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ARTICLES

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EARLY METALLURGY OF UKRAINE OF THE LATE 5TH-4TH MILLENNIA BC: AN OUTLINE

ABSTRACT

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According to the classical model of the metallurgical raw material supply chain proposed by Eugeniy Chernykh, the Eneolithic and Early Bronze age cultures of Ukraine were completely dependent on imported raw material. It seems that the main supplier of metal, as well as some complete goods during the 5th and 4th Millennia BC, was the '*Carpatho-Balkan Metallurgical Province (CBMP)*' while during the 3rd Millennium BC, the provision chain was reoriented towards the '*Circumpontic Metallurgical Province (CMP)*'. Yet, new discoveries that were made during the 1990s-2020s indicate the need for the amendment of such a model. This is the aim of the current paper. In the following text, the concept of four Ukrainian local metallurgical provinces and two metalworking foci will be introduced. The typology and dating of the recently discovered metal objects as well as metallurgical tools will be provided. The question of the existence of domestic metallurgical raw material deposits will be discussed.

Keywords: Metallurgy, Eneolithic, Early Bronze age, Trypillia, Ukraine
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INTRODUCTION

Copper and bronze are the defining metals of the European Eneolithic and Bronze ages, and in these periods they had significant practical and symbolic value. Effective working tools, deadly weapons, precious jewellery and symbols of power were made of those substances. The worth of these metals was additionally increased due to their unequal distribution in the world. While some areas of Europe and Asia are rich in raw material, others possess little or none. The exchange of coloured metals is often considered to be one of the motives for establishing cross-regional communication networks (Ling *et al.* 2014, 118) evolving at the beginning of the Late Bronze Age into the first world-system. Introduced in 1974 by E. Wallerstein (Wallerstein 1974) and adopted by prehistoric and early historic archaeologists during the late 1970s – early 1990s (Friedman and Rowlands 1978; Kohl *et al.* 1978; Rowlands *et al.* 1987; Bader ed. 1990; Chase-Dunn and Hall 2019), world-system theory proved to be a fruitful methodological framework with major interpretative capabilities. The revelation of exchange relations between communities appeared to be useful not only for the explanation of macro-level dependencies between core and periphery areas but also for understanding the micro-level inequity within communities based on restricted control of imported materials and artefacts (Harding 2013, 379). At the same time, while world-system theory was gaining popularity, certain scholars expressed scepticism and called for a critical examination of the model. W. J. Mommsen, for example, pointed out that inequality of exchange is often taken for granted as a network-inherent property rather than being an archaeologically attested fact (Mommsen 1987, 130). C. Gosden in turn warned that the phenomenon of of ambiguity in the dating of archaeological artefacts as well as fragmentation of quantitative archaeological data may disturb the results of modelling (Gosden 1993, 411). Indeed, in some cases, the foreign nature of certain raw materials may be challenged by a better survey of a region and discovery of previously unknown deposits.

Such is the precedent of Ukraine whose own metallurgical production was overlooked by the Soviet scholars working during the second half of the 20th century. In particular, the famous Russian archaeologist and head of the USSR's only archaeo-metallurgical laboratory specializing in the study of prehistoric use of coloured metals, Eugeny Chernykh, claimed that the Eneolithic and Early Bronze Age cultures of Ukraine were completely dependent on imported raw material (Chernykh 1966, 66). In his conception, the main supplier of raw metal, as well as some complete goods during the 5th and 4th Millennia BC was the 'Carpatho-Balkan Metallurgical Province (CBMP)' while during the 3rdMillennium BC the provision chain was reoriented towards the 'Circumpontic Metallurgical Province (CMP)'. Both provinces represent cross-cultural economic entities covering huge areas of approx.1.3-1.4 million sq. km and 4.5-5 million sq. km accordingly (Chernykh 2008, 38, 41). The relations between cultures constituting the 'metallurgical province' are modelled as a hierarchy where the 'metallurgical focus' is a centre while the 'metalworking focus' is a periphery. In this model, the Trypillia culture as well as the Late Eneolithic cultures of the Ukrainian steppe were described as ore-free and showing no evidence of local ore smelting. Expressed for the first time in the Soviet scholar's doctoral candidate thesis, the idea reappears in his later works (Chernykh 1970, 24; Černych 1991; Chernykh 1992; 2008, 39; 2014), while also being supported by his colleagues (Ryndina 1970, 22) and quoted by a younger generation of Russian archaeologists (Klimushyna and Tutaeva 2022, 186). The academic influence of Chernykh's model on the perception of Ukrainian prehistoric metallurgy was additionally reinforced by the circumstance that until recent time the English translation of his book published in 1992 was the only comprehensive monograph available for the wide European audience (Chernykh 1992).

Yet, as often happens in archaeology, rigorous fieldwork has revealed new evidence originating from what had formerly been believed to have been a blank territory. As is illustrated by the latest monograph of V. Klochko (Klochko *et al.* 2020), the prehistoric cultures of modern Ukraine were rich in metal objects. The earliest copper objects coming from Ukraine are dated to the end of the 5th Millennium BC which makes them contemporaneous with the Balkan Final Chalcolithic metallurgy (Radivojević and Roberts 2021, 206).

