Bakar u prapovijesnim zajednicama sjeverne Hrvatske s posebnim osvrtom na vučedolsku kulturu

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Prostor jugoistočne Europe imao je ključnu ulogu u razvoju prerade i obrade bakra još od kasnog neolitika. Razvojem metalurške tehnologije, rudarstva, stvaraju se proizvodni centri i distribucijske mreže kojima cirkulira velika količina metala. Istovremeno, na prostoru sjeverne Hrvatske nalazi bakrenih predmeta izuzetno su rijetki, a eneolitičke zajednice gotovo da ne poznaju metaluršku tehnologiju. Velika i nagla promjena nastupa u vrijeme kasnog eneolitika s nosiocima badenske i vučedolske kulture, kada se ovaj prostor intenzivno i aktivno uključuje u metaluršku proizvodnju. U ovom se radu, prema do sada istraženim arheološkim nalazima metalurških aktivnosti, analizira uloga eneolitičkih zajednica s prostora sjeverne Hrvatske, odnosno postavlja ih se u kronološki i tehnološki kontekst razvoja metalurgije jugoistočne Europe. Poseban naglasak stavlja se na vučedolsku kulturu kao glavnog nosioca metalurške tehnologije i ekonomskih i društvenih promjena koji stvara preduvjete i priprema ovaj prostor za ulazak u brončano doba.

KLJUČNE RIJEČI: eneolitik, bakreno doba, metalurgija, bakar, arenski bakar, antimonski bakar, protobronca, sjeverna Hrvatska

The area of southeastern Europe played a key role in the development of copper processing since the Late Neolithic. During that time, metallurgical technology and mining were being developed along with production centres and distribution networks circulating a large amount of metal. At the same time, finds of copper objects are extremely rare in northern Croatia, and its Early Eneolithic communities hardly knew metallurgical technology. A sudden change occurred with the arrival of the Baden and Vučedol cultures during the Late Eneolithic, when the area became intensively and actively involved in metallurgical production. This paper uses archaeological evidence to investigate the metallurgical role of Eneolithic communities in the area of northern Croatia and place them in the chronological and technological context of the development of metallurgy in southeastern Europe. Special emphasis is placed on the Vučedol culture, which became the main bearer of metallurgical technology and economic and social changes, thus creating the preconditions and preparing the area for the Bronze Age.

KEY WORDS: Eneolithic, Copper Age, metallurgy, copper, arsenic copper, antimony copper, proto-bronze, northern Croatia

UVOD

Početci obrade metala vezani su uz bakar i bakrene minerale, daljnjim razvojem metalurgije razvija se arsenski/antimonski bakar ili tzv. protobronca, a kao vrhunac tehnologije obrade tog metala nastupa pojava „prave" bronce. Bronca, kao slitina bakra i kositra, glavno je obilježje razdoblja brončanoga doba, ali metalni predmeti pojavljuju se nekoliko tisuća godina ranije. Zbog toga se pojavila potreba za definiranjem bakrenoga doba ili eneolitika kao razdoblja između neolitika, kada se metal ne poznaje, i brončanoga doba, kada je ustaljena upotreba kositrene bronce. Pojava bakra kao nove sirovine i širenje tehnologije metalurške proizvodnje rezultirali su povećanim razvojem komunikacija i trgovine, intenzivnim kretanjem ljudi i cirkulacijom robe na sve većim udaljenostima (Renfrew, Bahn 2005: 58). Prostor sjeverne Hrvatske periferni je prostor razvoja najranije metalurgije bakra jugoistočne Europe. U taj proces uključuje se tek sa zajednicama srednjeg i kasnog eneolitka koje samostalno razvijaju metalurgiju i nosioci su društvenih i tehnoloških promjena do početka brončanoga doba.

METALURGIJA I RUDARENJE – OSNOVNI POJMOVI

Bakar se u prirodi može pojaviti u svom elementarnom obliku, međutim, najčešće se pronalazi u obliku minerala gdje je kombiniran s drugim elementima, oksidima, karbonatima i sulfidima. Bakreni minerali mogu biti primarni i sekundarni. Primarni sadrže znatne količine

INTRODUCTION

The beginnings of metal processing were related to copper and copper minerals; further development of metallurgy brought arsenic/antimony copper or "proto-bronze"; finally, the appearance of "true" bronze is seen as the pinnacle of the metal processing technology. Bronze, as the alloy of copper and tin, is the main feature of the Bronze Age period; however, metal objects appeared several thousands of years earlier. This created the need to define the Copper Age or the Eneolithic as the period between the Neolithic, when metal was unknown, and the Bronze Age, which established the use of tin bronze. The appearance of copper as a new raw material and the spread of metallurgical production technology resulted in increased development of communications and trade, intensive movement of people, and circulation of goods over ever greater distances (Renfrew, Bahn 2005: 58). Northern Croatia was a peripheral area of the earliest development of copper metallurgy in southeastern Europe. It was only in the Middle and Late Eneolithic that its communities developed independent metallurgy and carried social and technological changes until the onset of the Bronze Age.

METALLURGY AND MINING – BASIC TERMS

Copper can appear in nature in its elemental form; however, it is most often found in the form of minerals where it is combined with other elements, oxides, carbonates and sulphides. Copper minerals can be primary and secondary. Primary ones contain significant amounts of sulphur

sumpora i drugih elemenata kao što je željezo, a kada se nalaze blizu površine zemlje, mogu na različite načine oksidirati i time oformiti sekundarne minerale (Đurković et al. 1963: 651–652; O'Brien 2014: 2–8, tab. 1). Rudna osnova, odnosno nekorisni dio iz kojega se izdvaja metalni mineral, zove se jalovina (eng. *gangue*) (Đurković et al. 1963: 651–652; O'Brien 2014: 3). Rudarstvo možemo definirati kao pronalaženje i vađenje korisnih mineralnih sirovina iz Zemljine kore, a u širem smislu, obuhvaća sve radove koji takve procese omogućuju i koji dobivene mineralne sirovine pretvaraju u koristan proizvod (Marušić 1988: 588). Rudna ležišta ili rudišta (engl. *orebody*) akumulacije su korisnih mineralnih sirovina u Zemljinoj kori nastale geološkim procesima (Šinkovec 1988: 696; O'Brien 2014: 2). Kako bi takva akumulacija imala značenje pravoga rudnog ležišta, ona mora sadržavati neki minimalni udio mineralne komponente – kvalitetu rude – i neku minimalnu količinu rude – rudne rezerve (engl. *grade*), a njezina eksploatacija mora biti tehnički moguća i ekonomski opravdana (Košćec et al. 1988; Šinkovec 1988: 696; O'Brien 2014: 2). Danas se ekonomski neisplativo rudno ležište naziva rudnom pojavom (Šinkovec 1988: 696).

