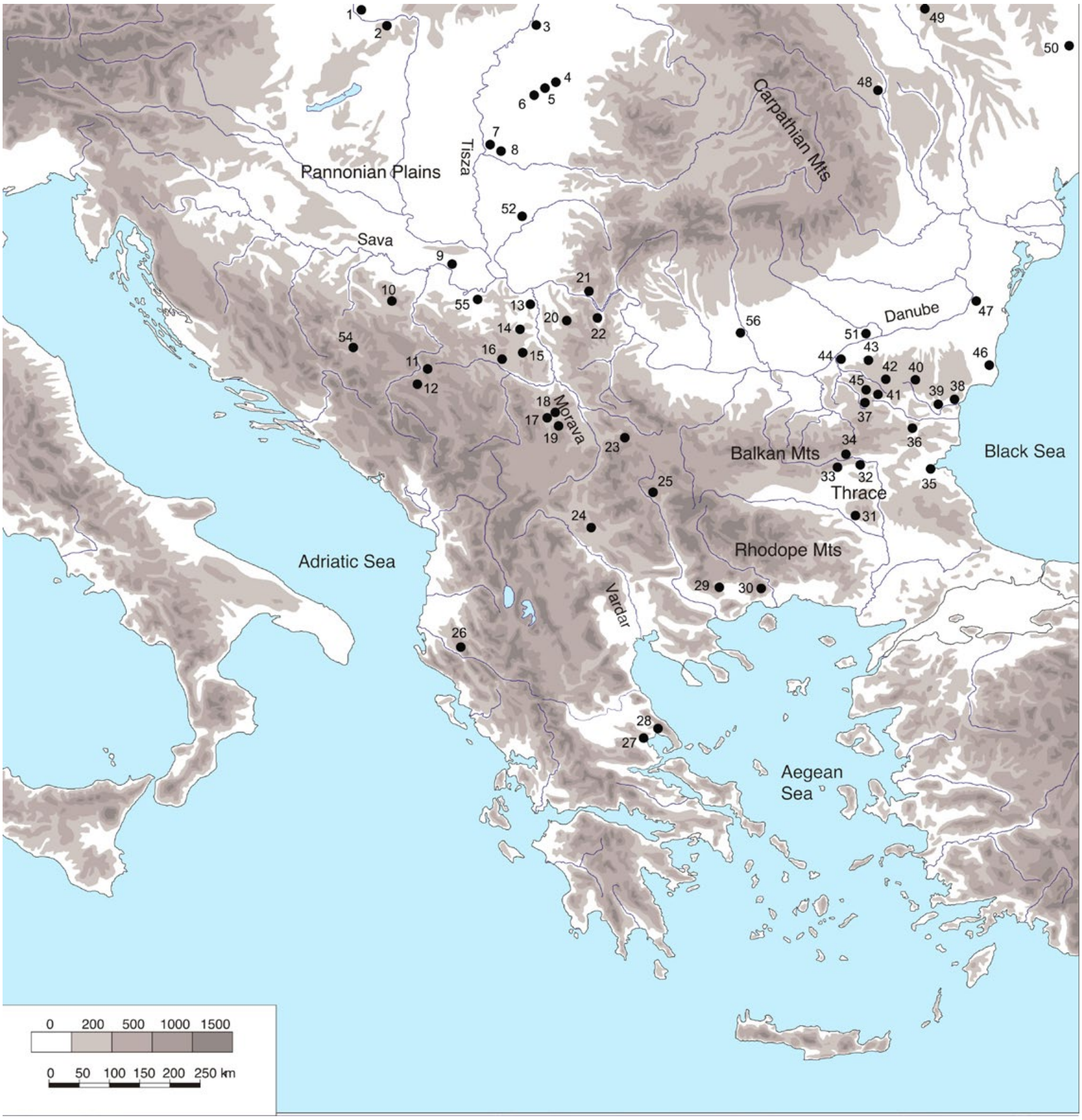

Figure 2. Map of the Late Neolithic / Early Chalcolithic sites (*c.* 5500–4600 BCE) mentioned here. 1- Mlynárce; 2- Neszmély; 3- Csöszhalom; 4- Hérpály; 5- Berettyószentmárton; 6- Zsáka- Markó; 7- Hódmezővársahely-Kopáncs-Kökénydomb; 8- Gorsza; 9- Gomolava; 10- Gornja Tuzla; 11- Stapari; 12- Jarmovac; 13- Selevac; 14- Mali Šturac; 15- Divostin; 16- Ratina; 17- Pločnik; 18- Merovac; 19- Mačina; 20- Belovode; 21- Gornea; 22- Rudna Glava; 23- Hisarluka; 24- Anzabegovo; 25- Slatino; 26- Kamnik; 27- Dimini; 28- Sesklo; 29- Sitagroi; 30- Dikili Tash; 31- Maritsa; 32- Azmashka Mogila; 33- Ai Bunar; 34- Karanovo; 35- Medni Rid; 36- Golyamo Delchevo; 37- Targovište; 38- Varna; 39- Devnja; 40- Vinitsa; 41- Ovcharovo; 42- Radingrad; 43- Kubrat; 44- Ruse; 45- Polyanica; 46- Durankulak; 47- Cernavodă; 48- Izvoare I; 49- Lukavrublevetskaya; 50- Karbuna; 51-Pietrele; 52-Foeni; 53-Ždrelo; 54 – Okolište; 55- Stubline; 56- Reșca (map CC BY-NC-ND 4.0 J. Pendić and M. Radivojević).

Sterud 1974: 258; Stratton et al. 2019; Todorova 1981: 4; Vlassa 1967). Lumps and flakes of copper minerals were also identified in the settlements of Zmajevac in eastern Serbia and Szarvas 23 in Hungary (Chapman 1981: 131; Chapman and Tylecote 1983: 375; Comşa 1991: 51; cf. Bailey 2000: 210) (Figure 1). Malachite beads and copper minerals are also commonly found in early Vinča culture settlements (pre-5000 BC) at the sites of Belovode, Pločnik, Vinča-Belo Brdo, Selevac and Medvednjak (Figure 2), and occur continually until the abandonment of the settlements, and throughout other, later Vinča culture manifestations, such as Gomolava (Glumac and Tringham 1990; Radivojević 2012; Radivojević and Kuzmanović Cvetković 2014; Šljivar 1993-2009; Šljivar and Kuzmanović Cvetković 1996-2009). Significantly, at Divostin II (Vinča D phase), malachite beads and a

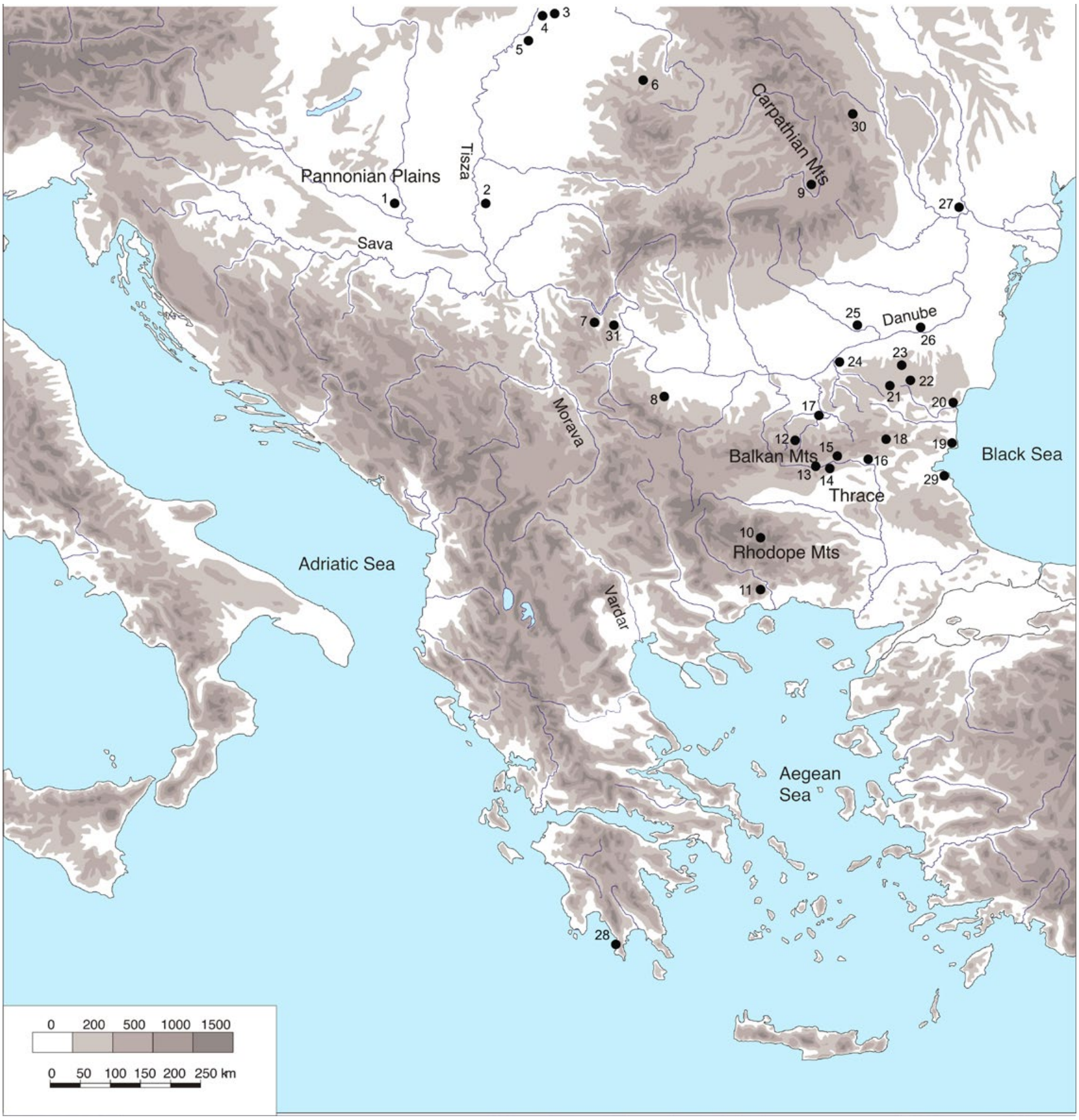

Figure 3. Map of the Middle, Late and Final Chalcolithic sites (4600–3700 BCE) mentioned here. 1- Zengővárkony; 2- Tiszapolgár-Basatanya; 3- Tibava; 4- Lucska; 5- Tiszapolgár-Hajdúnánás Road; 6- Moigrad; 7- Lazareva cave; 8- Gradeshnitsa; 9- Ariuşd; 10- Dolnoslav; 11- Dikili Tash; 12- Hotnica; 13- Bereketska Mogila; 14- Ai Bunar; 15- Karanovo; 16- Chatalka; 17- Kačica; 18- Smjadovo; 19- Kasla- Dere; 20- Varna; 21- Kodžadermen; 22- Bubanj; 23- Mečkjur; 24- Ruse; 25- Vidra; 26- Gumelniţa; 27- Traian; 28- Alepotrypa Cave; 29-Akladi Cheiri; 30-Poduri; 31-Kmpije; 32- Bubanj (map CC BY-NC-ND 4.0 J. Pendić and M. Radivojević).

metal bracelet were predominantly found in a group of large houses (McPherron and Srejović 1988) and were interpreted as a possible indication of the higher status of the occupants on the basis that larger households would have a larger labour force available to create a surplus and therefore an economic advantage (Porčić 2012a).

The provenance analyses of most of the Lepenski Vir, Vlasac and Vinča culture sites minerals indicated the use of local sources, predominantly Majdanpek in eastern Serbia, then Ždrelo (near Belovode, Figure 2) and an as yet unidentified copper source consistent with most of the Pločnik minerals and metal artefacts and copper slags from Belovode (Pernicka *et al.* 1993: 6, 1997: 93 ff.; Radivojević *et al.* 2010a: 2784, Figure 10; Radivojević 2012: 393 ff.). The only securely dated source where there is evidence for copper mineral exploitation within this period is the site of Rudna Glava, in Serbia (Figure 2) where copper mining

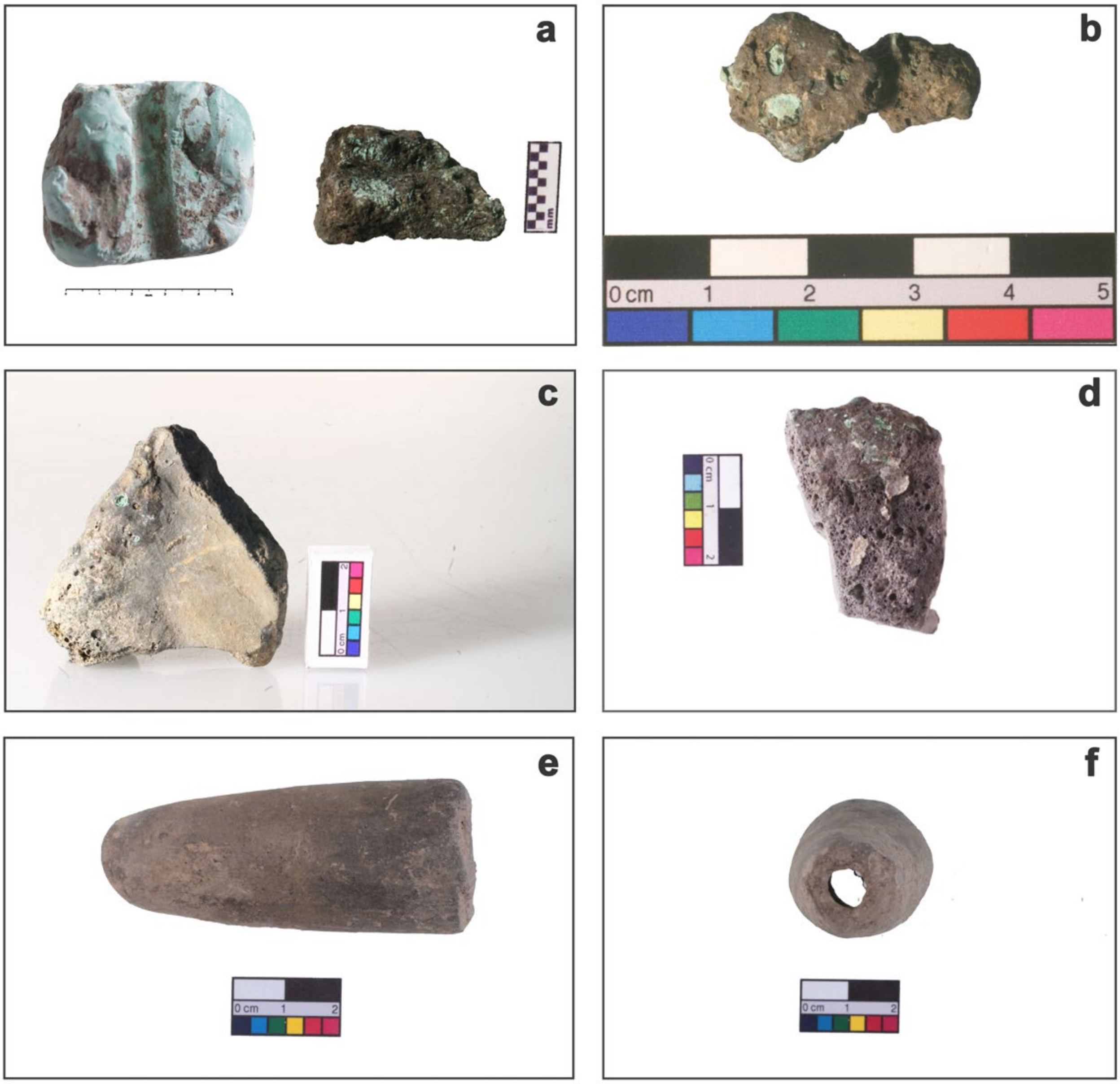

Figure 4. Copper mineral and metallurgical evidence from mid-6th – mid-5th millennium BC. a) typical malachite bead on the left and a black-and-green mineral on the right (Belovode); b) copper slag from Belovode; c) ceramic sherd with copper slag overflowing its top, most likely used to line a hole-in-the-ground smelting installation (Belovode); d) ceramic sherd with copper slag (Foeni); e & f) ceramic nozzle, potentially used for (s)melting (Bubanj, see also in Bulatović 2015) (adapted after Radivojević 2012; CC BY-NC-ND 4.0 M. Radivojević & Lj. Radivojević).