While evaluating the scholarly heritage of the Soviet school of paleo-metallurgical research, it is worth remembering that it was produced within a totalitarian empire and hence was affected by its social and political environment. Aiming to establish complete control over people's thoughts, the Communist Party of the Soviet Union established strict censorship of scholarly works, including archaeological research. While the interpretative application of Marxist-Leninist economic theory was mandatory, the use of other frameworks was denounced or even prohibited. Among suppressed ideologies, one should mention 'bourgeois nationalism'. Starting with the political trials of the 1930s (Mace 1993), the accusation of the spread of bourgeois nationalistic propaganda was frequently used as evidence of anti-Soviet subversion punished in imprisonment or execution. Among many victims of the Soviet regime in the context of the current paper, it is worth mentioning Mykhailo Boltenko, the first excavator of the Usatove culture, who spent the years 1934-1939 in a Gulag camp; Silvestr Mahura – the head of the Trypillia expedition, who was executed in 1938; Todos Movchanivskyi, the scientific secretary of the Institute of the History of Material Culture and the author of a research program into the Trypillia culture, who was executed in 1939. During the 1960s-1980s, the grip of the KGB diminished, yet remained tight. Although physical violence was less common, the discharge of academic positions, publication restrictions, and public critique campaigns sustained the role of governmental thought-control instruments. For example, in 1972 the historian Fedir Shevchenko was suspended from the position of the director of the Institute of Archaeology of the Ukrainian SSR due to the "deviation from the class and internationalistic positions in the interpretation of historical events" (Yaremchuk 2009, 58-60). The same year the famous researcher of the Bronze Age Donetsk Catacombna Culture, Stanislav Bratchenko, lost his position as the head of the Donetsk archaeological expedition due to his 'nationalistic statements' (Kolybenko 2015, 109). A consequence of the Soviet repressive policy was the reduction of the scholarly talent pool and the emergence of inequality between scholars. While the archaeologists working in national republics, including Ukraine, faced severe obstacles in pursuit of their academic careers, the archaeologists residing in Moscow possessed privileges.

The following paper aims to rework the models of the Soviet time and acquaint the European audience with a modern Ukrainian vision of the history of the earliest metallurgy. The concept of four local metallurgical provinces and two metalworking foci will be introduced. The typology and dating of the recently discovered metal objects as well as metallurgical tools will be provided. The question of the domestic metallurgical raw material deposits will be discussed.

DONETSK METALLURGICAL PROVINCE

Among several Ukrainian early metallurgical foci, the best studied so far is the Donetsk metallurgical centre (Fig. 1: 1). Its history of research begins in 1974 when a young enthusiast from the town of Bakhmut (formerly named Artemivsk or Artyomovsk), Serhiy Tatarinov (1948-2019) presented to the Kyivan Institute of Archaeology evidence of ancient mining activity discovered by him near the villages of Klynovo and Pylypchatyno (Tatarinov 2019, 35). Tatarinov published the first academic papers describing the evidence during the next two years in 1975 (Tatarinov 1975) and 1976 (Kopyl *et al.* 1976). Encouraged by his older colleagues, Dmytro Telehin and Ihor Artemenko, Tatarinov continued his prospecting and was lucky enough to discover several other prehistoric mines near the villages of Midna Ruda, Novo-Zvanivka (Kartamysh) (Tatarinov 1977), Vyskrivskyi, Novo-Otamanske, Pokrovske, Kyslyi Buhor (Tatarinov 1993, 26-30), Hurty and Lozove (Tatarinov 2018, 37, 38). The archaeological excavations of the filling of mines and spoilheaps conducted by Tatarinov provided the scholar with Late Bronze Age pottery, pieces of slag, and fragments of bones and antlers saturated with copper oxides. Also, at the site near the village of Pylypcahtyno, the archaeologist uncovered ruins of the Late Bronze Age ore smelting furnace (Tatarinov 1977, 195). The complete results of Tatarinov's work are presented in three monographs published after the restoration of Ukraine's independence (Tatarinov 1993; 2003; 2018). An unjust fact from Tatarinov's academic biography is the rather late institutional recognition of his input into the early history of paleo-metallurgical research in Ukraine: Tatarinov received the academic degree of candidate of sciences only 30 years after his first major publication in 2006 (Tatarinov 2006). Yet, Tatarinov's contribution as a pioneering scholar who drew public attention to the metallurgical sites of the Donetsk region is significant.