Prilikom arheološkog proučavanja prerade bakra valja razlikovati „hladnu" od „vruće" metalurgije. Temperiranje[1] (engl. *annealing*), toplinska obrada na nižim temperaturama, odvaja se od pirometalurgije, pravog taljenja koje zahtijeva temperature više od 1000 °C (Radivojević, Kuzmanović-Cvetković 2014: 8). Radikalna promjena u svojstvima materijala koju izaziva tzv. „vruća" metalurgija razdvaja pirometalurgiju od tehnologije „hladnog" oblikovanja minerala. Elementarni bakar, malahit i azurit dugo vremena bili su obrađivani udaranjem, rezanjem, brušenjem, struganjem, glačanjem i zagrijavanjem, tehnikama koje su ukorijenjene u neolitičkoj tehnologiji obrade kamena (Pernicka, Anthony 2010: 163–165; Radivojević et al. 2010: 2776; Pernicka 2014: 448). To vrijeme naziva se „predmetalurškom" ili „malahitnom" fazom, a podrazumijeva prve doticaje i eksperimentiranje s metalom. Tijekom ove faze nije iskorišten sav potencijal bakra i bakrenih minerala, ne poznaje se ekstraktivna tehnologija ni prava termička obrada rude. Zato se ova fa-

1 Eng. pojam *annealing* u hrvatskom strukovnom nazivlju može se naći preveden kao „popuštanje", „napuštanje" ili „temperiranje". Kroz tekst će se koristiti pojam „temperiranje" kao prijevod po preporuci J. Macan (2015: 292).

and other elements such as iron; when they are close to the earth's surface, they can oxidize in different ways and thus form secondary minerals (Đurković et al. 1963: 651–652; O'Brien 2014: 2–8 Tab. 1). The ore base – the unusable part from which the metal mineral is extracted – is called gangue (Đurković et al. 1963: 651–652; O'Brien 2014: 3). Mining can be defined as finding and extracting useful raw mineral materials from the Earth's crust; in a broader sense, it includes all the activities that enable such processes and turn the obtained raw mineral materials into useful products (Marušić 1988: 588). Ore deposits or orebodies are accumulations of useful raw mineral materials in the Earth's crust created by geological processes (Šinkovec 1988: 696; O'Brien 2014: 2). In order for such an accumulation to be considered an ore deposit, it must contain some minimum share of the mineral component – ore quality – and some minimum amount of ore – ore grade, and its exploitation must be technically possible and economically justified (Košćec et al. 1988; Šinkovec 1988: 696; O'Brien 2014: 2). Today, an economically unprofitable ore deposit is called an ore occurrence (Šinkovec 1988: 696).

The archaeological study of copper processing distinguishes between "cold" and "hot" metallurgy. Annealing,[1] heat treatment at lower temperatures, is distinguished from pyrometallurgy, true smelting, which requires temperatures of more than 1000°C (Radivojević, Kuzmanović-Cvetković 2014: 8). The radical change in material properties caused by "hot" metallurgy separates pyrometallurgy from the technology of "cold" mineral shaping. For a long time, elemental copper, malachite and azurite were processed by hammering, cutting, grinding, scraping, polishing, and heating, techniques rooted in Neolithic stone processing technology (Pernicka, Anthony 2010: 163–165; Radivojević et al. 2010: 2776; Pernicka 2014: 448). This period is called the "pre-metallurgical" or "malachite" phase, implying the first contact and experimentation with metal. This phase ignores the full potential of copper and copper minerals and the extractive technology or real thermal processing of ore. Therefore, it cannot be considered part of the development of metallurgical production (Antonović 2006; Killick, Fenn 2012: 563).

1 The term annealing, in Croatian professional terminology, can be translated as *popuštanje, napuštanje* or *temperiranje*. Throughout Croatian text, the term *temperiranje* will be used as a recommended translation by J. Macan (2015: 292).

za ne može smatrati dijelom razvoja metalurške proizvodnje (Antonović 2006; Killick, Fenn 2012: 563).

Pojam metalurgija odnosi se na kompleksan metalurški proces, tj. lanac operacija koji započinje u samom rudnom ležištu gdje se ruda vadi i separira, slijedi njezina primarna i sekundarna obrada (niz tehnoloških koraka) čiji cilj je ekstrakcija metala iz rude. Dobiveni proizvod potom se lijeva i dorađuje u određene oblike sa željenim karakteristikama (Ottaway 2001: sl. 1; Ottaway, Roberts 2008). Metalurgija može biti ekstraktivna, što podrazumijeva operacije ekstrakcije metala iz ruda i proizvodnju blokova (ingota) kao konačnog proizvoda, te prerađivačka, koja podrazumijeva preradu materijala lijevanjem i obuhvaća postupke za poboljšavanje svojstava, termičku i površinsku obradu (Paulin 1982: 433). Kako bi metalna ruda postala gotov proizvod, prolazi kroz nekoliko faza: prospekcija (engl. *prospecting*), rudarenje (engl. *mining*), sitnjenje/koncentracija rude (engl. *beneficiation*), taljenje (engl. *smelting*) oksidnih ruda / prženje (engl. *roasting*) + taljenje sulfidnih ruda, rafinacija (engl. *refining)*, legiranje (engl. *alloying*), lijevanje (engl. *casting*) i kovanje (engl. *smithing*) (Ottaway 2001: sl. 1; Ottaway, Roberts 2008). Razumijevanje pojedinih faza u lancu operacija prerade i obrade bakra važno je za pravilno prepoznavanje tih procesa u arheološkom kontekstu i omogućava uvid u tehnološki doseg određene prapovijesne zajednice te rekonstrukciju razvoja i širenja metalurgije na određenom području.

POČETAK I RAZVOJ RUDARSTVA

Metalurgija je usko vezana uz postojanje rudarstva, ali postojanje metalurške djelatnosti na nekom prostoru ne znači nužno i postojanje rudarstva kojim bi se osigurale potrebne sirovine (Pravidur 2014: 20). Paralelno s razvojem tehnologije obrade kamena morala se razvijati njegova sustavna eksploatacija, potom s vremenom i podzemno rudarenje. Razvoj metalurgije u eneolitiku dolazi kao novina, ali na rudarenje treba gledati kao na dio procesa eksploatacije kamene sirovine zato što je upravo ono omogućilo prvi kontakt s bakrenim mineralima (Jovanović 1979: 28–29, 42; Antonović 2006: 85–86; O'Brien 2013: 443; 2014: 1, 53, 196). Razni čimbenici kao geneza, klasifikacija i karakterizacija rudnog ležišta imaju veliku ulogu u modernom rudarenju, ali oni nisu bili bitni

Metallurgy is a complex process, a chain of operations that begins in the ore deposit itself, where the ore is extracted and separated, followed by its primary and secondary processing (a series of technological steps) with the goal of extracting metal from the ore. The obtained product is then cast and refined into certain shapes with the desired characteristics (Ottaway 2001: Fig. 1; Ottaway, Roberts 2008). Extractive metallurgy consists of the smelting operations of extracting metals from ores and the production of blocks (ingots) as the final product; processing metallurgy consists of casting and the procedures for improving properties, such as thermal and surface treatments (Paulin 1982: 433). In order for metal ore to become a finished product, it goes through several stages: prospecting, mining, beneficiation, smelting of oxide ores / roasting + smelting of sulphide ores, refining, alloying, casting, and smithing (Ottaway 2001: Fig. 1; Ottaway, Roberts 2008). Understanding the individual stages in the operational chain of copper processing is important for the correct identification of these processes in the archaeological context, providing insight into the technological reach of a certain prehistoric community and the reconstruction of the development and spread of metallurgy in a certain area.