activities intensify from *c.* 5500 BC in parallel with copper mineral use at nearby Belovode (Radivojević and Kuzmanović Cvetković 2014; O'Brien 2015). Importantly, the inhabitants of this site distinguished between pure green copper *minerals* (malachite) used for bead making and 'tainted' black-and-green copper *ores* for the smelting charge (Figure 4a). This argument was further strengthened by the identification of a distinctive lead isotope signature for the bead minerals and smelting ores at Belovode, indicating existing knowledge of the different properties of these materials (Radivojević *et al.* 2010a: 2784). Similar practices of distinguishing between pure green copper minerals and black-and-green manganese-rich copper ores have been detected throughout the entire Vinča occupation at the sites of Vinča-Belo Brdo and Pločnik (Figure 2, Figure 4a), indicating a similar awareness of the material properties of these distinctive copper occurrences for *c.* 800 years across all these settlements (Radivojević and Rehren 2016: 215).

In light of this existing evidence for the exploitation of copper minerals and potential copper ores and the debates surrounding their interpretation, *The Rise of Metallurgy in Eurasia* project retrieved, recorded and spatially mapped each and every fragment of copper mineral excavated at Belovode and Pločnik. This provided the most comprehensive possible range of stratified samples for analysing and evaluating patterns of exploitation in space and time relating to the provenance, selection, organisation and uses of the minerals/ores and contributing to Research Questions 1, 3 and 6 (see Chapters 11 and 26).

Mining

The only copper mining activities in the Balkans that have been securely dated to the 5th millennium BC occur at two sites: Ai Bunar in central Bulgaria (Chernykh 1978a; Pernicka *et al.* 1997) (Figure 2), and Rudna Glava in eastern Serbia (Jovanović 1971; O'Brien 2015). Rudna Glava (Jovanović 1980, 1982) is the earliest documented copper mine, not only in Europe but across Eurasia, and is radiocarbon dated to c. 5400-4650 BC (O'Brien 2015; Pernicka et al. 1993; Radivojević and Kuzmanović Cvetković 2014). It consisted of eight groups of mine shafts with access platforms, all following veins rich in magnetite, chalcopyrite and carbonate copper ores. Near the entrances and inside the shafts, hoards of distinctive Vinča culture-style ceramics were found, dating from the Gradac Phase, broadly between the early and mid-5th millennium BC (the later dates associated with a prolonged Gradac Phase in the southern Serbian sites), together with stone mallets and deer antler tools. Mining activities at Rudna Glava peaked around *c.* 5000 BC. Despite this extensive evidence for mining, no analyses prior to *The Rise of Metallurgy in Eurasia* project had confirmed that any analysed metal artefact from the Balkans was made from the Rudna Glava copper ores (Pernicka *et al.* 1993: 2; Pernicka *et al.* 1997: 143; for opposing view see Jovanović 1993; see Chapter 41 for the current state of research). Having visited and surveyed the area around Rudna Glava in various capacities from 2009, we contend that ancient mining evidence at this site survived only as a result of Rudna Glava not being particularly rich in malachite. Conversely, Majdanpek, the most abundant deposit of copper, which has lasted into modern times, is only 12 km away from Rudna Glava, and provenance analysis has long indicated Majdanpek copper to be one of the main sources for Vinča copper implements (Pernicka *et al.* 1993, 1997; Radivojević 2012).

Ancient mining activities are also known from several localities within Serbia, some potentially dating to the 5th millennium BC. These are: Ždrelo in eastern Serbia (near Belovode), Mali Šturac in central Serbia, Medvednik in western Serbia and Jarmovac in the southwest (Figure 2) (Antonović 2014a; Jovanović 1971; Pecikoza 2011; Radivojević *et al.* 2010a). In Mali Šturac on Mt. Rudnik in central Serbia, grooved stone mallets resembling those from Rudna Glava were recovered, leading scholars to believe that they were of the Vinča culture provenance (Bogosavljević 1995; Jovanović 1983). More recent and ongoing excavations at this site yielded additional material that roughly dates this mine to the mid to late 5th millennium BC (Antonović and Vukadinović 2012; Antonović *et al.* 2014). Furthermore, grooved stone tools, identical to those discovered at Rudna Glava and Mali Šturac, were found during field surveys of the Vinča culture settlements of Mačina and Merovac (Figure 2), both situated in the vicinity of the ore-rich deposits at Mt. Kopaonik and Radan in southern Serbia (Kuzmanović Cvetković 1998; Radivojević 1998); these are comparable with stone tools at mining sites throughout Europe (cf. De Pascale 2003; O'Brien 2015).

The Mid-Late Chalcolithic (*c.* 4600–(4450)–4100 BC) was dominated by exploitation of Bulgarian sources, predominantly at Ai Bunar in Bulgaria (Chernykh 1978b: 54–75). This source, near Stara Zagora in central Bulgaria (Figure 2), was much larger and had more productive efficiency than Rudna Glava, with shafts up to 500 m long. The material associated with the site belongs to the Kodžadermen-Gumelniţa-Karanovo (KGK) VI cultural complex and is therefore relatively dated to the mid to late 5th millennium BC (Chernykh 1978a, 1978b, 1992). Metal from Ai Bunar is known to have travelled long distances within the Balkans, as far south as Thessaly, and as far north as the northern Black Sea coast (Chernykh 1978b: 122, 263; Gimbutas 1977: 44; Pernicka *et al.* 1997; Radivojević and Grujić 2018; Renfrew 1972: 308, Figure 16/2). However, the results of provenance analysis suggested the exploitation of more than one copper deposit in this period, for example, that from Medni Rid, in southeastern Bulgaria (Pernicka *et al.* 1997: 143–146). The most recent excavations in this location revealed materials from Roman and later times, although some indicate exploitation activities by the communities of the KGK VI cultural complex (Leshtakov 2013), also supported by recently analysed metal production evidence from Akladi Cheiri (Figure 3), a settlement nearby. Metal production at this site is argued to date to the late KGK VI, or broadly to the middle of the 2nd half of the 5th millennium BC, based on the typology and ornamentation of pottery found in the same pit as metallurgical evidence (Rehren *et al.* 2016: 207; Rehren *et al.* 2020). The exploitation of the Medni Rid ores may have started earlier, given the finds of late 6th millennium BC malachite in nearby settlements or its use for making metal items in the Karbuna hoard which was found in a typical Tripolye A pot (*c.* 4700–4600 BC) (Figure 2) (cf. Pernicka *et al.* 1997; Rehren *et al.* 2016).

Rather than being mined, from *c.* 4650 BC Balkan gold was most likely collected from river streams as alluvial (washed) nuggets that had eroded from primary deposits (Avramova 2002; Boyadžiev 2002; Makkay

1995: 70). This suggestion has been elaborated recently in a study of Varna gold, where Leusch *et al.* (2014) presented a diversity of different gold, copper and silver ratios in the excavated gold artefacts, explaining them as originating from natural compositional variations in (alluvial) gold nuggets. This in turn demonstrates that various gold occurrences were exploited for the making of Varna gold, and possibly acquired through a well organised gold supply network (Leusch *et al.* 2015). Such supply networks also procured copper, *Spondylus*, carnelian, marble, serpentinite, long yellow flint blades (superblades) and other prestige commodities unearthed as paraphernalia in the Varna cemetery (Leusch *et al.* 2017).

In light of the existing evidence for mining, *The Rise of Metallurgy in Eurasia* project analysed the trace elements and lead isotopes of the newly excavated copper mineral and metal artefacts at Belovode and Pločnik in order to explore their provenance in relation to known and potentially unknown copper mining sites (Chapter 41). The project also excavated the potentially Chalcolithic mining site at Jarmovac (southwest Serbia) in conjunction with the Priboj on Lim Homeland Museum and the German Mining Museum in Bochum. This complex of ancient mines was first mentioned by Davies (1937) who identified Vinča culture sherds in one of the shafts. The site was previously excavated by the local museum authorities, who discovered an associated settlement with a Late Vinča culture phase (Vinča D) only 300 m away (Bunardžić *et al.* 2008: 86; Derikonjić 2010). The new excavations sought to obtain evidence of mining activity, stratified samples which would enable radiocarbon dates, and the analysis of the trace element and lead isotopes of the copper ores being mined for comparison to existing results in the region. The results will be published elsewhere; they detail the recovery of an antler pick fragment from a stratified sequence radiocarbon dated to the mid-4th millennium BC combined with trace element and lead isotope analyses demonstrating that the mine was most likely used to produce copper objects in the 5th millennium BC (Thomas *et al.* in preparation). All these results contribute to Research Questions 1, 3 and 6 of the project although it is highly likely that further mining sites remain to be discovered along the rich metallogenic belt running through the Balkans (cf. Janković 1977).

Smelting

Smelting evidence from the Early Chalcolithic is extremely scarce and mostly constrained to the Vinča culture phenomenon in the central Balkans (Table 1, Figure 4b-d). Prior to more analytically extensive studies of the early metal production debris from a selected number of Vinča culture sites (Glumac 1991; Radivojević 2007, 2012), there was mention of a copper slag lump from the settlement site of the Anzabegovo in the eastern part of Northern Macedonia (Figure 1), dated to *c.* 5200 BC (Gimbutas 1976a), although this has never been chronologically or analytically verified. Moreover, in its relative regional vicinity, though in the valley of Strymon River at the Greek-Bulgarian border, is the site of Promachon-Topolnica, which has yielded indicative field structures ('hollows' with traces of copper), of which the most important is a small clay crucible with a spout, dated broadly to the first half of the 5th millennium BC (Koukouli-Chryssanthaki et al. 2007: 51, Fig. 7.4). While the authors reported that the crucible contained traces of non-slagging copper processing with distinct traces of heavy burning, no analysis are made available, which makes its more accurate identification challenging. A similarly vague situation applies to the situation in the site of Stapari (Figure 2), where an alleged lump of slag was dated relatively to within the late Vinča culture phase (Jurišić 1959). Pieces of 'greenish slag resulting from intense fire' were reported at depths of ▼6.2, ▼6.4 and ▼7.0 m at Vinča-Belo Brdo (M. Vasić excavations), however no further analysis or details of these finds are available (Antonović 2002: 36, note 59). Microstructural, chemical and isotopic analysis of copper slag and other production evidence from the sites of Belovode, Vinča-Belo Brdo (N. N. Tasić excavations), Pločnik, Gornja Tuzla and Selevac are the first secure evidence for sustained metallurgical activities within the Vinča culture and highlight its role as the core archaeological phenomenon in the evolution of Balkan metallurgy (Glumac and Todd 1991; Govedarica 2016; Radivojević 2012; Radivojević and Rehren 2016; cf. Čović 1961).

The estimated chronological sequence of the finds studied by Radivojević (2015) starts with the Belovode slags at *c.* 5000 BC (until *c.* 4600 BC), which overlaps for around 200 years with the Vinča-Belo Brdo production evidence (dated in the range of *c.* 4800–4600 BC). Copper smelting took place at the settlement of Gornja Tuzla for up to 200 years after both Belovode and Vinča were abandoned (*c.* 4400 BC). Both macro- and micro-analytical approaches demonstrate that copper smelting was, in total, practiced throughout *c.* 600 years, with remarkable similarities in the level of expertise and technological choices, but with clear differences in the composition of the ores smelted. The striking detail that underlines the chemistry of ores smelted at the sites of Belovode, Vinča, and Gornja Tuzla is their dominant colour: whatever the exact minerals that were present in the ore charge, they most likely had strong colours in the range of green/blue (vivianite, arthurite, apatite, scorodite), and violet (strengite), in addition to black and green Mn-rich malachite

(Belovode and Vinča only). Such a conclusion has been corroborated by a detailed inspection of slag matrices and residual ores found in them. It is also important to underline that the indicated ores were not necessarily copper rich ones. Rather, they had striking green/blue/violet colours that attracted the Vinča prospectors (Radivojević and Rehren 2016: 225 ff.). Although it is not clear from the analyses whether black and green minerals were selected separately or as a mixed ore, the conclusion that emerges from the analytical discussion is the presence of a common knowledge regarding the suitability for smelting of distinctively coloured mixed minerals. Noteworthy is the ongoing analytical study of slagged sherds and a metal object from the site of Foeni in Romania (Figure 2), contemporary with the Vinča culture metal production which, in principle, confirms similar technological choices for early metal extraction across the Balkans (Draşovean 2006; Radivojević *et al.* in preparation).