Following Tatrinov's steps, in 1975, the Kyivan archaeologist Sofia Berezans'ka started her own excavation of the Eneolithic to Late Bronze age settlement of Usove Ozero spe-

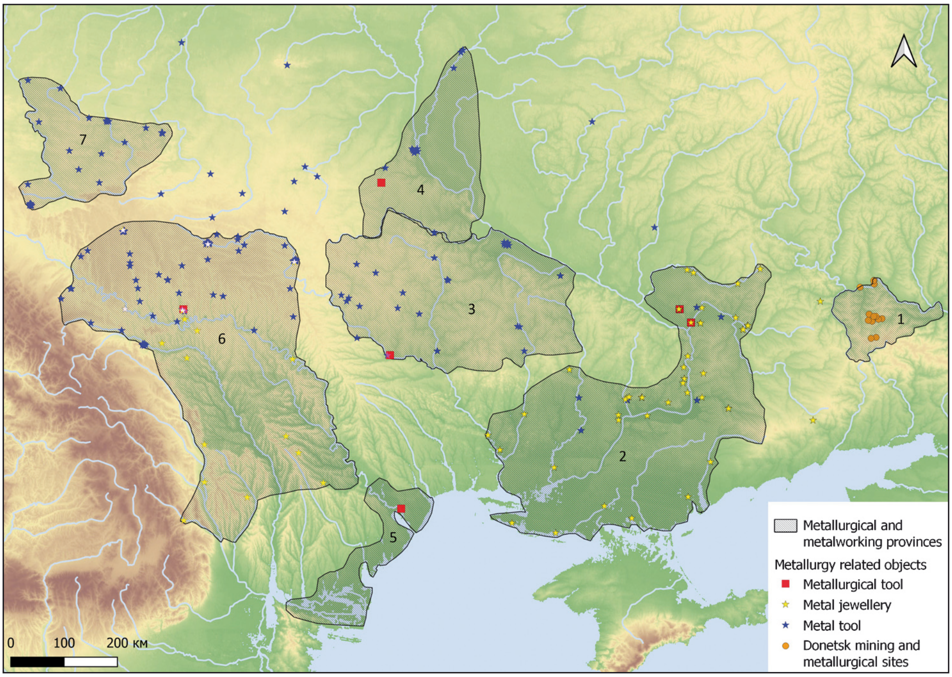

Fig. 1. Ukrainian metallurgical and metalworking provinces of the late 5th – 4th millennia BC. 1 – Donetsk metallurgical province, 2 – Kryvyi Rih metallurgical centre of the Central Ukrainian metallurgical province, 3 – Sabatynivka metallurgical centre of the Central Ukrainian metallurgical province, 4 – Kyiv-Chernihiv metalworking province, 5 – Usatovo metalworking province, 6 – Dnister metallurgical province, 7 – Carpathian-Volhynian Metallurgical province. Map by M. Ivanov

cializing in metallurgical production (Berezanskaya 1990). The site was located around 50-60 km to the north of the mines of the Bakhmut region and could be easily reached by the Siverskyi Donets and Bakhmutka rivers. The cultural deposits of the site consist of four layers. Although the most significant materials originate from the third layer attributed to the Late Bronze age Timber-grave culture (or Srubna culture), materials of Sredniy Stog culture (layer 1), Babyno culture (layer 2) and Bondarikha culture (layer 4) are also present.

The next big field campaign focused on the Bakhmut mines was launched in 1995 by Yuriy Brovender, twelve years after Berezanska finished her work (Otroschenko *et al.* 1997). The archaeological research was implemented step by step and involved the excavation of three underground mine stopes, three open pits, a technogenic (preparation) site and two miners' settlements (Brovender *et al.* 2021, 46). The volume of the copper smelted from the mined ore was measured as well and is evaluated to have reached 700 tons (Brovender *et al.* 2021, 51).

The dating of the earliest metallurgical activity in the Donets area is a subject of debate. While most of the reliable archaeological sources relate to the Berezhnovka-Mayovka Timber-Grave Culture (18/16th-13th centuries BC), we assume that the first episodes of ore smelting happened during the Late Eneolithic. The evidence proving such an early dating is rather new and is not yet known by the wide academic audience. Among the rare examples of Eneolithic metallurgy-related artefacts, one should mention the ore smelting bowl and a metal bracelet made of 2% As-bronze discovered in the cultural layer of the Kleshni-3 site (Telishenko and Brytiuk 2003). The other Eneolithic evidence includes a smelting bowl with drops of slag from the site at Sosnova Roscha and pottery fragments covered with slag from the site of Oleshyn Strumok (Brytiuk 2005, 183).

Further research that could have shed more light on the problem, unfortunately, is impossible. An end was put to archaeological research in the region in 2014 when the Russian Federation launched their military aggression against Ukraine. While combat operations placed archaeological sites at risk of physical destruction, the instalment of pro-Russian puppet regimes of the Donetsk and Luhansk National Republics threatened the personal safety of pro-Ukrainian scholars. Fearing for their lives, most active Ukrainian archaeologists were compelled to leave their homes and move to safer places. In October 2014, the Volodymyr Dahl East Ukrainian National University where Yu. Brovender taught and worked was evacuated from Luhansk to the town of Severodonetsk. The same decision to withdraw was made by the administration of the Vasyl Stus Donetsk National University whose campus has been occupied by pro-Russian combatants since July 2014. The Luhansk archaeologists mentioned above Serhiy Telizhenko and Oleksiy Brytuik also fled – one to Kyiv and the second to Warsaw.