THE BEGINNING AND DEVELOPMENT OF MINING

Metallurgy is closely related to mining, but the existence of metallurgical activity in an area does not necessarily mean the existence of mining that would provide the necessary raw materials (Pravidur 2014: 20). The development of stone processing technology must have been accompanied by its systematic exploitation and, over time, by underground mining. The development of metallurgy in the Eneolithic was something new, but mining should be considered within the process of developing the exploitation of stone and other minerals because it enabled the first contact with copper minerals (Jovanović 1979: 28–29, 42; Antonović 2006: 85–86; O'Brien 2013: 443; 2014: 1, 53, 196). Various factors such as the genesis, classification, and characterization of ore deposits play a major role in modern mining, but they were not important or known to the prehistoric miner. Other characteristics of the mine site played a key role: the visibility and physical manifestation of mineralization, metal concentration inside the mine site, and the technical feasibility

ni poznati prapovijesnom rudaru. Ključnu ulogu imale su druge karakteristike rudišta: vidljivost i fizička manifestacija mineralizacije, količina metala unutar rudišta i tehnička mogućnost izvedivosti eksploatacije rude iz njezina ležišta (O'Brien 2014: 4). Odlučujući faktor bila je tehnološka ograničenost tj. stupanj tehnološkog znanja potrebnog za eksploataciju i preradu određenog tipa rudače. Iako možemo pretpostaviti da je i mala količina bakra bila bitna prapovijesnom rudaru, udio bakra u mineralu morao je biti važan prilikom odluke o isplativosti eksploatacije. Tako ruda s premalim udjelom bakra i kompleksna ruda koja zahtijeva napredniju tehnologiju obrade nisu bile eksploatirane (O'Brien 2014: 13–14). Većinu rudarske aktivnosti iz prapovijesti danas je teško otkriti i dokazati. Na samom početku minerali su prikupljani s površine zemlje, dok su vidljivi dokazi prapovijesne rudarske djelatnosti uništeni kasnijim (rimskim, srednjovjekovnim i modernim) intenzivnim rudarskim djelatnostima (Durman 1983: 7; Pravidur 2014: 20–21). Krajem neolitika eksploatacija bakrenih minerala dokazana je s prvim otkrićima prapovijesnih rudnika Ai Bunar i Rudna glava (Jovanović, Ottaway 1976; Černych 1978; Jovanović 1980). Nakon toga, diljem jugoistočne Europe otkrivene su razne rudne pojave i rudišta s naznakama prapovijesnog rudarenja, posebno u istočnoj i središnjoj Srbiji, Transilvaniji i jugoistočnoj Bugarskoj (Jovanović 1979; Pernicka, Anthony 2010: 170; Antonović 2018; Kunze et al. 2018; Krauss et al. 2020).

Danas je općeprihvaćeno da rudarenje metala počinje s ekstrakcijom elementarnog bakra i sekundarnih bakrenih minerala iz površinskog sloja i oksidacijske zone ležišta (O'Brien 2013: 441; 2014: 8, 34). Ta činjenica odražava se i u sastavu metalnih predmeta balkanskog i podunavskog područja koji su izrađeni od samorodnog bakra ili iz oksidnih/karbonatnih minerala koji nisu zahtijevali kompleksni proces taljenja (Jovanović 1979: 46–47; 2009: 146; Durman 2006: 31; Pernicka, Anthony 2010: 171). Nakon iscrpljivanja ležišta oksidnih ruda, pokazala se potreba za istraživanjem drugih rudnih minerala. Počinju se upotrebljavati bakreni sulfarsenidi iz serije tenantit-tetraedrit, tzv. sinjavci ili sinja ruda (engl. *fahlore/gray ore*; njem. *Fahlerz*). Rudarenje sulfarsenida započelo je najvjerojatnije tijekom 4. tisućljeća pr. Kr., a najbolje se prepoznaje po pojavi arsenskog bakra (Durman 2006: 31; O'Brien 2013: 441; 2014: of exploiting ore from its deposit (O'Brien 2014: 4). The decisive factor was the technological limitation, i.e. the degree of technological knowledge required for the exploitation of a mine and the processing of a certain type of ore. Although we can assume that even a small amount of copper was important to the prehistoric miner, its mineral grade must have been important when deciding on the profitability of mine exploitation. Thus, ore with insufficient copper content, and complex ore that required more advanced processing technology, were not exploited (O'Brien 2014: 13–14). Most prehistoric mining activity is difficult to detect and prove today. At the very beginning, minerals were collected from the surface of the earth, while visible evidence of prehistoric mining activity was destroyed by later (Roman, medieval, and modern) intensive mining operations (Durman 1983: 7; Pravidur 2014: 20–21). At the end of the Neolithic, the exploitation of copper minerals was proven with the first discoveries of the prehistoric mines of Ai Bunar and Rudna Glava (Jovanović, Ottaway 1976; Černych 1978; Jovanović 1980). After that, various ore occurrences and mines with signs of prehistoric mining have been discovered throughout southeastern Europe, especially in eastern and central Serbia, Transylvania, and southeastern Bulgaria (Jovanović 1979; Pernicka, Anthony 2010: 170; Antonović 2018; Kunze et al. 2018; Krauss et al. 2020).

Today, it is generally accepted that metal mining began with the extraction of elemental copper and secondary copper minerals from the surface layer and oxidation zone of the deposit (O'Brien 2013: 441; 2014: 8, 34). This fact is reflected in the composition of metal objects from the Balkans and along the Danube, which were made from native copper or from oxide/carbonate minerals that did not require a complex smelting process (Jovanović 1979: 46–47; 2009: 146; Durman 2006: 31; Pernicka, Anthony 2010: 171). After the depletion of oxide ore deposits, the need to search for other ore minerals became apparent. Copper sulfarsenides from the tennantite-tetrahedrite series, known as fahlore or gray ore (Cro. *tenantit/tetraedrit*; Ger. *Fahlerz*), began to be used. Sulfarsenide mining most likely started during the 4th millennium BC, and is best recognized by the appearance of arsenic copper (Durman 2006: 31; O'Brien 2013: 441; 2014: 34). It is associated with the spread of the metallurgy of the Baden culture in the area of the Carpathian Basin and the Danube region during the 4th millennium BC (Durman 1997: 7; 2000) and the Bell

34). Povezano je sa širenjem metalurgije badenske kulture na prostoru Karpatske kotline i Podunavlja tijekom 4. tisućljeća pr. Kr. (Durman 1997: 7; 2000) i kulture zvonastih pehara u zapadnoj Europi tijekom 3. tisućljeća pr. Kr. (O'Brien 2013: 440–441). Upotreba ovog tipa rude smanjuje se usvajanjem kositrene bronce, ali u srednjoj Europi ostaje razvijena i tijekom kasnoga brončanog doba (Durman 2006: 32–33; O'Brien 2014: 441). Posljednja etapa u ekstrakciji bakra u Europi podrazumijeva sulfidne rude poput bornita i halkopirita. Najranija eksploatacija ovog tipa rude nije precizno određena, možda je započela u kasnom eneolitiku ili ranom brončanom dobu. Iako je tehnologija dubokog rudarenja i kompleksnog taljenja razvijena u vrijeme brončanoga doba, u većem dijelu Europe nije korištena sve do rimskoga doba (O'Brien 2014: 8).