The Vinča culture metal production practice fits well within the 'ephemeral model' of Chalcolithic metallurgy in western Eurasia (Bourgarit 2007); the individual slags weigh a little less than 10 g in total (see example in Figure 4b). This is commonly explained by the use of much cleaner ore at the early stages, resulting in a 'slagless' or nearly slagless metallurgy (cf. Craddock 1995). Depending on the relative proportions of (slag-forming) dark components in the ore and pure green mineral, a large amount of copper may have formed with only a small quantity of slag; this is the favoured scenario in the recent analytical studies (Radivojević and Rehren 2016: 227 ff). Of note though is the discovery of a lead-based slag cake in the undisturbed horizon dated to 5200 BC at Belovode, and weighing nearly 800 g. As this is a unique find currently unsupported by evidence for sustainable lead metal production, it will be addressed in detail in the 'Lead and silver' section below.

The structures in which smelting took place—so-called smelting 'furnaces'—are evidenced primarily by slagged sherds at both Belovode and Gornja Tuzla (example in Figure 4c–d), which suggest the presence of a hole-in-the-ground installation lined with broken pottery. Such installations were possibly operated by using blowpipes or bellows, where five to six blowpipes would normally suffice to bring the temperature to around 1100–1200 ºC (cf. Rehder 1994: 221). The only indication of how these blowpipes may have looked is found in the ceramic nozzles recovered from the sites of Bubanj (Figure 4e-f) and Kmpije in Bor (Figure 3). In the absence of any other evidence, the hole-in-the-ground installations appear to be the only technological possibility for primary metal production in the early to mid-5th millennium BC (see Figure 4c, 4d). In addition, although analysed crucibles are absent from the record, their presence must be assumed, given that they would have been needed for (re)melting and casting of the thousands of heavy metal objects known from this period. There is a possibility though, to identify as crucibles two oval, ladle-like vessels with a short, vertically pierced handle and secondary traces of firing, from the site of Reșca-Dâmbul Morii, in Vallachia (Romania, Figure 2), (Stefan 2018: 119, Table VII/1, 2). These have not yet been analysed, and their context is still under discussion, although argued to belong to the Vădastra culture horizon, which dates between 5200 and 5000 BC; nevertheless, this is the closest potential clue to how crucibles might have appeared during this period. Curiously, the casting moulds that are firmly contextualised for the vast number of metal implements produced in this period are also absent from the archaeological record (Kienlin 2010: 42 ff; Heeb 2014).

Copper production evidence is still scarce in the Mid-Late Chalcolithic (*c.* 4600–4100 BC), although it is documented in more settlements than for the previous period. In Bulgaria, copper smelting evidence comes from the sites of Dolnoslav, Chatalka and Akladi Cheiri (Figure 3), all dated to the mid to late 5th millennium BC (Ryndina *et al.* 1999; Rehren *et al.* 2016, 2020). All three sites yielded crucibles, amongst other finds, although only the Dolnoslav and Akladi Cheiri examples were preserved. The crucible from Dolnoslav was a vessel with an oval plan, round base and 10–25 mm thick walls (Ryndina *et al.* 1999); the well-preserved example from Akladi Cheiri had a similar flat oval base though the frontal part slightly profiled as a spout (Rehren *et al.* 2016: 207, Figure 2). Microstructural and compositional analyses of the Dolnoslav crucible indicated smelting of polymetallic ores (a mix of malachite with primary copper ores), which were rich in zinc and lead oxide (Ryndina *et al.* 1999: 1066, Table 2). The dominant presence of zinc and lead in the slag matrix, together with copper oxide in trace amounts, presents a copper smelting technology that is different and possibly more efficient than that encountered in the Vinča culture with slags rich in manganese oxide (Radivojević 2015: 332, Table 2). The Akladi Cheiri example on the other hand was for (re)melting: its inside was contaminated with copper and no other evidence for gangue elements such as iron, cobalt or sulfur (Rehren *et al.* 2020: 152). These are the earliest crucibles in the Balkans and become more common only from the mid-4th millennium BC Baden culture in the north-central Balkans (Ecsedy 1990: 224; Glumac and Todd 1991; Radivojević *et al.* 2010b).

More examples, although not analytically confirmed, come from the late 5th millennium BC Tiszapolgár culture cemetery of Tibava (Figure 3), in the form of a cylinder vessel with a crude inner surface, identified amongst pottery grave goods (Andel 1958: Plate I/7;

Šiška 1964: 317, Figure 12/5). It was thought to be a melting pot but was never analysed (Bognár-Kutzián 1972: 134). Another crucible described as a 'vessel covered with blue verdigris and with two small copper crumbs' was discovered among grave goods in the cemetery of Tiszapolgár-Hajdúnánás Road (Figure 3) and has been unfortunately lost (Bognár-Kutzián 1972: 98, 134). The ceramic vessels widely interpreted as crucibles at Cucuteni A2 and B1 levels at the site of Poduri-Dealul Ghindaru in Romania (Figure 3) (Mareş 2002: 85, 138–139, Table 64/8) have yet to be subjected to archaeometallurgical analyses so cannot be considered as confirmed metal production evidence despite the presence of two copper ingots from the same site (Monah *et al.* 2002). A similar situation is encountered in Sitagroi (phase III, roughly contemporary with KGK VI), where an assemblage of thirty-six slagged sherds, accompanied by copper metal artefacts, present a convincing evidence for local copper smelting as well as a distinctively similar slagging pattern to contemporaneous Akladi Cheiri for instance (Renfrew and Elster 2003: 306). These sherds are yet to be subjected to detailed technological analysis.

The hole-in-the-ground smelting installations identified earlier in the Vinča culture sites find parallels at the site of Akladi Cheiri, near Sozopol in Bulgaria (Figure 3), where an exceptional discovery of 300 ceramic sherds with traces of firing and slag adhered to them testifies to intensive metal production activities in the foothills of the Medni Rid copper deposits, dated to later phases of the KGK VI complex (Rehren *et al.* 2016). This mid to late 5th millennium BC metallurgical workshop contains fragmented slagged sherds (that possibly lined a hole in the ground), associated slags and the melting crucible mentioned above and similar to those hypothesised at the Vinča culture sites of Belovode and Gornja Tuzla (Radivojević and Rehren 2016). Analysis of slag from Akladi Cheiri revealed features already observed for early copper smelting, such as a high degree of variability in glassy to micro-crystalline slag matrix and the formation of inclusions, paired with equally varied redox conditions. The presence of fayalite, clusters of magnetite with matte and copper metal, copper sulphides, olivine crystals, delafossite and cuprite across the studied assemblage speaks of unstable firing conditions during the smelt and different levels of exposure of the slagged sherds during the smelting events (Rehren *et al.* 2020), all of which are known features of the earlier examples from the Vinča culture. More slagged sherds from the mid to late 5th millennium BC come from the site of Kmpije in Bor in eastern Serbia (Figure 3), where a slagged sherd was discovered in association with copper metal artefacts. Analytical work is underway in collaboration with one of the authors (MR) and I. Jovanović from the Mining Museum in Bor.

Interestingly, a piece of slag was deposited as a grave offering in the late 5th millennium BC Lengyel culture cemetery of Zengővárkony (Figure 3), Hungary. It was found in a well-contextualised grave of a middle-aged woman, together with numerous ceramic vessels and two pure copper spiral bracelets on each arm (Dombay 1939; Glumac and Todd 1991: 14). Slag analyses revealed mineral phases of cuprite and cassiterite, copper metal prills with a significant content of tin, ranging from 0.4 to 37 wt%, as well as relevant concentrations of tin in slag silicates (Glumac and Todd 1991: 14). Ottaway and Roberts (2008: 197) discuss this find as accidental co-smelting of copper and tin-bearing ores since, compositionally, it predates tin-alloys in the region. The recently discovered piece of tin bronze foil at the site of Pločnik in south Serbia, dated to *c.* 4650 BC (Radivojević *et al.* 2013) opens the possibility for the potential intentionality of the Zengővárkony copper-tin slag. In terms of cultural significance, Glumac and Todd (1991: 15) argue that copper smelting might have had a ritual role for the community buried at Zengővárkony. This view is supported by the discovery of more copper smelting debris in the early 4th millennium BC Lengyel culture burial site of Brzec Kujawski, central Poland.

In light of this existing evidence for smelting copper ores, *The Rise of Metallurgy in Eurasia* project retrieved, recorded, spatially mapped and analysed each fragment of copper slag excavated at Belovode and Pločnik as well as any associated finds and features (see Chapters 11 and 26). In addition, experimental reconstructions of copper smelting processes were performed to evaluate different interpretations of the existing evidence in relation to the creation of metal. Whilst these will be published elsewhere, the experimental reconstructions have provided strong evidence in relation to the extensive and co-ordinated labour and the material and pyrotechnological expertise required to reproduce early copper smelting. The results from the excavated slag analyses and experimental reconstructions enable the multiple debates surrounding the technology and organisation of copper smelting spanning Research Questions 1, 3 and 6 to be addressed.

Ceramic and metal pyrotechnologies

It is important to note that the smelting of copper ores was by no means the earliest application of pyrotechnology in either the Balkans or Anatolia. The transmission of ceramic forms and pyrotechnology from Anatolia to the Balkans occurred from *c.* 6600 BC, with ceramic production and consumption subsequently being extensively practiced and developed by early farming communities (Amicone *et al.* 2019; de Groot 2019; Spataro and Furholt 2020). Given that this process started around 1500 years before the earliest evidence for metallurgy in the Balkans or elsewhere, it leads us to the issue of the interdependence of pottery and metal pyrotechnologies.

The most common question with regards to this relationship is whether the ability to create and manage high temperatures (exceeding *c.* 1000 °C) could have led to the transformation of copper ore to copper metal. Earlier studies of Vinča pottery indicated that potters were not achieving temperatures beyond *c.* 900 °C (1083 °C is the melting temperature for copper) (Kingery and Frierman 1974: 204–205). Compositional analysis of the Vinča culture pottery revealed that all fine, medium and coarse fabrics were made of low calcareous clay (less than 6% CaO) and was normally fired under reducing conditions below 800 °C (Maniatis and Tite 1981: 73). In contrast, Renfrew's (1969) suggestion of a direct connection between the production of graphite painted ceramics and the invention of copper metallurgy provided a new explanatory framework. This pyrotechnological transfer model was subsequently also advocated by Gimbutas (1976a); however, this claim was not investigated from a pyrotechnological comparative perspective until *The Rise of Metallurgy in Eurasia* project nearly four decades later.

Frierman (1969) reported a two-step process of firing graphite-painted pottery, broadly similar to the two-step process of the earliest metal smelting reconstructed by Radivojević and colleagues (2010b: 2777). Specifically, experiments showed that graphite burns at 725 °C in an oxidising atmosphere, leading Frierman (1969: 43) to assume that pots coated with the graphite slip were fired in an oxidising atmosphere up to *c.* 500 °C or 600 °C, after which the atmosphere for the remainder of the firing had to be strongly reducing over a prolonged period to preserve the graphite. The use of a slow firing process under the reducing conditions is further corroborated by the evenness and the black colour of the resulting surfaces. This is important to the broader debate as the principle of two-step firing also applies to the reduction of copper ores to copper metal, however in reverse order: chemical reduction from ore to metal requires reducing conditions and relatively low temperatures from *c.* 700 °C upwards (Budd 1991), while the melting of the copper metal requires temperatures in excess of 1080 °C but has fewer constraints on the redox conditions. Graphite use and decoration principles in the Late Neolithic and Chalcolithic Balkans have been extensively documented (Chokhadzhiev 2000; Gaul 1948; Leshtakov 2005; Todorova 1986; Todorova and Vajsov 1993). Whilst cones of graphite were used to decorate pottery (cf. Gaul 1948: 98; Ryndina and Ravich 2000: 16–17), the possibility of graphite-rich moulds being used for metal casting is also speculated, arguing that craftspeople understood the protective role of graphite against oxidation of freshly cast metal.

The Rise of Metallurgy in Eurasia project specifically sought to address the debates surrounding the interdependence of pottery and metal technology in Research Question 2, through a dedicated PhD thesis. This analysed the excavated ceramics from Belovode and Pločnik in order to evaluate the Vinča potters' pyrotechnological skills, especially the temperatures achieved and the control of the firing atmosphere conditions, and the pyrotechnological technologies involved in graphite decoration (Amicone 2017; Amicone *et al.* 2020b) (see Chapters 14, 29, 43).

Metals and metal objects

In contrast to the fragmentary and copper-orientated mining and smelting evidence across the Balkans from *c.* 5000–3700 BC, recent research has produced a far greater quantity and quality of data relating to the creation of different metals by smelting, melting and alloying and of different forms in those metals by casting, annealing and cold/hot working.

Copper

Artefacts made of native copper appear in the Balkans only at the start of the Late Neolithic (*c.* 5500–5000 BC), but most have been only relatively dated and their cultural provenience is debatable. One out of three such artefacts, a fragmented copper object from Iernut (Horedt 1976; Lazarovici 1979, 2014; Mareş 2002), a site located deep in the Carpathian Mountains in Romania (Figure 1), has been ascribed to the last phase of the Starčevo-Criş-Körös phenomenon (mid-6th millennium BC). A 14 cm-long double pointed awl, discovered at the site of Balomir (Figure 1), is the earliest identified implement made of native copper in the Balkans (Vlassa 1967: 407, 423, Figure 6). It is relatively dated to the mid-6th millennium BC, around the same time as a fishhook from the site of Gornea in the Danube Gorges (Lazarovici 1970: 477). While it is challenging to distinguish between the use of native copper and that made of smelted copper ores, Pernicka (1990) argues that increased concentrations of cobalt (Co) and nickel (Ni) are a useful indicator of copper artefacts made of smelted copper. He synthesised Balkan and Anatolian copper metal artefacts trace element data and compared these to the analyses of native copper from the mentioned regions. The Co and Ni concentrations in native copper (approximately <20ppm) are extremely low in comparison to much higher concentrations of these elements in both Balkan and Anatolian copper metal artefacts (Pernicka *et al.* 1997: 124, 159–160, Figure 23, Table A3a). Interestingly, a few copper implements from Pločnik show borderline concentrations of Co and Ni (Pernicka *et al.* 1997: 147–148, Table A1), which might indicate their origin to be native copper. There is no evidence for the exploitation of native gold or silver in this period, despite the geological potential throughout the Balkans (e.g. Jovanović 2001).