The consequences of the full-scale war started by the Russian Federation on February 24th, 2022 for the paleo-metallurgical archaeology of the Donetsk region are even more devastating. From the very first day, the towns and villages of Donetsk and Luhansk regions bore the brunt of hard battles. Aiming at breaking Ukrainian resistance and spirit, Russian troops have not hesitated to continually target civilian infrastructure and cultural objects. As a result, the towns of Severodonetsk and Bakhmut mentioned above have been destroyed (by the end of August 2022, Severodonetsk had lost around 80% of its buildings while Bakhmut had lost almost 100% by December 9th 2022). The damage to the surrounding natural and historical landscape is also expected to be severe. It may appear turn out that all of the above-mentioned archaeological sites are already lost to science or will be by the end of the war.

DNISTER METALLURGICAL PROVINCE

Unlike the Donetsk and Luhansk regions, the Dnister valley (Fig. 1: 6) drew archaeologists' attention only during the second decade of the 21st century. The first paper expressing an idea of prehistoric usage of the Dnister copper sandstone was published as recent as five years ago – in 2017 and since then the amount of supporting evidence has kept increasing (Klochko 2017a; 2017b). The available data are associated with the Trypillia culture and relate to all the steps of the metal object's life cycle as reconstructed by B. Ottoway (Ottoway 1994, fig. 1): mining and smelting of sandstone, casting and smithing of metal artefacts, their practical and symbolic use with later deposition in the archaeological context.

The metallurgical raw material deposited in the region is represented by cupriferous sandstones layers of which include such copper ores as chalcopyrite, chalcosine, malachite, azurite, tenorite, and cuprite with a concentration of copper fluctuation from 0.01% to 7-8%. The sandstone distribution area is defined by its origin associated with the river sediments. The northern boundary of the sandstone outcrops extends to near the villages of Zhnyborody, Slobidka, and Koshylivska of the Ternopil region; the western boundary, lies along the river Strypa; the southern and south-eastern boundaries are not yet defined (Syvyi and Kitura, 2020, 104).

The archaeological evidence of prehistoric mining activity happening in the region is represented by rare finds of mining tools among which the Letichiv hoard of the Trypillia culture is the most interesting (Klochko 2017, 235). Discovered in 2005, the hoard included two functional tools and their symbolic representation in the shape of two small copper pendants. Morphologically, the discovered tools are reminiscent of modern pickaxes or mattocks, both used for prying, digging and mining. As for the pendants, while being the symbolic representation of the full-scale instruments they signify the genesis of an independent "miner's identity" happening within the Trypillia society during the mid. 4th Millennium BC manifested through personal adornment.

The processing of raw ore most probably was carried out within the Trypillian settlements, although reliable evidence is lacking. The only smelting facility excavated so far is object No. 2 from the site Kamianets-Podilskyi of the Petrenskaya group (Trypillia CI phase) investigated by D. Chernovol in 2016 (Chernovol 2021, 59). The pit's filling included several items relating to copper casting including around two dozen amorphous copper droplets, a piece of copper wire, and 40 fragments of crucibles some of which were partly slagged (Chornovil 2022, 121, 122). The other evidence is the finding of a copper ingot originating from the Nezvys'ko site (Trypillia BI phase). The metallographic analysis conducted by N. Ryndina revealed that the ingot represents a copper splatter dropped from the crucible (Ryndina 1962).

The large scale of Trypillia copper production is attested by several hundreds of metal objects found within the Trypillia habitation area. According to the most recent figures provided by V. Dergachev and V. Parnov, there are currently 18 hoards of copper adornments known to scholarship (Dergachev and Parnov 2022, 26). The number of jewellery pieces composing the hoard is different and varies from several dozen to thousands. The richest collections so far are the Kamianets-Podilskyi hoard I which included 2050 copper objects with a total weight of 2074 g (Dergachev, 2016, 36), the Condrița hoard which in-

Fig. 2. Examples of the unique copper hammer-axes and pickaxes found in Ukraine.
1 – Vinnytsia region, 2 – Verben, Rivne region, 3 – Vinnytsia region, 4 – Cherkasy region, 5 – Chernivtsi region. Photo by V. Klochko

cluded 544 copper objects with a total weight of 1653 g (Dergachev and Parnov 2022, 7), and the Carbuna hoard which included 444 copper objects (Dergachev 1998, 29). In terms of total metal weight, the volume of known working tools is even greater. The most complete catalogue of Trypillia metal instruments published by V. Klochko (Klochko *et al.* 2020) lists more than 85 copper hammer-axes, flat axes and axe-adzes.

Technologically the metallurgical craft of Trypillia people derives from the artisan tradition of the Eneolithic cultures of Central and Southern Europe. The list of similar artefacts includes axes of Pločnik, Nádudvar, Codor, Ariuşd, Agnita, Mezőkeresztes, Vidra, and Jászladány types, as well as flat axes of Coteana, Cucuteni, Ostrovul-Corbului, Vinča-Altheim, and Remedello-Bytyń types. Yet, despite significant kinship, the Trypillian craft demonstrates several unique features signifying the development of a local system of metallurgical knowledge. Among copper artefacts having no analogies within the Balkan cultures, one should mention flat axes of the Nova Ushytsia type. Composed of almost pure metal (98.26% - 99.74% copper) (Klochko *et al.* 2020, table 4) they were probably cast from the local native copper deposited near the town of Haisyn (Pavliuk and Pavliuk 2009a) and the village of Chemerpil (Pavliuk and Pavliuk 2013). The other unique objects are the copper axes and pick-axes found in the Vinnytsia region (2 items), Cherkasy region, Chernivtsi region and village of Verben (Fig. 2).