RAZVOJ I AUTONOMIJA RANE METALURGIJE JUGOISTOČNE EUROPE

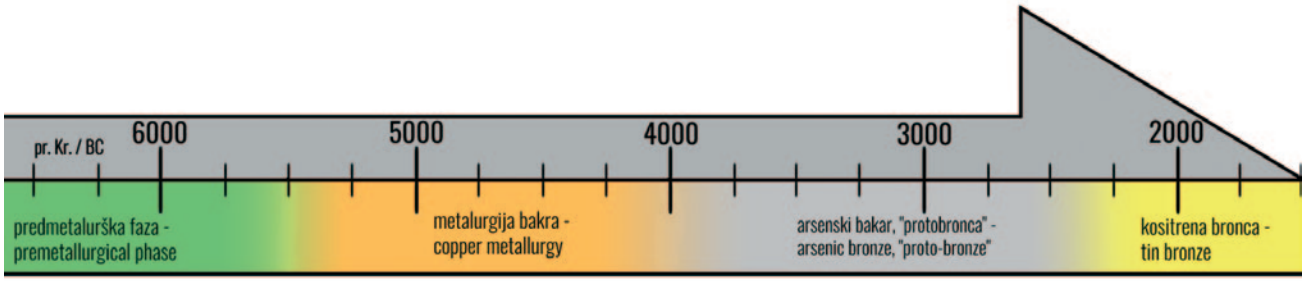
Krajem 19. i početkom 20. stoljeća arheološka misao obilježena je difuzionističkim pristupom kada se otkriće metalurgije pripisivalo jednom bliskoistočnom izvoru odakle se širi u Europu (Childe 1944; Trigger 2006: 246–256; Amzallag 2009: 497). Potaknut rezultatima kalibriranih radiokarbonskih datuma C. Renfrew (1969.) predlaže hipotezu o samostalnom razvoju metalurgije na prostoru Europe u više pojedinačnih centara koji su neovisni o bliskoistočnim utjecajima (Trigger 2006: 259, 383–384). Tako su stvorene dvije osnovne struje o nastanku i širenju metalurgije bakra. Prva, predvođena G. Childom, smatra da se ta tehnologija raširila iz jedinstvenog centra na Bliskom istoku, a druga smatra da se metalurgija razvila u najmanje tri različita centra: na Bliskom istoku, Balkanu i Iberskom poluotoku (Killick, Fenn 2012: 564–566; Pernicka 2014: 452). Većina današnjih znanstvenika složit će se da je metalurgija djelatnost koja se vjerojatno razvila na više međusobno izoliranih područja (Ottaway, Roberts 2008; Amzallag 2009; Radivojević et al. 2010; O'Brien 2014: 38; Radivojević, Rehren 2016).

Pojava predmeta od samorodnog bakra i bakrenih minerala na prostoru jugoistočne Europe prisutna je od vremena neolitika, naročito tijekom druge polovice 6. tisućljeća pr. Kr. Većina Beaker culture in western Europe during the 3rd millennium BC (O'Brien 2013: 440–441). The use of this type of ore decreases with the adoption of tin bronze, but it remains in use in central Europe during the Late Bronze Age (Durman 2006: 32–33; O'Brien 2014: 441). The last stage in copper extraction in Europe involves sulphide ores such as bornite and chalcopyrite. The earliest exploitation of this type of ore is not precisely determined; it may have started in the Late Eneolithic or Early Bronze Age. Although the technology of deep mining and complex smelting was developed during the Bronze Age, it was not used in most of Europe until the Roman era (O'Brien 2014: 8).

THE DEVELOPMENT AND AUTONOMY OF EARLY METALLURGY IN SOUTHEASTERN EUROPE

In the late 19th and early 20th centuries, archaeological thought was characterized by a diffusionist approach that attributed the discovery of metallurgy to a single Middle Eastern source from where it spread to Europe (Childe 1944; Trigger 2006: 246–256; Amzallag 2009: 497). Relying on the results of calibrated radiocarbon dating, C. Renfrew (1969) proposed a hypothesis about the independent development of metallurgy in Europe in several individual centres that are independent of Middle Eastern influences (Trigger 2006: 259, 383–384). This resulted in two basic currents of the origin and spread of copper metallurgy. The first, led by G. Child, states that this technology spread from a single centre in the Middle East; the second states that metallurgy developed in at least three different centres: the Middle East, the Balkans, and the Iberian Peninsula (Killick, Fenn 2012: 564–566; Pernicka 2014: 452). Today most scientists will agree that metallurgy is an activity that probably developed in several isolated areas (Ottaway, Roberts 2008; Amzallag 2009; Radivojević et al. 2010; O'Brien 2014: 38; Radivojević, Rehren 2016).

Objects made of native copper and copper minerals existed in the area of southeastern Europe since the Neolithic period, especially during the second half of the 6th millennium BC. Most of these objects can be attributed to the pre-metallurgical phase of copper processing, when new raw materials and local sources of copper were discovered (Fig. 1) (Kalicz 1992; Antonović 2002: 33; Ottaway, Roberts 2008: 195; Hansen 2011: 139; 2013:



Sl. 1 – Pojednostavljeni prikaz tehnoloških faza razvoja metalurgije bakra i njegovih slitina kroz vrijeme (izradile: S. Bošnjak, D. Roksandić Vukadin)

Fig. 1 – Simplified representation of technological stages of the development of the metallurgy of copper and its alloys through time (made by: S. Bošnjak, D. Roksandić Vukadin)

ovih predmeta može se pripisati predmetalurškoj fazi obrade bakra, kada se upoznaje nova sirovina i lokalni izvori bakra (sl. 1) (Kalicz 1992; Antonović 2002: 33; Ottaway, Roberts 2008: 195; Hansen 2011: 139; 2013: 140–141; Heyd, Walker 2014: 674–675; Siklósi, Szilágyi 2019: 57–58). Prijelazom iz 6. u 5. tisućljeće pr. Kr. pojavljuju se rudnici bakra i lijevani bakreni predmeti. Još nije moguće odrediti točno vrijeme početka obrade bakrene rude i lijevanja bakra, ali sa sigurnošću možemo reći da su ta tehnološka znanja bila raširena na području Balkana prije 5. tisućljeća pr. Kr. (sl. 1) (Pernicka, Anthony 2010: 169). Specifične tipove lijevanih predmeta u ovom razdoblju na prostoru jugoistočne Europe poznaje nekoliko istovremenih kulturnih skupina, što je snažan argument o neovisnoj metalurškoj „industriji" toga područja (Radivojević et al. 2010: 2776; 2021; O'Brien 2014: 53; Sava 2015: 274–277; Radivojević, Rehren 2016: 205). Rano upoznavanje s metalom i autohtoni razvoj metalurgije posljedica je postojanja bogatih ležišta metalne rude, poznavanja tradicije, razvoja rudarstva i razvijene pirotehnologije koja se vidi u izradi grafitno ukrašene i crno pečene keramike 5. tisućljeća pr. Kr. (Jovanović 1979: 46; Antonović 2002: 39–41; O'Brien 2014: 38–39). Nositelj i predstavnik velikih promjena u metalurškoj tehnologiji je vinčanska kultura. Arheometalurška istraživanja postavila su je kao prvu rudarsku i metaluršku kulturu na prostoru jugoistočne Europe (Borić 2009; Hansen 2013: 147) i kao pokazatelj postojanja tehnologija metalurške obrade bakra i produkcije metala već tijekom 6. tisućljeća pr. Kr. (Antonović 2002; Borić 2009: 207; Radivojević et al. 2010; 2021; Hansen 2013: 146–147; Radivojević, Rehren 2016).