Copper metal jewellery and small tools appear alongside malachite beads and pendants in the early 5th millennium BC in the Balkans. These are usually found in settlements and cemeteries located in the lower Danube basin and further towards the northern Black Sea coast, such as Gomolava (Brukner 1977), Gornea (Lazarovici 1970: 477), Cernavodă (Berciu 1967: 53) and Izvoare I in Romania (Vulpe 1957: Figures 72/3; 85/5,6), or Lukavrublevetskaya on the Dniester (Bognár-Kutzián 1976: 71; cf. Bibikov 1953) (Figure 2). Also, a copper metal bead from the site of Dikili Tash I in northern Thessaly is speculated to be made either of native or of smelted copper (Séfériadès 1992a: 114). Noteworthy is the unique context of Gomolava metal found with some of the deceased in this male-only cemetery dated to 4700–4650 BC, including copper beads buried with an infant. Ancient DNA analysis has shown that the individuals in the cemetery are of the same lineage, prompting assumptions of copper metal related to an inherited status in the case of the infant (Brukner 1980; Stefanović 2008).

The earliest *smelted* copper metal implements originate from the sites of Pločnik in south Serbia, Slatino in western Bulgaria, Devebargan-Maritsa in northern Thrace and Durankulak on the Black Sea coast (Figure 2) (Pernicka *et al.* 1997: 48, 72, 131, Table A1; Radivojević 2012); of these, only Durankulak is a cemetery, while the others are settlements. The difference between the artefacts made from native copper or smelted copper ores lies in the trace element analyses; while objects made of the latter contain relevant readings of cobalt and nickel as discussed above, the concentrations of these elements in the former are close to non-detectable (Pernicka 1990; Pernicka *et al.* 1997). In burials, copper implements were usually accompanied by *Spondylus* and *Dentalium* beads, or bone, clay or marble figurines, as in the Devnja cemetery in the Bulgarian Black Sea coast (Todorova-Simeonova 1971: 23–25). One of the most impressive collections of massive copper implements comes from Pločnik, where 38 copper metal artefacts were discovered (Antonović 2014a; Grbić 1929; Radivojević and Kuzmanović Cvetković 2014; Šljivar *et al.* 2006; Stalio 1964). These include: four hammer-axes of Pločnik type, 25 chisels, a copper ingot bar and a pin, altogether weighing *c.* 16 kg. They are a unique and exceptional assemblage of early copper metal and, based on the most recent AMS dating of the context of a fragmented copper chisel to *c.* 5040–4840 BC (Radivojević and Kuzmanović Cvetković 2014: 23; Whittle *et al.* 2016), they are one of the earliest in this part of Eurasia. Seventeen copper metal tools from Pločnik were studied for their chemical composition and lead isotopes (Pernicka *et al.* 1993), revealing an unexpected complexity of ore/metal exchange networks. At least three different copper deposits from eastern Serbia, Macedonia and across Bulgaria provided metal for their production. The only closely comparable collection is that from the Rakilovci hoard in western Bulgaria, where a total of nine copper metal implements were recovered from a ceramic pot (Mihaylov 2008).

A further exceptional copper metal assemblage comes from the site of Karbuna, in Moldavia: among 852 precious objects discovered as a hoard in a typical Tripolye A pot (*c.* 4700–4600 BC); 444 were made of pure copper (Dergachev 2004; Sergeev 1963: 135; Videiko 2004). Significantly, the hoard included two massive copper implements, one being a hammer axe of Pločnik type (broadly dated to the early to mid 5th millennium BC) (see also Diaconescu 2014). The considerable volume of the find and distinctive typology of its contents suggest close associations with contemporary cultures in both Serbia and Bulgaria (Chernykh 1991: 581, 587). Chernykh (1966: 53–58, 86–88, 1978b: 122; 1991: 387, 581) argues that the Karbuna hoard metal could have come from Ai Bunar, while Pernicka speculates that it might have derived from Medni Rid in eastern Bulgaria, since artefacts from northeastern Bulgaria, southeastern Romania and further to the northeast fit well with the compositional pattern of Medni Rid (Pernicka *et al.* 1997: 141). Interestingly, based on its distinctive chemical signature, this metal was probably recycled and traded further north towards the Volga valley and into the steppes (Chernykh 1991: 587–588, Table 5).

In the northwestern Balkans, the early appearance of copper artefacts is more modest and accumulated mostly in the Great Hungarian Plain and Transdanubia, or the Tisza-Hérpály-Csöszhalom group, Železiowce and Lengyel cultures (Ecsedy 1990: 220; Scharl 2016). Copper jewellery, awls and chisels come from the sites of Mlynárce (Novotný 1958: 28), Neszmély, Csöszhalom or Hódmezővársahely-Kopáncs-Kökénydomb (Bognár-Kutzián 1963: 331–333), all located along or near the major rivers in this area. Metal artefacts are also recorded at sites located along the Tisza River and closer to the Carpathian Mountains, such as the settlements of Hérpály, Berettyószentmárton and Zsáka-Markó, or the Gorsza cemetery (Bognár-Kutzián 1963: 331–336, 487).

During the second half of the 5th millennium BC, the production of massive copper metal implements flourished in eastern Bulgaria, in contrast to the central Balkans, after the collapse of the Vinča culture. This can be followed archaeologically from the mid-5th millennium BC Hamangia IV phase (Table 1) (Boyadžiev 2002: 67), when mass metal consumption is reflected by the exceptionally rich grave goods recovered from burials in Varna and Durankulak, including both copper and gold objects (Ivanov 1978a, 1978b, 1988a, 1988b;

Ivanov and Avramova 2000; Todorova 2002a). Massive copper implements and gold decorations were also found in settlements, for example at Hotnica, Ruse, Kasla-Dere, Gumelniţa or Vidra, all set along or in the hinterlands of the lower Danube (Bognár-Kutzián 1976: 71; Gimbutas 1977: 44).

Comprehensive typological schemata have been developed to track the appearance of specific types of massive copper implements. Changes in the morphology of hammer-axes are particularly interesting as they appear to be related to specific regions across the Balkans. For instance, hammer axes of the Pločnik type are generally associated with the Vinča culture (these start to appear in the Early Chalcolithic), the Vidra type with the north central Bulgarian sites (associated with the KGK VI), while the Čoka-Varna type is characteristic of the northeastern Bulgarian sites (Varna culture) (Antonović 2014ac; Chernykh 1978b; Govedarica 2001; Kuna 1981; Novotna 1970; Radivojević 2006; Schubert 1965; Todorova 1981; Vulpe 1975; Žeravica 1993). Importantly, lead isotope analyses of the late 5th millennium BC Vidra and Čoka-Varna hammer-axes showed that they were made of the same metal (Pernicka *et al.* 1997: 94–98, 105–106, 142, Table 3), indicating that there was no relationship between a metal source and the tool type. The strong preference for a specific tool type regardless of source potentially suggests that particular technological choices reflect the identity of a producer or consumer group.

Scholarly debates regarding Final Chalcolithic period in the Balkans (*c.* 4100–3700 BC) have traditionally been dominated by narratives of a societal collapse in eastern and central Bulgaria as indicated by a substantial reduction in archaeologically visible (and dated) settlements (Kienlin 2010; Weninger *et al.* 2009). Metal provenance data also support this interpretation with a noticeable shift in copper supply networks from the eastern to the central Balkans, where it not only continues but also intensifies with the exploitation of novel sources in the Carpathian Basin (Pernicka *et al.* 1997; Schalk 1998; Siklósi et al. 2015; Siklósi and Szilágyi 2019). The presence of increasing numbers of copper objects in the northern Alpine region (cf. Bartelheim 2007; Cevey *et al.* 2006; Kienlin 2010, 2014; Klassen 2000; Scharl 2016; Turck 2010), as well as throughout the neighbouring central Mediterranean region (Dolfini 2013, 2014) provides evidence for the emergence of other copper industries outside the 'core' Balkan region but still, however, associated with the Balkan sources (Höppner *et al.* 2005).

Copper production rapidly changes in the late 5th / early 4th millennium BC with metal production re-emerging in the central and northwestern Balkans, shown in the increase of metal consumption in the Bodrogkeresztúr culture and intensified exploitation of eastern Serbian and western Bulgarian copper sources (Pernicka *et al.* 1997: 98–101, 105–106, Table 3). As a consequence, the earliest metal using cultures emerge north of the Alps, such as at Mondsee or Pfyn (Kienlin 2010; Krause 2003; Ottaway 1989). In contrast to the quantity of copper implements, production evidence is extremely rare and understudied. Cultures of the late 5th millennium BC Great Hungarian Plain produced the first known metal knives, and massive copper implements are found in both settlements (e.g. Lucska) and cemeteries (e.g. Tibava) (Bognár-Kutzián 1972: 140; Hansen 2013b; Šiška 1964: 7 ff.; Todorova 1995: 90). One of the most exceptional collections of metal artefacts in this region comes from the late 5th millennium BC

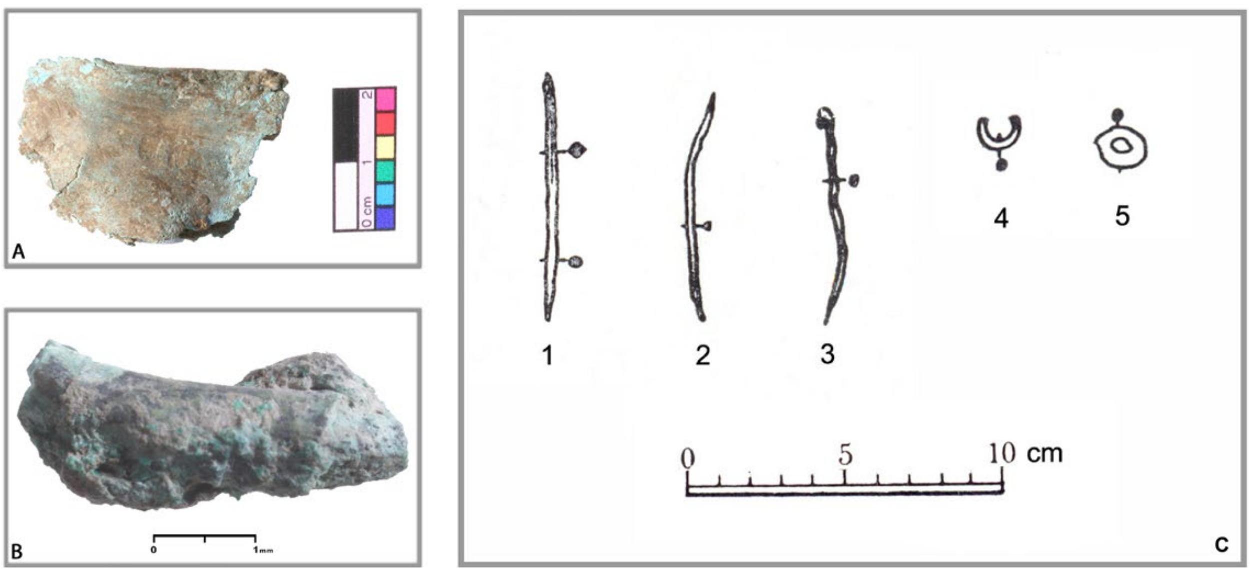

Figure 5: A selection of the 5th millennium BC tin bronze artefacts from the Balkans. a) Pločnik foil; b) Gomolava ring; c) 1- Bereketska Mogila, 2- Gradeshnica, 3, 5-Ruse, 4-Karanovo (adapted after Chernykh 1978b: Tables 15/24,42; 18/30; 19/4,7; Radivojević *et al.* 2013).

Lengyel culture cemetery of Zengővárkony (Figure 3), where a large number of spiral copper metal bracelets, rings and malachite beads were deposited as grave goods (Dombay 1939: 50–64; Dombay 1960: 75–144; Ecsedy 1990: 212–218). Of note are the cemeteries, like Rákóczifalva-Bagi-föld, where the uneven distribution of grave goods, including copper and gold objects, potentially indicates a degree of social inequality (Csányi *et al.* 2009) as evaluated across the Eastern Carpathian Basin by Siklósi (2013).

Tin bronze

The recent excavation and archaeometallurgical analysis of a tin bronze foil at Pločnik from a secure context radiocarbon dated to *c.* 4650 BC (Radivojević *et al.* 2013) revealed the emergence of tin bronze metallurgy at this time. The compositional analyses of the Pločnik tin bronze foil indicated that copper ore including stannite (Cu_2FeSnS_4), a copper-tin bearing mineral, or its secondary weathering products was the probable raw material used for making this natural alloy with *c.* 12wt% Sn and relevant traces of As, Fe, Co and Ni (see Radivojević *et al.* 2013: 1035, Table 1). This means that the earliest known tin bronze artefact was not made by alloying two elements (copper and tin) but rather by smelting a copper-tin bearing ore.

There are 14 additional tin bronze artefacts known from the mid-late 5th millennium BC, however these finds only occurred together in what appears to be a short-lived tin bronze horizon in the Balkans based on geochemistry that links them with the Pločnik foil. Twelve finds originate from the Bulgarian sites of Ruse, Karanovo, Gradeshnitsa, Smjadovo, Zaminec and Bereketska Mogila (Chernykh 1978b; Pernicka *et al.* 1997), and two from the Serbian sites of Gomolava and Lazareva Cave (Ottaway 1979; Tasić 1982; Glumac and Todd 1991: 15). The assemblage of awls, rings, needles, borers, and a rod from Bulgaria and Serbia (Figure 5) has tin concentrations ranging from 1–10 wt%, with consistently significant levels of lead, arsenic, nickel, cobalt, iron and gold (Chernykh 1978b: 112, 339, 342–343, 351–352, Tables 15/24, 42, 18/30, 19/4,7; Pernicka *et al.* 1993: 190, Table 3; Pernicka *et al.* 1997: 70, 121–126, 156, Table A1).

In terms of context, the majority of these finds remain under question with the exception of a borer from Ruse that originated from the secure, primary context of a child's burial (Glumac and Todd 1991: 15; Pernicka *et al.* 1997: 125–126). Despite having different chemical compositions, these tin bronzes typologically match contemporary regional counterparts in pure copper. Yet, their form is culturally and chronologically non-distinctive, thus offering little information about their exact provenance. The Pločnik tin bronze foil was therefore crucial in determining their chronology based on a common unique chemical signature (Radivojević *et al.* 2013); this, and the fact that no other tin bronze artefacts are known in the Balkans before the 3rd and 2nd millennia BC (Chernykh 1978b; Schickler 1981; Pernicka *et al.* 1997; Pare 2000), make it very unlikely that these early finds are intrusions from later layers.