CARPATHIAN-VOLHYNIAN METALLURGICAL PROVINCE

The research history of the Carpathian-Volhynian Metallurgical province (Fig. 1: 7) is also rather short and begins with the expedition organized by archaeologist Viktor Klochko and geologist Viacheslav Manichev in 2000-2001 (Klochko *et al.* 2000; 2003). After the review of historical data from the early 20th century as well as their own field investigation, the scholars identified more than 12 potential deposits of copper-bearing basalts that could have been used by prehistoric people including deposits near villages Rafalivka, Janowa Dolina, Velykyi Mydsk, Dovge Pole, Gutvin, Beresovets, Oleksandria, Gorynrod, Vapnytsa, Rudavytsy, Studny, and Velica Osnytsa. The total reserves of Volhynian raw material are evaluated at 28 million tons of metal while the weight of some of the native copper plates reaches 1 kg. The distinctive features of the native copper in the Volhynian deposits are the increased concentration of zinc followed by the low inclusion of arsenic, cobalt and bismuth.

The earliest metal items found in the region are the hammer-axes of Vidra, Codor, Varna, Pločnik, Agnita and Nádudvar types, as well as flat axes of Coteana type dated approximately to the Trypillia BI phase. One of the Nadudvar type hammer-axes, - an item from the vicinity of the town of Torchyn – was studied for the metal composition and production technology. The spectral analysis conducted by T. Goshko revealed that the item was cast from almost pure copper (99.68%) with little admixture of Pb (0.0002%), Bi (0.035%), Ag (0.05%), Fe (0.15%) and other elements. As a mould, the ancient craftsmen had chosen a container with low heat conduction. After the casting, the axe was heated to a temperature of around 900-1000°C and smithed until the compression degree reached 80-90% (Markus 2009, 137).

The Trypillia BII-CI stage tools documented within the Volhynia region are represented mainly by flat axes of Cucuteni, Nova Ushytsia and Ostrovul-Corbului types. A rare example of an adze-axe found in the region is the Jászladány type item from the vicinity of the village of Lystvyn. The production technology applied in the manufacturing of this axe was in many ways similar to that used in the case of the Nádudvar hammer-axe described above. As a casting alloy, the ancient craftsmen used 1249 g of almost pure copper with little admixture of Pb (0.0001%), Si (0.2%) and other elements. Considering the nature of the eutectics location, T. Goshko suggests that the item was cast in a mould with low heat conduction and later was smithed until the compression degree reached 80-90% (Markus 2009, 138).

During the Early Bronze Age, the exploitation of the Volhynian deposits of native copper was continued by the craftsmen of the Corded Ware Culture who established there their metallurgical province of the Willow leaf (see Klochko and Klochko 2013).

CENTRAL UKRAINIAN METALLURGICAL PROVINCE

Although some scholars scarcely mentioned prehistoric metallurgical activity happening in the vicinity of Kryvyi Rih before (Otroschenkno 2009, 472; Brovender 2019, fig. 1; Klochko and Kośko 2013, 14; Klochko *et al.* 2020, 15, 41) the detailed concept of a Central Ukrainian metallurgical centre had not been developed until the current paper.