No, ono što izdvaja područje jugoistočne Europe od drugih jest izuzetno velik broj nala-

140–141; Heyd, Walker 2014: 674–675; Siklósi, Szilágyi 2019: 57–58). Metallurgy first began with the appearance of copper mines and cast copper objects at the turn of the 6th and 5th millennia BC. It is still not possible to determine the exact time when copper ore processing and copper casting began, but we can say with certainty that this technological knowledge was widespread in the Balkans before the 5th millennium BC (Fig. 1) (Pernicka, Anthony 2010: 169). Specific types of cast objects in this period in southeastern Europe were known by several contemporary cultural groups, which is a strong argument for the independent metallurgical "industry" of that area (Radivojević et al. 2010: 2776; 2021; O'Brien 2014: 53; Sava 2015: 274–277; Radivojević, Rehren 2016: 205). The early acquaintance with metal and the autochthonous development of metallurgy is the result of rich deposits of metal ore, tradition and development of mining and pyrotechnology, which is best seen in the graphite-decorated and dark burnished pottery of the 5th millennium BC (Jovanović 1979: 46; Antonović 2002: 39–41; O'Brien 2014: 38–39). The Vinča culture is the bearer and representative of the great changes in metallurgical technology. It was identified by archaeometallurgical research as the first mining and metallurgical culture in southeastern Europe (Borić 2009; Hansen 2013: 147) and as the clearest indicator of the existence of copper metallurgical processing and metal production technologies during the 6th millennium BC (Antonović 2002; Borić 2009: 207; Radivojević et al. 2010; 2021; Hansen 2013: 146–147; Radivojević, Rehren 2016).

However, what sets southeastern Europe apart from other regions is the extremely large number of finds of copper and gold objects that exceeds the metallurgical production in all known contemporaneous areas. The peak of copper production

za bakrenih i zlatnih predmeta koji premašuju metaluršku proizvodnju na svim poznatim istovremenim područjima. Vrhunac proizvodnje bakra u jugoistočnoj Europi počeo je oko 4700. – 4600. g. pr. Kr. i trajao je do oko 4300. – 4200. g. pr. Kr. (Pernicka, Anthony 2010: 169, 171; Hansen 2013: 139, sl. 6). Ovakav trend porasta broja metalnih nalaza na balkanskom i karpatskom prostoru upućuje na kvantitativni i kvalitativni iskorak u metalurgiji bakra, iako je samih dokaza o bakrenoprerađivačkim djelatnostima u naseljima iznimno malo (Sava 2015: 276). Procijenjeno je da između 4500. i 3800. g. pr. Kr. preživjela količina bakra koja cirkulira balkanskim prostorom (jugoistočna Europa i Mađarska) iznosi 4,7 tona, odnosno 4300 bakrenih alatki, te više od 6 kg zlata (Pernicka, Anthony 2010: 169). Istovremeno na cijelom Bliskom istoku broj lijevanih bakrenih predmeta manji je od 300 (Radivojević et al. 2010: 2776). Nakon perioda sve većeg porasta broja nalaza od bakra i zlata slijedi značajan pad u količini metalnih nalaza tijekom druge polovice 4. tisućljeća pr. Kr. (Strahm, Hauptmann 2009: 119–120; Hansen 2011: 137; 2013: 148–150; Heyd, Walker 2014: 680; O'Brien 2014: 54; Pernicka 2014: 452; Sava 2015: 276). Za ovo razdoblje često se koristi pojam „metalurška kriza", koja se pojavljuje u srednjoj i jugoistočnoj Europi te na egejskom području. Neki smatraju da se radi o degradaciji metalurgije i padu proizvodnje (Siklósi, Szilágyi 2019: 5276), dok drugi čvrsto negiraju postojanje metalurške krize (Hansen 2011: 137; 2013: 153). To razdoblje obilježeno je gotovo istodobnom pojavom arsenskog bakra na prostoru od Bliskoga i Srednjega istoka do srednje Europe. Ovaj fenomen često se objašnjava jačanjem veza između Anatolije i Europe, što je dovelo do formiranja tzv. cirkumpontskog metalurškog kruga ili provincije (Pernicka 2014: 452, sl. 4). Arsenski bakar u odnosu na čisti bakar ima nekoliko prednosti: niža točka taljenja, veća kvaliteta odljevka, povećana tvrdoća, bolja obradivost i srebrna boja (Ottaway 2001: 98). Pojava arsenskog bakra nije do kraja razjašnjen fenomen i još postoji dilema je li ona posljedica namjernog legiranja bakra i arsena ili je slučajni nusprodukt taljenja rude koja je u sebi već sadržavala arsen (Durman 1983: 4; 2000: 91–93; Ottaway 2001: 98; Ottaway, Roberts 2008: 208; Pernicka 2014: 452–453). Tijekom 3. tisućljeća pr. Kr. prapovijesne zajednice u južnoj i srednjoj Europi dobro poznaju metaluršku tehnologiju te dolazi do njezina razvoja

in southeast Europe began around 4700–4600 BC and lasted until about 4300–4200 BC (Pernicka, Anthony 2010: 169, 171; Hansen 2013: 139, Fig. 6). This trend of the increase in the number of metal finds in the Balkan-Carpathian area points to a quantitative and qualitative step forward in copper metallurgy, although there is very little evidence of copper-processing activities in the settlements (Sava 2015: 276). It is estimated that between 4500 and 3800 BC the surviving amount of copper circulating in the Balkans (southeastern Europe and Hungary) amounts to 4.7 tons, i.e. 4300 copper tools, and more than 6 kg of gold (Pernicka, Anthony 2010: 169). At the same time, there are fewer than 300 cast copper objects in the entire Middle East (Radivojević et al. 2010: 2776). The period of the increasing growth in the number of copper and gold finds was followed by a significant drop in the amount of metal finds during the second half of the 4th millennium BC (Strahm, Hauptmann 2009: 119–120; Hansen 2011: 137, 2013: 148–150; Heyd, Walker 2014: 680; O'Brien 2014: 54; Pernicka 2014: 452; Sava 2015: 276). This period, often considered a "metallurgical crisis", appeared in central and southeastern Europe and the Aegean region. Some believe that the cause was the degradation of metallurgy and the decline of production (Siklósi, Szilágyi 2019: 5276), while others firmly deny the existence of a metallurgical crisis (Hansen 2011: 137; 2013: 153). The period was marked by the almost simultaneous appearance of arsenic copper in the area from the Near and Middle East to central Europe. This phenomenon is often explained by the strengthening of ties between Anatolia and Europe, which led to the formation of the Circumpontian metallurgical circle or province (Pernicka 2014: 452, Fig. 4). Compared to pure copper, arsenical copper has several advantages: lower melting point, higher casting quality, increased hardness, better workability, and the ability to obtain a silver colour (Ottaway 2001: 98). The appearance of arsenical copper is not a fully elucidated phenomenon, and it is still an unsolved dilemma whether it is the result of the intentional alloying of copper and arsenic or an accidental by-product of the smelting of ore that already contained arsenic (Durman 1983: 4; 2000: 91–93; Ottaway 2001: 98; Ottaway, Roberts 2008: 208; Pernicka 2014: 452–453). During the 3rd millennium BC, prehistoric communities in southern and central Europe were well acquainted with metallurgical technology, which significantly spread towards the west during that time (Strahm, Hauptmann 2009: 120). Arsenic copper