Another artefact with relevant tin content (*c.* 1.5 wt%) and minute concentrations of silver and nickel in the copper base, originates from a mid to late 5th millennium BC phase in Dikili Tash II (Figure 3) (Sériadès 1992a: 114–115, Table 12). The trace element signature of this object is not, however, consistent with the tin bronze assemblage from Bulgaria and Serbia, although it was probably also made by co-smelting malachite and tin-rich ore. A tin-rich slag piece from the late 5th millennium BC cemetery of Zengővárkony, the only technological debris of its kind at the time, adds more chronological certainty for the production of tin bronzes mentioned above. Yet, the context of this particular artefact remains uncertain (Pernicka *et al.* 1997: 125).

Radivojević and colleagues (2013: 1040) further argued that the golden hue of fifteen 5th millennium BC Serbian and Bulgarian tin bronze artefacts, which contain between *c.* 1 wt% and *c.* 12 wt% Sn, must have been critical to their value, particularly as these artefacts were roughly contemporary with the emergence of the earliest known gold artefacts, unearthed in the cemeteries of Varna and Durankulak in Bulgaria (cf. Avramova 2002; Dimitrov 2002; Higham *et al.* 2007; 2018; Ivanov 1988b; Krauss *et al.* 2017; Leusch *et al.* 2014; Todorova and Vajsov 2001). The importance of the new colour palette at the time has been emphasised in detailed compositional analyses by Leusch *et al.* (2014), which showed that not all gold items in the Varna cemetery had the same shade of yellow. We may assume that the rarity of objects coloured in these new shades in the 5th millennium BC Balkans might have dictated their limited production, but also that demand for them was both social and technological, since tin bronzes in particular disappear with the collapse of the KGK VI and related cultural phenomena at the end of the 5th millennium BC in the Balkans. In contrast to the tin bronzes, there is currently no evidence for arsenical copper objects and their production in the Balkans prior to the early to mid-4th millennium BC (e.g. Antonović 2014a; Chernykh 1978b; McGeehan-Liritzis and Gale 1988; Nerantzis *et al.* 2016; Pernicka *et al.* 1997).

In order to investigate the golden hue argument in greater detail, Radivojević *et al.* (2018) designed a Cu-As-Sn colour ternary diagram based on an extensive set of experiments that yielded 64 binary and ternary metal pellets further exposed to colorimetric analysis.

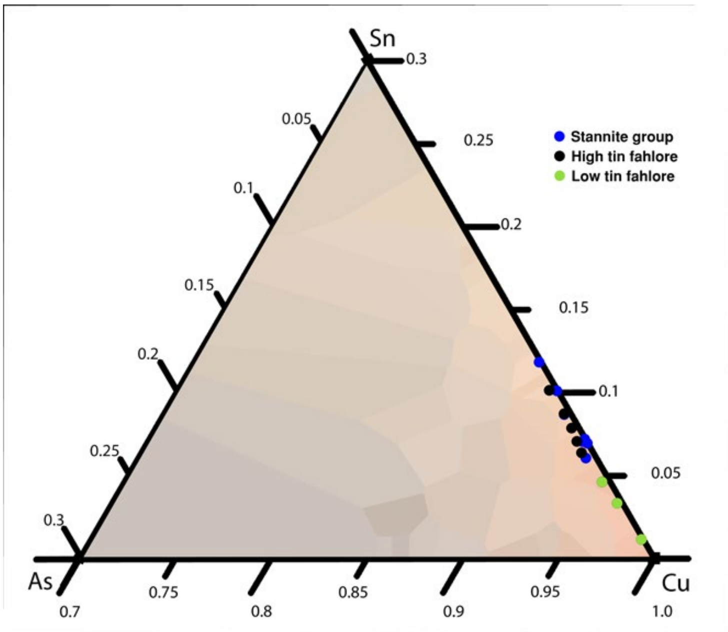

Figure 6: The mid to late 5th millennium BC Balkan bronzes plotted against the Cu-As-Sn ternary colour diagram (100 wt% Cu – 30 wt% As – 30 wt% Sn corner, see Figure 8). Fifteen artefacts split into three groups indicate a variety of colour changes, significantly visible after *c.* 5wt% Sn on the Cu-Sn axis. Data from Radivojević *et al.* (2013: 1035, Table 1); image from Radivojević *et al.* (2018: 118, Figure 12).

The analysis of 15 5th millennium BC Balkan tin bronzes were then plotted on this colour diagram in three distinctive groups, based on the likely mixture of ores other than malachite in the smelting charge: stannite, high-tin fahlore and low-tin fahlore (data from Radivojević *et al.* 2013: 1035, Table 1). Figure 6 indicates that the stannite and high-tin fahlore group (12 artefacts, Sn range between 6 wt% and 12 wt%) had a visibly emphasised golden hue when produced, as opposed to the low-tin fahlore group where, although colour change would have been noticeable, it was not as significant as for those above *c.* 5 wt% (Radivojević *et al.* 2018: 115–118, Figure 12).

It was therefore concluded that the group of 5th millennium BC Balkan tin bronze artefacts, in particular the assemblage of stannite and high-tin fahlore group, must have appeared significantly different, aesthetically, from pure copper artefacts, since the addition of tin increased the golden hue of their resultant colour. With such a different appearance, it is very likely that the production of the 5th millennium BC Balkan tin bronzes was dictated by the demand for the 'exotic' golden colour at the time, or by the pursuit of its closest imitation, which supports the claims in the original publication (Radivojević *et al.* 2013; see also Radivojević *et al.* 2014a). It is also very interesting that the shape of the Pločnik foil (Figure 5a) indicates that it was wrapped around an object, which could have been a pottery vessel or a stone, wood, bone or copper object.

If we seek inspiration for the use of foils at that time (*c.* 4650 BC), metal foils with the same, golden colour (see Figure 7a) are found in abundance in Varna burials. The most notable examples come from the rich burials 36 and 43, including the (infamous) golden 'penis sheath' (Leusch *et al.* 2017).

Ryndina and Ravich (2001: 4, Figure 3) maintain that the provenance of the Balkan early tin bronze artefacts may have been associated with local sources, since their chemical signatures correlate well with those of copper metal that circulated in Transylvania, Hungary and northern Yugoslavia, extending towards Moldavia and Ukraine. Conversely, Pernicka *et al.* (1997: 141) argue that the tin bronze artefacts they analysed did not fall within the isotopic range of the majority of artefacts from the 5th millennium BC. In her doctoral thesis, Radivojević (2012) showed that the provenance of the Pločnik tin bronze foil was highly consistent with the rest of the Pločnik copper implements.

While the provenance of these artefacts remains to be explored in future publications, it is important to emphasise that the information we have assembled thus far speaks in favour of the limited use of tin bronzes across the Balkans in the late 5th millennium BC. Furthermore, it is essential to remember that, although the excavation methodology used in their discovery varied, the excavators were not aware of the relevance of tin bronze objects based on their appearance (the green patina would be similar to that on pure copper objects), and hence they could not have been biased in their recording. If anything, these items were mislabelled as 'usual copper' until chemical analysis showed otherwise, which was initially the case with the Pločnik tin bronze foil. Although this early use of copper-tin ores to make natural alloys has only started to emerge in the literature, special caution is needed regarding claims that involve superficial or rapid analyses and insufficiently elaborated contextual evidence.

Gold

The appearance of thousands of small decorative objects made of gold dates from the mid-5th millennium BC in northeastern Bulgaria, southeastern Romania and northern Thessaly (Makkay 1991; Higham *et al.* 2007; Krauss *et al.* 2017). Although the gold from the cemetery of Varna I is claimed as the earliest known (dated most recently between 4690 and 4330 cal. BC) (Krauss *et al.* 2016), there are earlier uses of gold ornaments (although not as securely dated) in the Varna II cemetery (Todorova and Vajsov 2001: 54), as well as in the cemetery of Durankulak (Avramova 2002: 193, 202, Table 24; Dimitrov 2002: 147). The Durankulak finds are, for instance, dated to the Hamangia IV phase, between *c.* 4650/4600–4550/4500 BC (Bojadžiev 2002: 67). Gold also appears in more modest quantities in sites located in the lower Danube basin: Vidra (Dumitrescu 1961: 80), Hotnica (Jovanović 1971: 37), Traian, Gumelniţa (Dumitrescu 1961: 70–71, 80–81) or deep in the Carpathians, as in Ariuşd (Makkay 1995: 74) (Figure 3).

The most exceptional collection, including *c.* 3100 gold objects (and 160 copper implements), however, comes from the cemetery of Varna I, weighing *c.* 6.5 kg in total (Biehl and Marciniak 2000; Fol and Lichardus 1988; Ivanov and Avramova 2000; Leusch *et al.* 2017). The volume of the collection and the range of techniques applied in its production deserves special attention here. Around 70 of the 320 burials (inhumations, deposits, symbolic/ cenotaph graves) contained gold artefacts ranging from one item to 990 objects (totalling 1.5 kg of gold) in a single burial, no. 43. Of 61 graves with gold artefacts, 34 were symbolic / cenotaph, 10 male, 13 female (?) and 4 disturbed (Biehl and Marciniak 2000: 186). Leusch *et al.* (2017: 112, Table 2) indicate cenotaphs as the richest graves, followed by male and then female burials. It is notable that no comparable range of prestige items and status markers have been found in adjacent settlements, which do not exhibit evidence for structural hierarchies or inequalities. Hence, scholars agree that the Varna cemetery served several local communities of an unspecified scale, rather than just a single settlement (Biehl and Marciniak 2000; Chapman *et al.* 2006; Ivanov 1988b; Lichardus 1991b; Renfrew 1978a).

The Varna gold collection includes a range of decorative artefacts made of small beads, appliques and sheets. Although made of native gold, the varying naturally occurring concentrations of copper and silver in the golden nuggets exploited resulted in golden objects having many different shades of gold (Figure 7d) from white, via yellow, to light pink (Leusch *et al.* 2014:175, Figure 11b). Overall, silver concentrations range between 5 and 45%, and copper between 0.05 and 2.5% (Leusch *et al.* 2017). Leusch *et al.* (2016: 108, Figure 7.8) use the Pt/Pd ratio to discriminate between four different groups of gold in the Varna assemblage (300 objects analysed in total), which may be indicative of discrete geological resources, suppliers or workshops. While any of these scenarios need further research, the recent discovery of placer gold deposits near Varna (Yovchev 2014) points to potential regional resources being exploited at the time.

The artefacts buried in these graves include awls, chisels, cushion stones, stone adzes, flint scrapers, hammer axes and antler tools. A sound case has been made that these might have been the tools of artisans. The deposition of such items alludes to the significance of artisans and crafting for the community at Varna (Leusch *et al.* 2017: 118). Anthropological analysis of one of the richest burials, no. 43, has shown that the male individual, aged between 50 and 65 years, had pathological conditions related to squatting and hard work, particularly to great robusticity of the lower arm muscle attachments, which supports the interpretation of this individual as an artisan or craftsperson rather than as ‘royalty’ (Leusch *et al.* 2017).

To further contextualise the paraphernalia related to crafts at Varna I, 122 out of 226 burials have items identified as tools that have never been used. These tools are as common as any other object deposited in the burials. Two potential imitations of objects are also present in the collection, adding to the assemblage of artisan tools: a copper pick (imitation of an antler pick?) and a golden ‘penis sheath’ (a likely imitation of a tuyère?) (Leusch *et al.* 2017: 107, Table 1). The latter has been famously claimed as unearthed between the thighs of the individual in Burial No. 43, which led to its interpretation as a penis sheath. However, its original position was beside the right thigh (Biehl and Marciniak 2000: 186; Ivanov 1988b: 55, Figure 25; Leusch *et al.* 2014: 168, 177, Figure 4a). An alternative interpretation, that it was an imitation or gilding of a tuyère, has typologically close parallels with clay imitations from across sites in Bulgaria (Kubrat, Goljamo Delčevo), Romania (Pietrele, Radovanu) and Serbia (Bubanj, Kmpije) (Figure 4e-f) (Bulatović 2015: 12, Table II/13; Comşa 1990; Hansen 2009; Lichardus 1988; Lichardus 1991a: 174; Todorova 1982). The idea of gilding is equally interesting, given that this golden object had two perforations at the base, indicating that it was stitched to another item, hence potentially serving as an ornament. Leusch *et al.* (2017: 114) claim that the item could not have been a tuyère imitation since the output vent has a wider diameter than the clay models; nevertheless, imitations do not need to be exact copies. Finally, if the item was used as a foil decoration for clay tuyères, it would fit well with the practice of working with gold foil in the Varna cemetery (see Figure 7a) (Leusch *et al.* 2015).

Careful examination of a total of 300 golden objects analysed within the Varna-project (led by E. Pernicka) revealed different shaping techniques applied with hammers, punches and doming blocks, chisels used for chasing and parting, conical points for perforations, and sand, stones, ashes and siliceous plants used for finishing and polishing. Little is known, however, about the production debris of gold making. Similarly to native copper, native gold would not produce any slags. Casting equipment required a similar set of tools to those needed for copper processing:

Figure 7. A selection of gold objects from Varna. a) Sheet-gilded copper bead from burial no. 41; b) Gold bead from burial no. 4 with a hollow body made with lost wax casting technique; c) The ring-idol from grave no. 271 is the earliest known gold-copper alloy (*c.* 50 wt% gold, 14 wt% silver, and 36 wt% copper); d) Gold beads with different shades of gold due to the variable silver content. The silvery beads (top right) from grave no. 43 contain on average 58 wt% gold, 40 wt% silver, and 2 wt% copper (adapted after Leusch *et al.* 2014: 167, 175, Figure 3a, 10b, 11a-b; c_CC BY-NC-ND 4.0 by B. Armbruster and V. Leusch).

crucibles, casting moulds, hearths and tuyères (Leusch *et al.* 2015). The exquisite craftsmanship required for making these objects is showcased using techniques borrowed from copper working, together with complex casting techniques, to produce three of the world's first examples of alloying, gilding and lost-wax casting (Figure 7a-c). A small group of gold-copper alloys was found to contain copper content exceeding *c.* 30 wt%, which is significantly higher than the naturally occurring concentrations within native gold (Hauptmann *et al.* 2010) and hence implies intentional alloying (ring idol example in Leusch *et al.* 2014: 175, Figure 11a) (Figure 7c). A copper bead from grave no. 41 was sheet-gilded (Figure 7a) (Leusch *et al.* 2014: 167, Figure 3a), probably to bring up the much sought-after golden colour, while a hollow and solid globular bead from another burial was produced using a lost-wax technique (Figure 7b) (Leusch *et al.* 2014: 175, Figure 10b). This bead is the earliest known record of a lost wax cast object and predates the spoked wheel shaped native copper amulet from the site of Mehrgarh (Pakistan) by as much as 500 years (Thoury *et al.* 2016). The amulet came from the Early Chalcolithic horizon on this site broadly dated between 4500 and 3600 BC, the authors settling on *c.* 4000 BC as the likely date for the emergence of lost wax casting in the far eastern end of the Iranian Plateau.