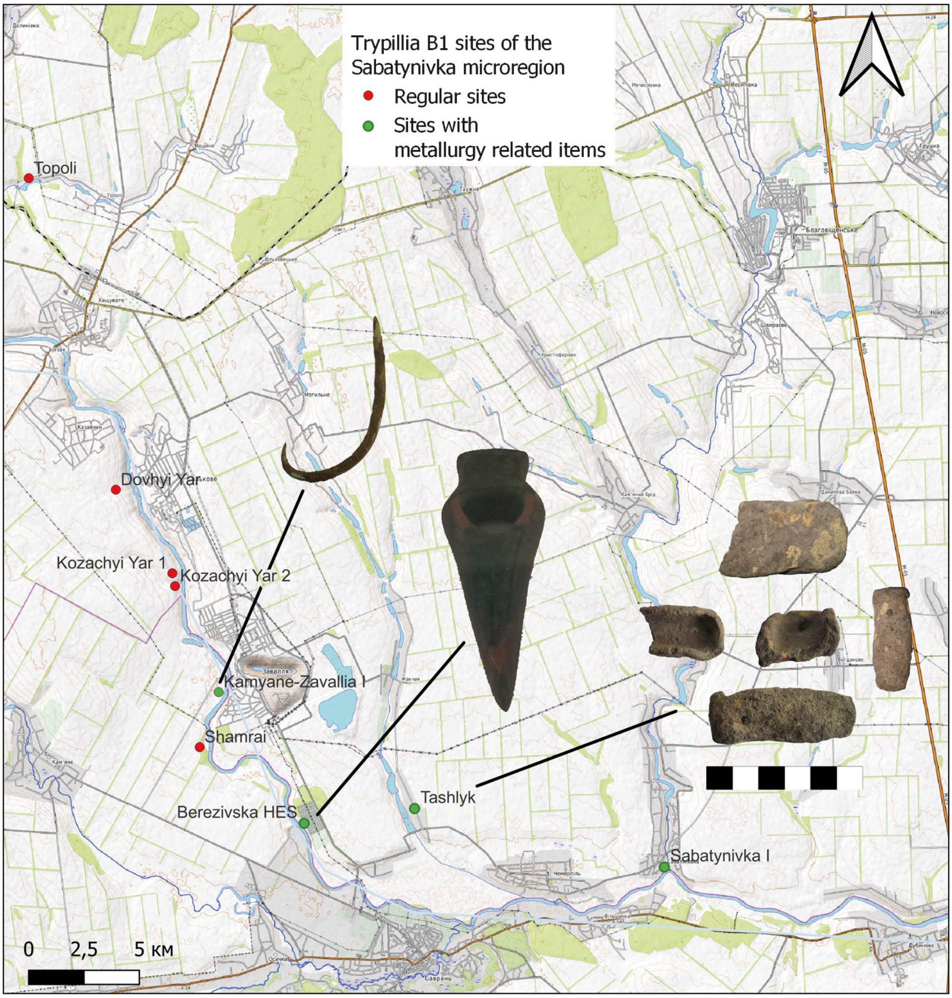

Fig. 3. Trypillia BI sites of the Sabatynivka microregion located near native copper deposits of the Chemerpil area. Map after Kiosak and Lobanova 2021, modified by author

The oldest metal objects found in the region so far are the Vidra type axe from the cultural layer of the Trypillia BI site Berezivska HES (Ryndina 1970, 19), a Pločnik type axe (Klochko *et al*. 2020, 12) found near the famous Trypillia BII-CI mega-site of Nebelivka (Gaydarska 2020), the Ariuşd type axes found near the village of Lysianka and within the Orativ district, and a Coteana type flat axe found near the town of Bohyslav.

The raw material used for casting the above-mentioned artefacts was most probably obtained from local deposits of native copper associated with the eastern slopes of the Ukrainian Shield. According to the data of modern geological prospects, the outcrops of

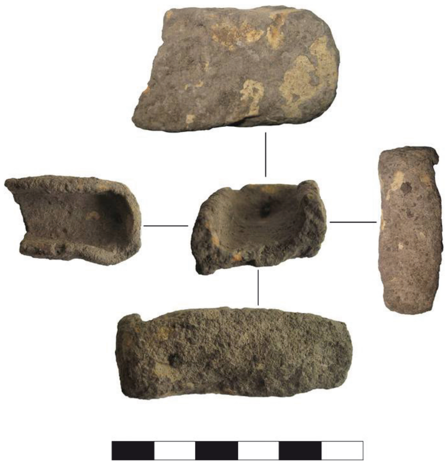

Fig. 4. Ceramic casting mould collected on the surface of the Tripillia BI site Tashlyk. Photo by O. Peresunchak

native copper in Central Ukraine concentrate within the Haisyn area (Pavliuk and Pavliuk 2009a), the Bilyi Kamin structure (Pavliuk *et al.* 2009b), Mohyl'ne area (Pavliuk *et al.* 2009a), and Chemerpil area (Pavliuk and Pavliuk 2013). The latter is of special interest due to its overlap (Fig. 3) with the area of discovery of several metal and metalworking tools. The first is the above-mentioned Vidra type axe from the settlement Berezivska HES (4600-4400 BC), – a site that is also famous for the increased number of small copper items, needles, pins and fishing hooks (Burdo 2015, 18), as well as metalworking instruments: hammers, anvils and abrasives (Tsvek 2005). The collection of metal items from the site Sabatynivka I is less fascinating but still valuable and includes six copper needles (Burdo 2015, 18). The local casting of flat axes is attested by the fragment of clay casting mould (Peresunchak 2019,160) found on the surface of the site at Tashlyk (Fig. 4). Additional evidence of the prehistoric exploitation of the Cemerpil native copper are the results of the composition analyses of alloys. According to E. Chernykh (analyses No. 3798), the mentioned Vidra type axe was cast from almost pure copper with micro admixtures of Ag, Ni and Pb (Ryndina 1970, 19). The same set of admixtures is also present in samples of Chemerpil copper (Pavliuk and Pavliuk 2013, 62). In such a way, the Sabatynivka microregion (Kiosak and Lobanova 2021) demonstrates all the evidence required for the identification of a metallurgical focus: local deposits of raw material, casting and metalworking equipment, and complete metal artefacts. Further research should shed more light on this issue.

At the Trypillia stage CII (3500-3000 BC), the metallurgical knowledge spread further to the east and reached the banks of the river Dnipro. Here, the metallurgical raw material is represented by the deposits of chalcopyrite in the areas of Verkhivtseve, Kruta Balka, Surs'ke, Kremenchuk (Grinchenko *et al.* 2006, 91) and Kryvyi Rih (Berezovsky *et al.* 2021).