i značajnog širenja prema zapadu (Strahm, Hauptmann 2009: 120). Arsenski bakar počinje se zamjenjivati kositrenom broncom, iako još nije jasno gdje i kako je došlo do takve promjene (sl. 1) (Ottaway, Roberts 2008: 197; Pernicka 2014: 456). U arheološkim zapisima, naročito na prostoru jugoistočne Europe, počinju se odražavati značajne društvene i ekonomske promjene potaknute metalurškom tehnologijom i trgovanjem metalom (Heyd, Walker 2014: 685). Sama metalurgija bakra doživljava značajan napredak, počinje svojevrsna „serijska proizvodnja" identičnih metalnih predmeta i metalurgija dostiže gotovo industrijsku razinu tijekom 3. tisućljeća pr. Kr. (Durman 1983; Strahm, Hauptmann 2009).

POČETCI UPOTREBE BAKRA NA PROSTORU SJEVERNE HRVATSKE

Rani i srednji eneolitik

Rani eneolitik na prostoru sjeverne Hrvatske najvećim dijelom obilježen je kasnim razvojnim ili regionalnim stupnjevima sopotske kulture, koja nastavlja svoj tradicionalni neolitički način života. Kraj sopotske kulture i početak eneolitičkog perioda u istočnoj Slavoniji obilježen je fazom Sopot IV, dok je u sjeverozapadnoj Hrvatskoj raširen tip Seče sopotske kulture (Marković 1985; 2012; Balen 2016: 60–61; 2018a: 65–66). Završni stupnjevi sopotske kulture istovremeni su s vinčanskom kulturom (stupanj Vinča D), lenđelskom kulturom (stupanj Lengyel III) i tisapolgarskom kulturom (Balen 2016: 59–61). Sopotska kultura posljednji je predstavnik neolitičkog načina života na samom pragu eneolitika, a slična situacija „produženog neolitika" istovremeno se može primijetiti i na području Transdanubije (Bánffy 1994). Sopotska kultura ne poznaje metal dok istovremene kulture rasprostranjene na bakrom bogatijim prostorima vladaju metalurškom tehnologijom lijevanja i stvaraju kompleksne opskrbno-distribucijske trgovinske mreže (Jovanović 2009: 147; Pernicka, Anthony 2010; Hansen 2013; Siklósi, Szilágyi 2019).

Jedine bakrene izrađevine (dva fragmenta) u kontekstu naselja sopotske kulture na prostoru sjeverne Hrvatske, Baranje, spominju se na lokalitetu Kneževi Vinogradi – Osnovna škola (Šimić 2004: 77). Razlog sopotskom nepoznavanju metala možemo tražiti u činjenici da se kultura rasprostire izvan bakrom bogatih pod-

began to be replaced by tin bronze, although it is still unclear where and how such a change occurred (Fig. 1) (Ottaway, Roberts 2008: 197; Pernicka 2014: 456). Archaeological records, especially in the area of southeastern Europe, begin to reflect significant social and economic changes sparked by metallurgical technology and metal trade (Heyd, Walker 2014: 685). Copper metallurgy itself experienced significant progress, there began a kind of "serial production" of identical metal objects, and metallurgy reached an almost industrial level during the 3rd millennium BC (Durman 1983; Strahm, Hauptmann 2009).

BEGINNINGS OF COPPER USE IN NORTHERN CROATIA

Early and Middle Eneolithic

The Early Eneolithic period in Northern Croatia is mostly marked by the late developmental or regional stages of the Sopot culture, which continued its traditional Neolithic way of life. The Sopot IV phase marks the end of the Sopot culture and the beginning of the Eneolithic period in eastern Slavonia, while the Seče type of the Sopot culture is widespread in Northwestern Croatia (Marković 1985; 2012; Balen 2016: 60–61; 2018a: 65–66). The final stages of the Sopot culture are contemporaneous with the Vinča culture (Vinča D stage), the Lengyel culture (Lengyel III stage), and the Tisapolgar culture (Balen 2016: 59–61). The Sopot culture was the last representative of the Neolithic way of life at the very threshold of the Eneolithic, and a similar situation of the "extended Neolithic" can be observed in the area of Transdanubia (Bánffy 1994). While the Sopot culture did not know metal, the contemporary cultures that spread in copper-rich areas mastered the metallurgical technology of casting and created complex supply-distribution trade networks (Jovanović 2009: 147; Pernicka, Anthony 2010; Hansen 2013; Siklósi, Szilágyi 2019).

The only copper artifacts (two fragments) in the context of Sopot culture settlements in the area of northern Croatia (Baranja) are mentioned at the site of Kneževi Vinogradi – Elementary school (Šimić 2004: 77). The reason for the lack of knowledge of metals in the Sopot culture can be found in the fact that it did not inhabit the copper-rich areas. On the other hand, an absolute lack of knowledge of metals is somewhat unusual considering its strong communication with the neighbouring, metallurgically developed cultures

ručja. S druge strane, apsolutno nepoznavanje metala donekle je neobično s obzirom na jake komunikacije te kulture sa susjednim metalurški razvijenim kulturama (npr. vinčanskom kulturom) (Marković 1985; 1994: 86–91). Odgovor možda leži u zaključku Z. Markovića (1994: 86), koji sopotsku kulturu vidi kao zatvorenu pojavu koja je prijenosnik različitih utjecaja, ali čvrsto čuva vlastiti identitet i tradiciju.