The mastery of gold production did not only include the production of gold objects, but also extended to the decoration of non-metal objects (like pottery) with gold. Éluère and Raub (1991: 13) investigated the technology of gold coating on a large plate recovered from one of the rich Varna graves, and showed that its gold layer consisted of natural Au-Ag alloy with *c.* 7% Ag, and some copper. After coating, no polishing tools were used, as this may have removed the gold. Éluère and Raub (1991: 19) speculated that washed (alluvial) gold dust was applied onto a plant glue which covered a ceramic surface in a process called sintering, which welded together particles without requiring a liquid stage (Raub 1995: 247–248). The tradition of decorating pottery with gold extends into the Krivodol-Salcuţa-Bubanj Hum complex in southwestern Bulgaria / southeastern Serbia, continuing well into the first centuries of the 4th millennium BC (Bulatović *et al.* 2018; Gajić-Kvaščev *et al.* 2012).

During the late 5th to early 4th millennium BC, the production of gold artefacts shifted towards the west Carpathian Basin, where gold pendants and decorations appeared within the late Tiszapolgár, Lasinja and Bodrogkeresztúr cultures (Dumitrescu 1961: 92–93). Gold ornaments of varying size were deposited as grave offerings in the cemetery of Tibava, in Slovakia (Šiška 1964: 332) or in hoards, as at Moigrad, in Romania (Dumitrescu 1961: 71) (Figure 3). Gold metal from this period amounts to a total of *c.* 5–6 kg of extant objects (Makkay 1991: 119–120); of these the most impressive is the heaviest golden object currently recorded from the Balkan Chalcolithic, a 31 cm-diameter disc from the Moigrad hoard that weighs *c.* 800 g (Makkay 1989).

Silver and lead

Objects made of silver emerge in parallel to those fashioned from gold, although to a lesser extent. Only a few pieces, of unknown context, originate from the Carpathians (Makkay 1991), while in Greece, hundreds of small items of silver jewellery have been found (Maran 2000; Muhly 2002). The richest find is a hoard from the Alepotrypa Cave (Figure 3) on the Mani peninsula in Greece, dated roughly between the mid-5th and early 4th millennium BC (Muhly 2002: 78; Papathanasiou *et al.* 2018); other sites with silver ornaments were discovered in the islands of Crete and Lemnos. One of the large silver pendants from the Alepotrypa Cave has a distinctive shape: it is circular, with a central perforation and a pierced suspension tab; as such, it resembles a slightly earlier golden counterpart from the cemetery of Varna. There is no contemporary evidence for silver production, with the earliest evidence for litharge fragments coming from Limenaria, Thassos and northern Greece, dating to the early 4th millennium BC (Nerantzis *et al.* 2016; Papadopoulos 2008).

The earliest processing of lead ore in the Balkans is documented at the site of Belovode, where a large slag 'cake' (Figure 8) was recovered from an undisturbed and secure context associated with 5200 BC (Radivojević and Kuzmanović Cvetković 2014; Šljivar *et al.* 2012). Microstructural analysis conducted by the first author of this chapter reveals well formed—and once molten throughout—fayalitic slag with magnetite, matte inclusions and droplets of lead metal, which suggests the use of complex lead ore and would require temperatures in excess of 1100 °C. Most importantly, it could not have been made by chance (Radivojević and Rehren 2019). While there are no preserved lead objects known currently from this site, the only contemporary evidence in the broader 'Old World' sphere is the lead bracelet from layer 12 at Yarim Tepe I in Iran (Merpert and Muncaev 1987). The results of chemical (qualitative) analyses conducted by E.N. Chernykh (Merpert and Munchaev 1972) speak of pure lead metal as the base, some silver and traces of iron. This suggests the use of a lead ore of high purity, like galena, or native lead which is very rare (Patterson 1971). However, without an exact quantification of the silver content it is difficult to say which type of lead ore was used. Tylecote (1962: 76) reported that lead can be smelted easily from galena by a 'simple fire', which possibly refers to the melting point of lead at 328 °C. Interestingly, the wider Levant / Northern Syria region hosts some of the earliest known lead objects in the world, at least from the late 5th millennium BC onwards (cf. Yahalom-Mack *et al.* 2015).

The use of lead minerals (for beads) has also been documented at the Vinča culture sites of Autoput,

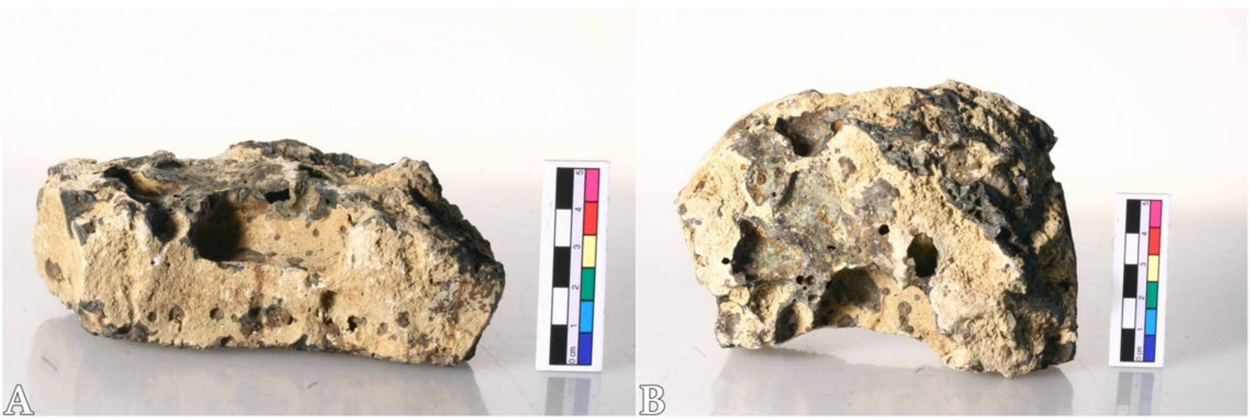

Figure 8. Slag 'cake' from the site of Belovode, eastern Serbia, discovered in a context dated to 5200 BC. Compositional analysis revealed lead metal to be the likely product of the smelt (photo CC BY-NC-ND 4.0 M. Radivojević).

Selevac and Opovo in Serbia and Donja Tuzla in Bosnia, in all cases in horizons that end in 4500/4400 BC at the latest (Glumac and Todd 1987; Vogel and Waterbolk 1963; Quitta and Kol 1969). As such, these artefacts, together with the lead slag, predate the use of lead ores at the site of Pietrele (set at *c.* 4400–4300 BC), erroneously claimed as the first and only evidence of lead ore processing in the Balkans (Hansen *et al.* 2019). The biconical crucibles in question are a very interesting find and are apparently present in at least two Chalcolithic Romanian sites besides Pietrele: they are small biconical objects (*c.* 6 cm in diameter on average) with a narrow opening at the top, yet with inconsistent traces of heating across the discovered assemblage. The purpose of these crucibles is yet to be resolved, as it remains unclear what the smelting of galena (PbS) in such a way produced. Hansen *et al.* (2019) dwell on the possibility of manufacturing a colouring agent, a yellow or red lead oxide, which would fit with the earlier practice of painting pottery in the Vinča culture (e.g. Gajić-Kvaščev *et al.* 2012; Mioč *et al.* 2004).

Miloje Vasić described two interesting situations that might have indicated the presence of smelting (lead) installations at the site of Vinča-Belo Brdo. The first refers to finds from 1913, when several ellipsoid-shaped shallow pits were discovered within a small area at ▼8.1 to ▼8.9 m (this translates into Vinča A phase in this settlement, *c.* 5300–5200 BC), the largest being 2.1 x 0.5 x 0.1 m in size (Antonović 2002: 35–36, note 60, Figure 3). Their walls were *c.* 8 cm thick, and they were intensely fired only in the centre and filled with soot and ash in the bottom. A galena bead was identified in the vicinity of one of these features. Similar shaped shallow installations were used for lead smelting in the village of Vinča (near Belgrade) in the early 20th century; this prompted Vasić to propose a similar function for these pits (cf. Antonović 2002).

Conclusion

In light of this existing evidence for metals and metal objects, *The Rise of Metallurgy in Eurasia* project retrieved, recorded and spatially mapped each metal object excavated at Belovode and Pločnik, as well as any associated finds and features. All metal objects were subsequently analysed to determine their metal composition, metal provenance and techniques of manufacture. Given the earlier discoveries of copper and tin bronze objects at Pločnik and copper smelting slag and lead ore at Belovode, it was important to explore, where possible, where the different metal production evidence and objects were placed on each site and how these may have been organised. This pertains especially to Research Questions 1, 5 and 6.

Metal circulation

Analyses of metal objects and the large scale of copper production during the 5th millennium BC prompted Chernykh (1978b, 1992, 1997, 2008b, 2008a) to define the Carpatho-Balkan Metallurgical Province (CBMP) as a distinctive (and the earliest) technological and cultural entity, from where metallurgical knowledge was carried eastward in staged migrations over the following *c.* 4000 years. 'Metallurgical Provinces' (MPs) represent large interconnected systems of shared metallurgical technology, trade and exchange, which encompassed areas of up to a few million km^2 across Eurasia, and which lasted for a few thousand years. On a practical level, they were linked through: i) shared utilisation of morphologically defined ornaments and implements; ii) common principles of metalmaking with the availability of or access to the same ore resources; and iii) comparable dating. Chernykh (1992: 7) goes further, making a fine distinction between metallurgical *province* and metallurgical *foci*, the latter of which refers to smaller-scale regions where similar metal artefacts were produced by a group of skilled craftsmen over a certain period. The current understanding of the extents of metallurgical provinces currently relies on the growing database of compositional analyses (nearly 120,000; see Chernykh 2008a) and associated datable materials from between the Adriatic and the northern forests of Mongolia. As such, the MPs are detached from the concept of culture, and may encompass an area of up to 8 million km^2 and endure over long periods of time.

The CBMP area included several cultural phenomena in the northern Balkans and the Carpathian Basin related to the emergence and spread of copper metallurgy during the 5th millennium BC, and most notably around the mid-5th millennium BC, which is defined as the 'metal boom' phase by Chernykh (1978b; 1991; 1992). This province spanned *c.* 1.3–1.4 million km^2 at the peak period of metal production. Chernykh (2008b: 76) distinguished three groups of the 5th and early 4th millennium BC metal-producing and consuming cultures. The first, 'core' group (Butmir, Vinča C/D, Lengyel, Karanovo V-Maritsa, KGK VI, Varna, Tiszapolgár, Bodrogkeresztúr cultures, see also Figure 10), broadly includes the central, eastern and northern Balkans and spans over *c.* 500 years across an area of 0.75–0.8 million km^2. A second group is represented by the Tripolye-Cucuteni culture, which extended from the Carpathian Mountains to the Dniester and Dnieper regions, with centres in modern-day Moldova and western Ukraine, and occupied *c.* 0.16-0.18 million km^2, while a third group consists of communities occupying the steppes to the north and northeast of the Black Sea coast.

Several technological features emerge as common to the cultures within reach of the entire CBMP area: a similar set of classes and types of products, similar technology of working and (pure copper) metal composition (Chernykh 1978b, 1992; Ryndina and Ravich 2000, 2001). The most recent technological and metallographic study showed that the massive copper implements from the Vinča culture sites of Pločnik were worked in the same way as those from KGK VI and Varna sites in northeastern Bulgaria (Radivojević 2012), confirming the existence of a shared technological principle (or recipe) for metal working across the Balkans, in place from the very beginnings of the 5th millennium BC. Radivojević (2012) further observed that the shared metallurgical tradition, mirrored in the specific technique for finishing the massive copper implements across the Balkans reveals that the network of metalsmiths was resistant to various cultural collapses (like Vinča or KGK VI), and that it probably existed outside the remits of archaeological cultures as defined by distinctive material traits. The study and subsequent publications relating to the invention, innovation and cultural transmission of metallurgical knowledge in the 5th millennium BC Balkans (Radivojević 2015; Radivojević *et al.* 2013; Radivojević and Kuzmanović Cvetković 2014; Radivojević and Rehren 2016) support the concept of the metallurgical province as an entity independent of particular cultural phenomena, and highlights shared technological knowledge as the key to understanding the social dynamics of this period. This concept needs further probing in relation to (extractive) production and all aspects of the metallurgical *chaîne opératoire* in order to interpret the nuanced detail of the knowledge transmission.

Extensive programs of compositional analyses indicate that the 5th millennium BC metal artefacts in the Balkans were made of almost pure copper (e.g. Chernykh 1978b; Junghans *et al.* 1968; Radivojević and Grujić 2017; Pernicka *et al.* 1993, 1997; Radivojević 2012; Radivojević and Grujić 2018: Table S1), which is why the trace element signature, along with the lead isotope analyses, have proved particularly useful for indicating plausible sources of metal. The Early Chalcolithic period was dominated by sources in eastern Serbia, probably Majdanpek, although other outcrops in this region, like Ždrelo, could also have been exploited (Radivojević *et al.* 2010a). Bulgarian sources, like Ai Bunar, become active only towards the mid-5th millennium BC, and are associated with the earliest copper implements from southern and northeastern Bulgaria (Chernykh 1978a; Pernicka *et al.* 1997: 93, Table 3;). An important point arising from the available provenance data is the existence of multi-producer and multi-consumer networks of copper from the early stages of metallurgical development, as is the case with the Vinča culture sites of Belovode and Pločnik. While provenance analyses of copper slags from Belovode indicate trace elements highly consistent with 16 Chalcolithic copper metal implements found mostly along the lower Danube, similar analyses of copper implements from Pločnik point to a minimum of three different copper deposits that provided metal for their production (Pernicka *et al.* 1993, 1997: 93–94, 105–106, Table 3; Radivojević *et al.* 2010a).