Fig. 5. New finds of the Samara type axes discovered in Ukraine. 1-8- Cherkasy region, 9 – Kharkiv region, 10 -Novi Petrivtsi, Kyiv region, 11 –Vinnytsia region. Photo by V. Klochko

The most common metal artefact originating from the Dnipro basin is the copper jewellery found within the kurgan burials of the Serezlievka local group of the Late Trypillia culture. Produced according to the Trypillia technology and fashion, the copper tubes, beads, rings, and spiral pendants played a significant role in the construction and manifestation of the personal identity of the earliest "kurgan peoples". As of today, 19 burials accompanied by copper adornments are known, which constitutes 25% of all equipped graves of the Buh-Dnipro interfluve (Ivanov and Tupciyenko 2022). One of those burials was unusually rich and included a total of 242 copper tubes and rings (Rassamakin 2004, 38).

The cultural transformations happening in Central, Southern and Eastern Europe during the second half of the 4th millennium BC and the transition to the Early Bronze Age are reflected in the transformation of prehistoric metallurgy as well. An important technological innovation of the Central Ukrainian metallurgical centre that was embraced during that time was the adoption of the shaft-hole axes named the Samara type axes (Klochko 2019, 69). Deriving their design from the artefacts of the Kura-Araxes culture, the Samara axes differ in several details including the less distinguished poll (Fig. 5). As of today, 21 Samara type axes are known, 75% of which come from the Right Bank of the Dnipro River. The local production of Samara-type axes is proven by two finds of casting moulds discovered within burials of the Serezlievka local group at Maivka XII, k.2/10 and Sokolove 1/6 (Kovaleva 1984, 36), as well as the use of local pure and sulphide copper for the casting (analyses 1808 and 996 from Klochko *et al.* 2020). The dating of the Samara axes is problematic. As of today, the only available AMS date was obtained from the samples from the Dolynka kurgan burial (Ivanova and Rassmann 2014, 214). Considering the geographic location of the find, the Crimea peninsula, the burial's construction date which fluctuates between 3500-3300 cal. BC, it may serve as the terminus post quem for the spread of Samara axes in Ukraine. At first, the production technology of Samara axes diffused from the south Caucasus to Crimea and later, further north to Central Ukraine. During the Early Bronze Age, the Samara axes transform into Baniabic type axes characteristic of the Yamna and Coţofeni-Kostolac cultures.

KYIV-CHERNIHIV METALWORKING PROVINCE

Considering the typological dating of Pločnik and Ariuşd axes to around 4000 BC, the metallurgical production within the Kyiv-Chernihiv Metallurgical province began in the Trypillia stage BI-II, although the direct contextual correlation between the Trypillia sites and those axes is not yet documented. At stage CII, the metallurgist of the Sofievka (3300-2950 BC) local group of the Late Trypillia culture switched towards the making of items of smaller forms: jewellery, blades and flat axes (Klochko 1995). Morphologically, the Sofievka knives derive their shape from the knives of the Bodrogkeresztúr culture (Kuna 1981, 64, 65; Vajsov 1993, fig. 34), while the axes stem from the Vinča-Altheim metallurgical

Fig. 6. Ceramic casting found near the town of Fastiv, Kyiv region. Photo by V. Klochko

tradition. The evidence of the local production of axes is the finding of several two-part closed casting forms. The first one was made in 1893 by V. Khvoika at the Kyrylivska Hora site situated within modern Kyiv, whilst the second one was made in 2022 near the town of Fastiv (Fig. 6). The most probable source of metallurgical raw material used by the craftsmen of the Sofievka local group is the Skvira deposits (Pavliuk and Pavliuk 2009b) of native copper and copper sandstone located 150 km to the south-west from the closest Sofievka site. At the end of their use, most of the copper items of the Sofievka culture were deposited as grave goods. According to material gathered by V. Klochko, 150 of the 202 known Sofievka metal objects were found within cremation burials (Klochko 1995, 205).

USATOVE METALWORKING PROVINCE

The existence of local metallurgical production within the Usatove culture (3500-3000 BC) is a subject of discussion. While most scholars claim that the famous Usatove daggers are the products of Eastern Mediterranean workshops (Zbenovich 1966; 1974, 119; Ryndina and Konkova 1982; Klochko *et al.* 2020, 40), others suggest their North-Western Pontic origin (Matuschik 1998; Petrenko 2013, 205). The typology of Usatove daggers is also debatable. As of today, at least seven different typological schemes exist, among which the scheme proposed by V. Petrenko is the most detailed one (Petrenko 2013, 204). Reviewing the 16 currently known blades, the scholar divides them into eight types underlining in such a way the uniqueness of their morphology. The production technology of Usatove daggers is rather complex and was mastered during a series of many trials and failures. To avoid the solidification of the liquid metal, the stone mould had to be heated at a temperature of around 300°C. After the casting, the blade of the dagger was heated at temperatures around 400°C but not higher than 450°C and then forged. At the end of production, the edges of the dagger were also forged, but now while cold (Ryndina and Konkova 1982, 38).The question of the origin of these daggers is additionally entangled by the absence of reliable metallurgy-related evidence. The local deposits of raw material are absent while the only known metallurgical instrument is a ceramic nozzle found within the cultural layer of the Usatove settlement. The other metal items of the Usatove culture include chisels and flat axes.