Završetkom neolitika i početkom eneolitika, odvija se kontinuirani prijelaz iz vinčansko-soptsko-lengyelskog supstrata u lasinjsku kulturu kao nasljednicu kasnoga neolitika (Dimitrijević 1979a: 170; Balen 2010: 23–24; 2018a: 67–68; Čataj 2018a: 25–28; 2020: 435–440). Metalni nalazi u kontekstu lasinjske kulture vrlo su rijetki. Na području Hrvatske zasad jedini poznati metalni predmeti koji se sa sigurnošću mogu pripisati lasinjskoj kulturi su s lokaliteta Pajtenica – Velike Livade kod Selaca Đakovačkih. Riječ je o tri bakrena predmeta: dlijeto, ulomak sječiva sjekire i dio šila (sl. 2D) (Balen 2010: 37, T. 8: 2, 5; Čataj 2018a: 40, sl. 8; Balen, Zorić 2020: T. 1: 1–3). Predmeti su izrađeni od čistog bakra gdje su kositar i željezo prisutni samo u tragovima, dok u šilu ima i neznatnih tragova arsena (Balen, Zorić 2020: tab. 1). Osim nabrojenih nalaza, lasinjskoj kulturi ili možda mlađoj retz-gajarskoj kulturi može se pribrojiti nekoliko metalnih igala ili šila s lokaliteta Čepinski Martinci – Dubrava pored Osijeka. Predmeti su nađeni prilikom istraživanja eneolitičkog naselja lasinjske i retz-gajarske kulture, ali nije objavljen detaljan opis predmeta kao ni njihov specifičan kontekst (Kalafatić 2009: 22).

Nakon lasinjske kulture, na prostoru sjeverne Hrvatske rasprostranjena je kultura Retz-Gajary. Počinje krajem lasinjske kulture, dok njezin kraj odgovara početku Boleráz faze ili grupe badenske kulture, uz moguće razdoblje suživota u oba slučaja (Balen 2016: 6–65; 2018a: 68; Čataj 2016; 2018b: 49–52; 2020: 431–434). Na prostoru Hrvatske jedini metalni nalazi koji su sigurno pripisani ovoj kulturi nekoliko je bakrenih igala ili šila s lokaliteta Čeminac – Vakanjac u Baranji (Kalafatić, Hulina 2016: 29, 32, sl. 11). Nalaz koji nam bolje svjedoči o metalurgiji ove kulture je ulomak keramičke posude s lokaliteta Josipovac Punitovački kod Đakova. Najvjerojatnije je riječ o ulomku posude za taljenje – talionika, na čijoj su unutrašnjoj stijenci i rubu pronađeni tragovi bakra (sl. 2E) (Čataj 2009a: 47–48, sl. 37–40, T. 36: 3; 2018b: 60). Analiza metalnih naslaga pokazala je da je uz bakar pri-

(e.g. the Vinča culture) (Marković 1985; 1994: 86–91). The answer may lie in the conclusion of Z. Marković (1994: 86), who sees the Sopot culture as a closed phenomenon that carried different influences while firmly preserving its own identity and tradition.

With the end of the Neolithic and the beginning of the Eneolithic, there was a continuous transition from the Vinča-Sopot-Lengyel substrate to the Lasinja culture as the successor of the Late Neolithic (Dimitrijević 1979a: 170; Balen 2010: 23–24; 2018a: 67–68; Čataj 2018a: 25–28; 2020: 435–440). Metal finds in the context of the Lasinja culture are very rare. In the territory of Croatia, the only known metal objects that can be attributed with certainty to the Lasinja culture come from the site of Pajtenica – Velika Livada near Selci Đakovački. They are three copper objects: a chisel, a fragment of an axe blade, and a part of an awl (Fig. 2D) (Balen 2010: 37, Pl. 8: 2, 5; Čataj 2018a: 40, Fig. 8; Balen, Zorić 2020 Pl. 1: 1–3). The objects are made of pure copper, with tin and iron found only in traces, while the awl includes faint traces of arsenic (Balen, Zorić 2020: Tab. 1). In addition to the listed finds, several metal needles/pins or awls from the Čepinski Martinci – Dubrava site near Osijek can be attributed to the Lasinja culture or perhaps the younger Retz-Gajary culture. The objects were found during the excavations of an Eneolithic settlement of the Lasinja and Retz-Gajary culture, but a more detailed description of the objects and their specific context has not been published (Kalafatić 2009: 22).

After the Lasinja culture, the Retz-Gajary culture spread throughout Croatia. This culture begins at the end of the Lasinja culture, while its end corresponds to the beginning of the Boleráz group or phase of the Baden culture, with a possible period of coexistence in both cases (Balen 2016: 6–65; 2018a: 68; Čataj 2016; 2018b: 49–52; 2020: 431–434). On the territory of Croatia, the only metal finds that are definitely attributed to this culture are several copper needles/pins or awls from the Čeminac – Vakanjac site in Baranya (Kalafatić, Hulina 2016: 29, 32, Fig. 11). The find that better testifies to the metallurgy of this culture is the fragment of a ceramic pot from the Josipovac Punitovački site near Đakovo. It is most likely a fragment of a vessel for the melting of metal – a crucible, with traces of copper on the inner wall and edge (Fig. 2E) (Čataj 2009a: 47–48, Fig. 37–40, Pl. 36: 3; 2018b: 60). The analysis of these metal deposits showed not only copper, but

sutan i visok udio željeza i arsena, što je navelo na zaključak da se radi o neuspješnom taljenju bakrene rude (za detaljnije vidi: Čataj 2009a: 47–48, sl. 38, 40). Ovaj nalaz je zasad najstariji objavljeni dokaz o odvijanju ili pokušaju metalurškog procesa na prostoru Hrvatske. Još jedan lokalitet s naznakama metalurške aktivnosti koja se pripisuje kulturi Retz-Gajary, Medvođe – Glogovica kod Slavonskog Broda, istražen je 2009. i 2010. godine. Informacije s istraživanja su dostupne samo prema kratkoj preliminarnoj objavi i izvješću (Kuzmanović 2010; 2011).[2] Tijekom istraživanja pronađen je objekt (zemunica) s dvije peći. Oko jedne od peći pronađena je značajna količina ulomaka keramike s tragovima naslaga metala na unutarnjim stijenkama (interpretirani kao talionici), nekoliko komada metalne troske i nekoliko ulomaka bakra. Ovi nalazi išli bi u prilog odvijanja konkretne metalurške aktivnosti, pa bi se objekt mogao definirati kao moguća metalurška radionica. Nakon sustavne analize, ovaj lokalitet mogao bi biti ključan za razumijevanje metalurgije retz-gajarske kulture u sjevernoj Hrvatskoj.

Snažniji dokaz istovremenih metalurških djelatnosti imamo na prostoru Slovenije. Nalazi bakrenih predmeta i metalurških djelatnosti (kalupi, posude za taljenje) na tom prostoru pojavljuju se tijekom 4. tisućljeća pr. Kr., a kronološki tome razdoblju pripada lasinjska kultura, horizont keramike s brazdastim urezivanjem (HKBV) i badenska kultura (Velušček 1999: 60; 2004a: sl. 7.1.1; 2008). Dokaz metalurške djelatnosti horizonta keramike s brazdastim urezivanjem pronađen je na lokalitetu Hočevarica, gdje su pronađena dva ulomka keramičke posude za taljenje te kaplja bakra koja je najvjerojatnije nusprodukt obrade (Velušček 2004a: 301; 2004b: 51–52, T. 4.1.8: 11, sl. 3.1.27–3.1.28).