Provenance (lead isotope and trace element) analyses of several hundred copper artefacts from the mid to late 5th millennium BC indicate the use of local Balkan sources, amongst which the signature of Ai Bunar was predominant (Pernicka *et al.* 1997: 117, Figure 20, Table 3). All copper artefacts analysed by Pernicka *et al.* (1997) were assigned to ten distinctive lead isotope grouplets each relating to a particular deposit, a group of spatially tight deposits or to the same geochronological unit (not necessarily spatially close). These grouplets are therefore not sufficiently well characterised to allow predictions of the exact location of origin of the smelted metal. The information on grouplets is then paired with that for clusters (derived from clustering of trace element signatures) and used together with archaeological information to ensure the best estimate of metal provenance (Pernicka *et al.* 1997). Given the widespread presence of copper metal implements from various copper deposits across this region, we may assume that these local sources were shared among different cultural groups. There is, indeed, a prevalence of KGK VI material culture in the ancient mines of Ai Bunar, however the distinctive chemical signature of this source is found in nearly one quarter of Middle-Late Chalcolithic copper objects analysed thus far.

Another distinctive provenance signature is ascribed to Majdanpek in eastern Serbia, although this deposit was more intensively exploited in the Early and Final Chalcolithic. Pernicka *et al.* (1997) observed large shifts in copper supply throughout the Balkan Chalcolithic in the provenance data. For example, the copper in a significant number of analysed artefacts from the first half of the 5th millennium BC originates from the Majdanpek copper field. It is almost absent from the Middle and Late Chalcolithic artefacts but becomes a dominant source again in the Final Chalcolithic (Pernicka *et al.* 1997: 106). These changes go hand in hand with the known cultural dynamics at the time: the use of eastern Serbian sources decreases sharply with the end of the Vinča culture, while the exploitation of Ai Bunar and other Bulgarian deposits intensifies with the rise of the KGK VI, Varna and Krivodol-Salcuţa-Bubanj Hum cultural phenomena. As noted above, with the collapse of these cultures—commonly ascribed to an environmental catastrophe (Weninger *et al.* 2009) but remaining the subject of considerable debate (see

Tsirtsoni 2016a)—the eastern Serbian deposits became more actively used again, followed by the appearance of the Bodrogkeresztúr groups.

More recently, Radivojević and Grujić (2018) developed a unique approach to investigating the networks and dynamics of copper supply between *c.* 6200 and *c.* 3200 BC, based on the currently available datasets from Pernicka *et al.* (1993, 1997), Radivojević (2012) and the project presented in this monograph (see Chapter 41), including 410 copper-based objects from 79 sites (all made freely available in Table S1 in Radivojević and Grujić, 2018)[2]. The authors applied a complex networks approach, using a modularity maximisation method (Blondel *et al.* 2008) in order to explore the structure of the most densely connected sites through the strength of copper supply, trade or exchange links. They identified three highly interconnected systems—community structures or 'modules'—composed of supply networks that reflect organisation of the copper industry and, effectively, social and economic ties in the Balkans between *c.* 6200 and *c.* 3200 BC (Radivojević and Grujić 2018: 116, Figure 6). The intensity of algorithmically calculated social interaction revealed three main groups of communities that appeared spatiotemporally and statistically significant: the resulting structures held a strong resemblance to at least three dominant economic and social cores of copper industry in the Balkans across *c.* 3000 years, traditionally defined as Vinča, KGK VI and Varna, and Bodrogkeresztúr (Figures 9 and 10). Importantly, the complex wiring topologies of these three modules were quantified independently of cultural, chronological and geographical attributes.

Besides suggesting spatiotemporal patterning, this resemblance showed that algorithmically calculated community structures currently represent the most precise mathematical model available for identifying such archaeological phenomena. The dynamics of copper exploitation, production and consumption practices reflected closely those of recorded social interactions for the time and region studied. Although Radivojević and Grujić (2018) did not suggest that metallurgy-related practices were the sole factor in defining interactions such as collapses or rises of cultural complexes, their research indicates that these industries must have been sufficiently powerful to play a major role in their shaping.

Radivojević and Grujić (2018) also observed the selective formation of network ties amongst site populations in relation to both specific regional copper sources (e.g. eastern Serbian Majdanpek, central Bulgarian Ai Bunar) and communication routes (e.g. lower Danube), as well as their association with either seemingly 'monopolised' (e.g. Bodrogkeresztúr) or 'open-market' (e.g. KGK VI) organisation of copper supply networks across the periods analysed (Figure 11). These results are consistent with previous research on metal provenancing in the Balkans (Pernicka *et al.* 1993, 1997; Radivojević 2012). Importantly, this study also indicated an overall tendency for communities identified as archaeological cultures to maintain their own regional network of copper exploitation, production, exchange and consumption. In this light, metal recycling practices are plausible, although they may have happened within specific regional networks of copper supply (or 'modules'). In such cases, recycling would not be easily identified in provenance analyses, as this activity homogenises the metal pool – and if the metal were coming from a single source or deposit, the signature would stay the same regardless of the reuse or recycling process.

This is not to say that modules or archaeological phenomena identified in this way did not cooperate amongst themselves. Quite to the contrary, there were links (see Figure 9) *between* the modules although these were not as strong as those *within* them. Knowledge of metalmaking spread through these links across the Balkans from the Vinča culture 'core' centre. It expanded and collapsed along with the rise and fall of the cultural complexes, but it never ceased to be practiced. Although the dataset beyond 3200 BC was not targeted in the networks research, we are aware of continuing metalmaking practices at the fringes of the 'core' metallurgical area: the western Balkans, eastern Alps, Slovakian Alps, Carpathians (both Transylvania and Moldova) and well into the Caucasus Mountains, all arising during the early to mid-4th millennium BC with copper and arsenical copper production (e.g. Antonović 2014a; Bognár-Kutzián 1972; Courcier 2014; Dolfini 2014; Hansen 2013b; Höppner *et al.* 2005; Novotna 1970; Radivojević *et al.* 2010b; Roberts *et al.* 2009; Ryndina and Ravich 2012; Scharl 2016; Vulpe 1975).

Given this existing evidence for metal circulation, *The Rise of Metallurgy in Eurasia* project evaluates the metal composition and metal provenance of the new copper finds from Pločnik and Belovode in the light of networks modelling and related interpretations to metal circulation. This addresses Research Questions 4 and 6.

Metallurgy, metallurgists and societies

In order to re-investigate the interpretations of early metallurgy, metallurgists and societies, as per the aim of *The Rise of Metallurgy in Eurasia* project, it is not only necessary to build interpretations from all the available and relevant data which is gathered and analysed by new and innovative approaches, but also to acknowledge and critically evaluate the existing narratives that

[2] Data also available at: https://www.repository.cam.ac.uk/handle/1810/265760

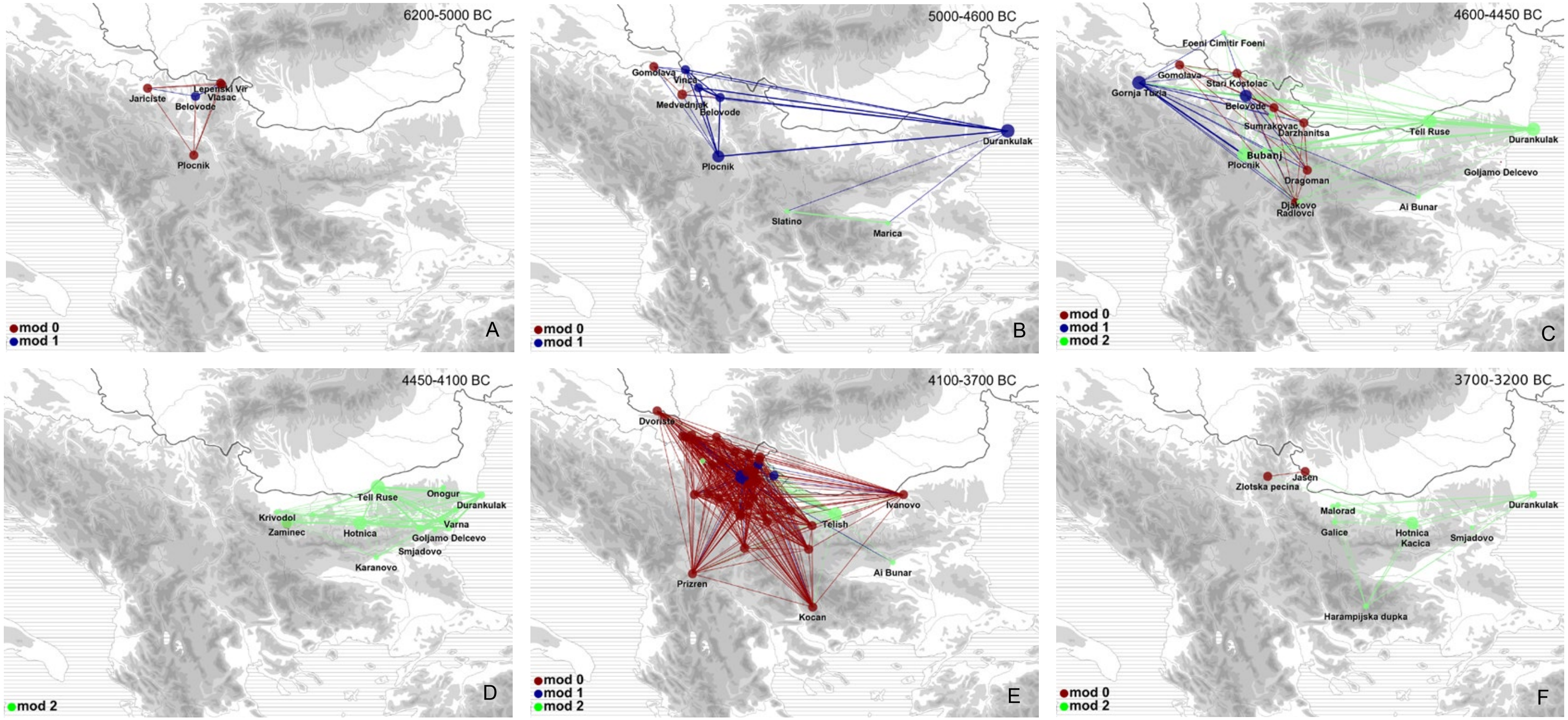

Figure 9. Networks of copper supply throughout *c.* 6200–3200 BC in the Balkans. (a) Period 6200–5000 BC illustrates the early core of supply networks for copper mineral-only artefacts; (b) Period 5000–4600 BC is dominated by the supply networks of Module 1 (proxy for Vinča culture, see Figure 9); (C) Period 4600–4450 BC is dominated by the developing Module 2, which emerged in parallel with the slow disappearing supply regional networks of Modules 0 and 1; (D) Period 4450–4100 BC demonstrates the supremacy of Module 2 in the east Balkans (proxy for Kodžadermen-Gumelniţa-Karanovo VI cultural complex, Figure 9); (E) Period 4100–3700 BC shows the rise of supply networks of Module 0 in central Balkans (eastern Serbia, proxy for Bodrogkeresztúr culture, Figure 9) following the collapse of the eastern Balkan networked systems by 4100 BC; (F) Period 3700–3200 BC presents a picture of nodes scattered in eastern Balkans, altogether reflecting the incoherent set of available data (after Radivojević and Grujić 2018: Figure 6).

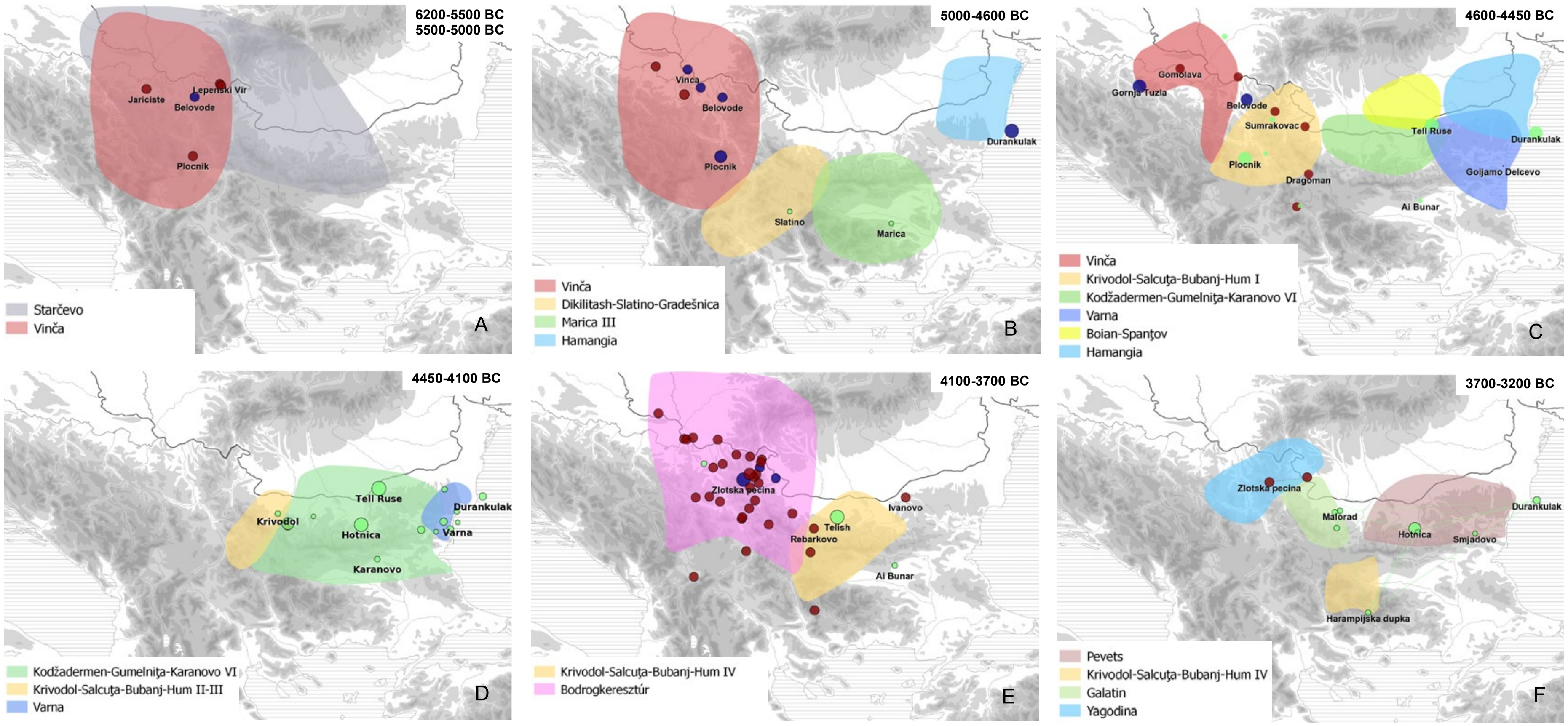

Figure 10. Distribution of archaeological cultures / copper-using societies in the Balkans between c. 6200 and *c.* 3200 BC, with the most relevant sites. Note colour-coding and size of nodes consistent with the module colour (Module 0 – red, Module 1 – blue, Module 2 – green) (after Radivojević and Grujić 2018: Figure 7).