DISCUSSION

As is demonstrated by the typological analysis of metal artefacts provided above, the earliest metallurgy of Ukraine stems from the metallurgical tradition of South-Eastern and Central Europe. In this regard, the Trypillia culture should be included in the Balkan early metallurgy heartland as it is defined by (Radivojević and Roberts 2021) and should be treated as its equal unit rather than peripheral. The quality and quantity of recently obtained data suggest that the scale of Trypillian metallurgical production was relatively high while the Trypillian craftsmen could produce items of many different types including unique ones.

The earliest metallurgical knowledge came to Ukraine not in isolation but as a part of a wider cultural complex that included advanced agriculture, stockbreeding, high-quality painted pottery, flint processing and social cooperation. While reclaiming new lands, the Trypillia people profited from all of the locally available resources including water, soil, clay, flint, fauna, flora, metallurgical raw materials – native copper as well as copper ores. Moreover, the ‘search for metals’ could have been one of the motives for further colonization.

The localization of previously unnoticed Ukrainian copper ore and native copper deposits suggests that existing models (Chernykh, 1966, 66; 1970, 24; 2008, 39) linking all the Eastern European raw metal to five South-European mines – Ai Bunar, Rudna Glava, Jarmovac, Veliki Majdan, Majdanpek and others may appear unreliable. Instead of modelling long-distance exchange routes, scholars would do better to pay closer attention to how prehistoric communities managed scarce but local resources. Such a notion corresponds with the recent model by Radivojević and Grujić (2018, 120) suggesting the habit of culturally related communities to preserve regional networks of copper prospecting, production and consumption. In such a way, the hierarchical core-periphery model appears irrelevant for the Eneolithic period clearing the space for more horizontal interpretative approaches.

The economic role of copper tools is yet to be discussed. It may appear that the use of copper flat axes and adze-axes was one of the elements that facilitated the high productivity of land cultivation practised by the inhabitants of mega-sites and was necessary for the fulfilment of the demand for wood.

With the disappearance of the Trypillia culture at the end of the 4th Millennium BC, the metallurgical achievements of the Trypillian metallurgists did not vanish. The Trypillian knowledge about the geographical distribution of metallurgical raw material was inherited by the Early Bronze Age societies of Yamna and Corded Ware cultures who prospected the very same deposits of Kryvyi Rih and Volhynia accordingly. At the same time, metallurgy goes through major changes which coincide with the major cultural and social transformation within the Trypillia culture. The tradition of mega-sites declines, leaving the scene free for less centralized forms of social organization. A new cycle of colonisation begins. Some Trypillia people migrated to the steppe zone which resulted in the emergence of the Usatove and Serezlievka cultures, while others moved to the forest zone which resulted in the emergence of the Sofievka culture. All these new cultural entities are known as the early adopters of significant metallurgical innovations. The Usatove culture is best known for long bronze knives and daggers, the Sofievka culture for copper knives with shorter blades, and the Serezlievka culture is known for the Samara-Baniabic-Novosvobodnaya axes. Quick adoption of the most progressive trends was was probably facilitated by the demands of new social elites whose high social status was communicated through the construction of labour-consuming kurgans and cromlechs (Usatove and Serezlievka cultures), rich sepulchre inventory (Serezlievka and Sofievka cultures), or weaponry (Usatove and Sofievka cultures).

CONCLUSION

Summing up all the above, it can be noted that research into the earliest metallurgy of Ukraine is only beginning. The increasing new evidence is promising, although fragmented and chaotic. The land, previously considered as an 'ore-free' zone, now appears to have been rich in copper and bronze artefacts and raw material veins. Yet, the question of whether the local deposits were used during prehistory remains disputable. On one hand, the archaeological evidence of the prehistoric exploitation of some of the raw material sources mentioned above in the text is yet to be obtained. On the other hand, the usage of scarce yet local resources is a more realistic explanation than the reconstruction of thousand kilometres of exchange networks for the historical period when even the wheel was not yet invented. A final conclusion on this account can be reached only after large-scale physicochemical studies, including analyses of the lead isotope ratios and the chemical composition of both copper ores and copper artefacts found in Ukraine.

As for further research, it should be focused on such activities:

1) Extensive field examination of the Trypillian sites of the Sabatynivka cluster with the appliance of metal detectors and geomagnetic scanners in search of metallurgy-related technological structures

2) Further monitoring of websites and social media for information about new findings of metal artefacts by members of the public (for example, so-called "black archaeologists" with metal detectors) in combination with stricter control over the illicit artefact hunting of archaeological sites.

3) Documentation of the metalwork use ware traces (Dolfini and Crellin 2016) present on the known artefacts.

4) Appliance of the lead isotope analysis which is believed to be the most reliable method of provenance studies (Radivojević *et al.* 2019, 138).

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