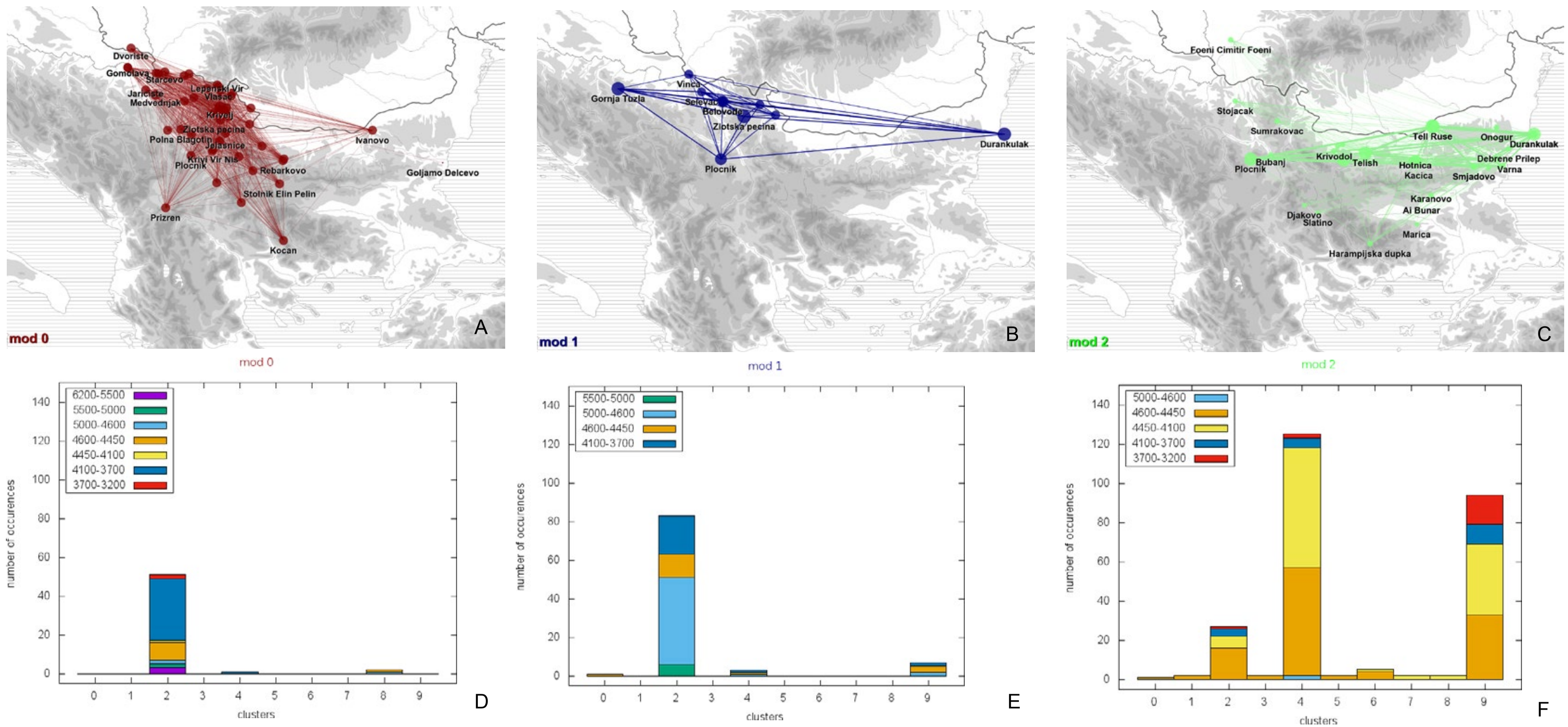

Figure 11. Three individually presented modularity structures of copper producing and exchanging communities in the Balkans (*c.* 6200 – *c.* 3200 BC) paired with diagrams illustrating the frequency of ten different chemical clusters within each of these modules, throughout different periods. (A, D) Module 0 is represented with 50.5 % of nodes in the total network and three chemical clusters only, of which No. 2 is predominant and covers *c.* 6200–3200 BC. (B, E) Module 1 is represented with 11.8 % of all nodes and four chemical clusters. Within the chronological span of *c.* 5500–4450 BC and *c.* 4100–3700 BC, chemical cluster No. 2 is the most dominant, while clusters 0, 4 and 9 have a minor presence. (C, F) Module 2 includes 37.6% of nodes in the total network and includes all ten chemical clusters (0–9). Chronologically it covers the period between *c.* 5000 and *c.* 3200 BC, with two divisions (*c.* 4600–4450 BC and *c.* 4450–4100 BC) representing together 85% of all artefacts in this module (after Radivojević and Grujić 2018, Figure 5).

dominate the discourse. The relationship between early metallurgy, metallurgists and societies in the Balkans has been the subject of extensive and wide-ranging scholarship (e.g. see review in Kienlin 2010). This has invariably concentrated upon the proposed significant impact of metallurgy on the societal themes of social complexity and craft specialisation, especially in relation to the emergence or (self-) identification of elites, as both producers and/or consumers, across the region.

The interpretative narratives in which early metallurgy, metallurgists and societies are deeply embedded can be defined accordingly:

1. The knowledge and expertise relating to production of metal represented a technological revolution.
2. The invention and/or innovation of metallurgy impacts significantly upon the social, political and ritual lives of the farming communities across the Balkans.
3. The knowledge and expertise relating to metallurgy was restricted to specialist individuals who practiced in relative secrecy and held a distinct and elevated status.
4. The properties of metal objects—whether hardness, lustre and/or colour—ensure that they are fundamentally and consistently desirable and valuable to the farming communities across the Balkans.
5. The production, circulation and consumption of metals was integral to the creation and maintenance of elite status and identity in farming communities across the Balkans.

Each of these five inter-related interpretative narratives builds on 19th century ideas that equated (pyro-) technological abilities with societal development within a social evolutionary scheme (Díaz-Andreu 2007; Pearce 2019; Roberts and Radivojević 2015; Rowley-Conwy 2007). The consequence for scholarship regarding the Balkans from *c*. 6200–3700 BC are ongoing debates as to whether a Copper, Eneolithic or Chalcolithic Age represents a distinct historical epoch (Lichardus 1991a; Schier 2014a) and the extent to which metals, elites and social complexity are inter-related (e.g. Hansen 2012, 2013b; Kienlin 2010; Kienlin and Zimmermann 2012). It is also inevitable that the contemporary and historical and contemporary perceptions of the metals involved are influential, with the gold at Varna leading to narratives of the emergence of wealth and social differentiation (e.g. Ivanov and Avramova 2000; Renfrew 1978a, 1986), with copper throughout the Balkans leading to narratives of technological and industrial production, distribution and scale (Chernykh 1992; Ryndina 2009), and with lead in the Balkans and elsewhere being largely ignored as a low value and technologically uninteresting material.

It is therefore not surprising that the interpretation of the life of the prehistoric Balkan communities (and especially of the 5th millennium BC) has frequently been influenced by the conventional, metal-orientated approaches in archaeological research in the area, even with the rapid growth of settlement, landscape and environmental research, and interpretational perspectives. Unsurprisingly, it derived from a seductive idea that the presence of craft specialisation indicated the presence of a complex social organisation (Childe 1950), and that the technology is tightly correlated with the increase in social complexity (e.g. Childe 1944; Morgan 1985 [1877]; White 1959). This notion led to the pursuit of centralised decision making in any society with metallurgical practice, making the Balkan case—with the earliest traces of metal making and the earliest large-scale production and circulation of metal ornaments and implements—a fertile ground to justify the advent of highly specialised knowledge with accumulation of individual wealth and emerging hierarchy (e.g. Renfrew 1986; Hansen 2013b).

This metal-construct is still frequently dominant in scholarship, in defining the (elite) socio-economic dynamics of prehistoric communities at the time. This is despite the fact that other materials such as ceramics, flint, polished stone, obsidian and spondylus (e.g. Amicone *et al.* 2020a; Ifantidis and Nikolaidou 2011; Klimscha 2016, 2020; Milić 2015; Spataro 2018; Whittle *et al.* 2016; Windler 2018; 2019) were also comparably, if not much more extensively, sourced, shaped, traded and/or deposited in settlements and graves prior to, and along with, metal objects. It is evident that, especially in the last decade, many major Balkan Neolithic-Chalcolithic projects have explicitly sought to go beyond traditional metal-orientated perspectives, especially given the infinitely larger scale and depth of the non-metallurgical archaeological and environmental record. This is reflected in recent syntheses, whether encompassing the Balkans (Chapman 2020) or the Black Sea region (Ivanova 2013). In particular, research engaging with population dynamics, subsistence strategies, settlement practices, and responses to local and regional environmental and climatic change is thriving (e.g. Benecke *et al.* 2013; Chapman and Souvatzi 2020; Filipović *et al.* 2017, 2018; Gaastra *et al.* 2018, 2019; Ivanova 2012; 2020; Ivanova *et al.* 2018; Marić 2013a, 2015, 2017; Müller 2012, 2017; Orton 2010; Orton *et al.* 2016; Porčić 2011, 2012a, 2020; Porčić *et al.* 2016; Silva and Vander Linden 2017). It is also worth noting that several major, modern excavation and survey projects of Neolithic-Chalcolithic sites in the Balkans such as Okolište (Bosnia), Uivar (Romania), and Vinča (Serbia) (Draşovean and Schier 2021; Müller *et al.* 2013a; Schier 2014b; Tasić *et al.* 2016a) have yet to reveal substantial metal objects or evidence for metal production. However, where metal objects and/or metallurgical remains are found as for instance at Pietrele (Romania) (Hansen and Toderaş 2012; Hansen *et al.* 2019), familiar interpretative narratives relating to metals and elites are proposed (Hansen 2012, 2013a; Klimscha 2020).

The primary challenge, at least at the broader interpretative scale, in investigating the origins, development and societal inter-relationships of early metal objects and metallurgy in the Balkans. What this means in practice is to analyse and interpret the metal-orientated evidence, not in technological or intellectual isolation, but in relation to the other practices and activities of communities living in the region in the Late Neolithic and throughout the Chalcolithic (*c.* 6200–3700 BC).

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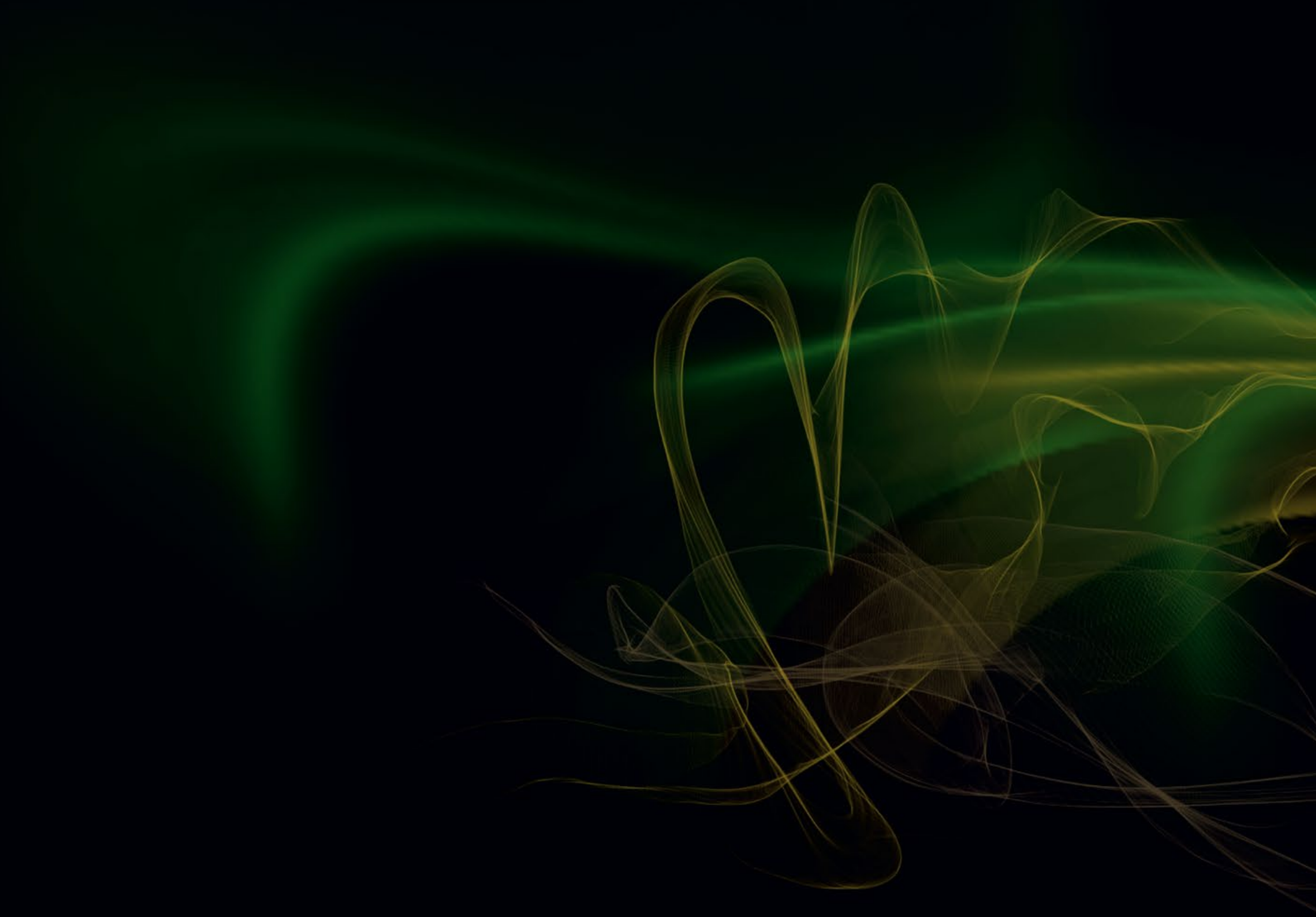

The Rise of Metallurgy in Eurasia is a landmark study in the origins of metallurgy. The project aimed to trace the invention and innovation of metallurgy in the Balkans. It combined targeted excavations and surveys with extensive scientific analyses at two Neolithic-Chalcolithic copper production and 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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