Velik problem definiranja stupnja razvoja metalurške djelatnosti za vrijeme ranoga i srednjega eneolitika, kako u Hrvatskoj tako i mnogo šire, jest velika količina pojedinačnih i slučajnih bakrenih te zlatnih nalaza (Brunšmid 1902; Bulat 1962; Jovanović 1979: 37–41; Kuna 1981; Marković 1994: 111–112; Raczky 1999; Glogović 2003). Riječ je o nalazima nakita, masivnog oruđa (razni tipovi sjekira, dlijeta) i sitnog alata (igle, šila) koje je teško pripisati određenoj

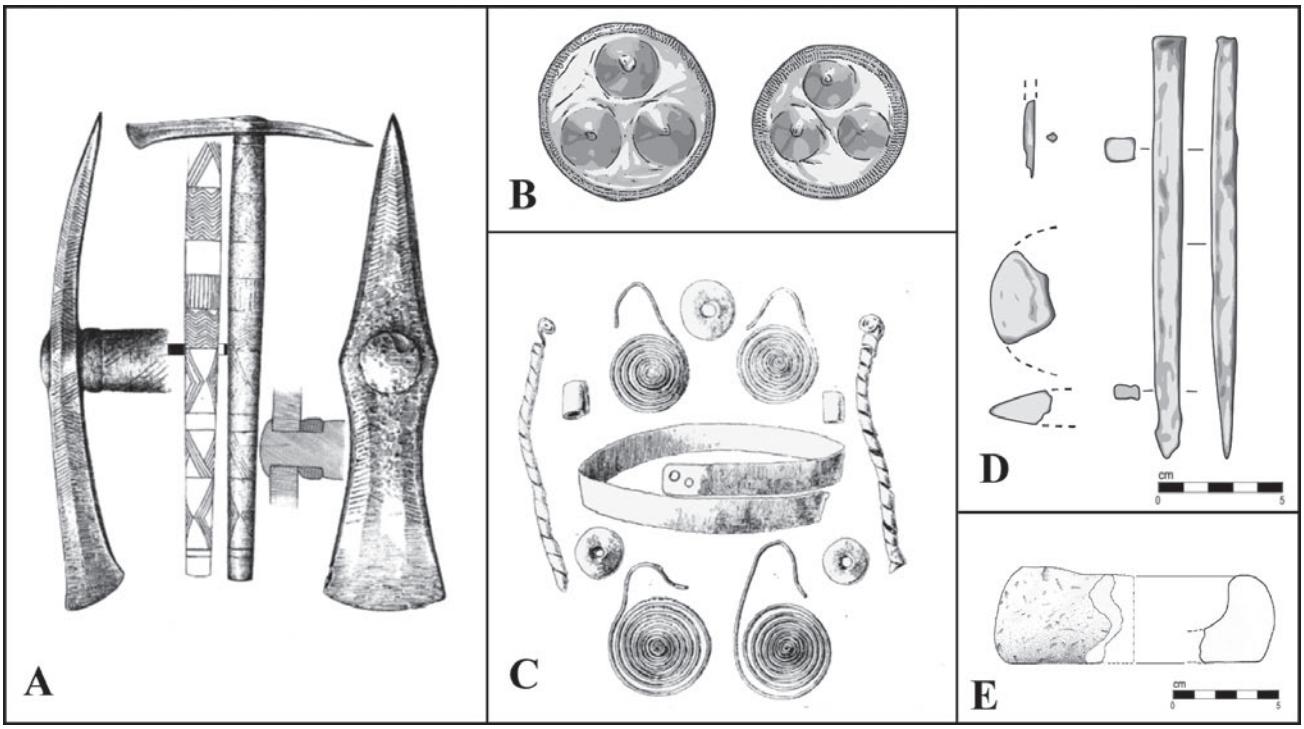
also a high proportion of iron and arsenic, which led to the conclusion that it was an unsuccessful smelting of copper ore (for details, see: Čataj 2009a: 47–48, Fig. 38, 40). This find is the oldest published evidence of the conducting of or an attempt at a metallurgical process in the territory of Croatia. One more site with indications of metallurgical activity attributed to the Retz-Gajary culture, Medvođe – Glogovica near Slavonski Brod, was excavated in 2009 and 2010. Information about the excavation is only available as a short preliminary publication and the excavation report (Kuzmanović 2010; 2011).[2] During the excavation, an object (a pit dwelling) with two furnaces was found.A significant amount of fragmented pottery with metal residues on the inner walls (interpreted as crucibles), a few pieces of metal slag, and a few pieces of copper, were found around one of the furnaces. These finds strongly indicate that a metallurgical activity was carried out there and that the structure could be interpreted as a possible metallurgical workshop. After a systematic analysis of these finds, this site could become crucial for understanding the early metallurgy of the Retz-Gajary culture in northern Croatia.

There is stronger evidence of metallurgical activities on the territory of Slovenia at that time. Copper objects and metallurgical activities (moulds, crucibles) in that area appear during the 4th millennium BC; chronologically, this period includes the Lasinja culture, the horizon of the Furchenstich (stab-and-drag style) pottery (HKBV), and the Baden culture (Velušček 1999: 60; 2004a: Fig. 7.1.1; 2008). Evidence of metallurgical activity of the horizon of the Furchenstich pottery was found at the site of Hočevarica: two fragments of a smelting pot and a drop of copper, most likely a by-product of copper processing (Velušček 2004a: 301; 2004b: 51–52, Pl. 4.1.8: 11, Fig. 3.1.27–3.1.28).

A major problem in defining the level of development of metallurgical activity during the Early and Middle Eneolithic, both in Croatia and far beyond, is the large amount of single and chance finds of copper and gold (Brunšmid 1902; Bulat 1962; Jovanović 1979: 37–41; Kuna 1981; Marković 1994: 111–112; Raczky 1999; Glogović 2003). These are finds of jewellery, massive tools (various types of axes, chisels), and small tools

2 Podaci koji se koriste preuzeti su iz neobjavljenog izvještaja tvrtke Geoarheo d.o.o. (Kuzmanović 2010) i temeljeni su na preliminarnoj analizi arheološkog materijala od strane autorica teksta. Zahvaljujemo Goranu Skelcu iz tvrtke Geoarheo d.o.o. i djelatnicima Muzeja Brodskog Posavlja na ustupljenim podatcima.

2 The information comes from an unpublished report by Geoarheo Ltd. (Kuzmanović 2010) and is based on the preliminary analyses of archaeological material by the authors of this paper. We would like to thank Goran Skelac from Geoarcheo Ltd. and the employees of the Museum of Brodsko Posavlje for the provided data.



Sl. 2 – Nalazi metala i metalurškog pribora ranog i srednjeg eneolitika s područja sjeverne Hrvatske: A križna sjekira, tip Jászladány, Pustara – Tufek (Jovanović 1979: T. II: 1–3); B zlatni diskovi, tip Stollhof-Csáford, Tenja – Orlovnjak (nacrtala: S. Bošnjak; prema: Raczky 1999: sl. 11, kat. br. 4); C inventar metalnih nalaza iz groba, Vukovar – Velika skela (Brunšmid 1902: sl. 19); D bakreni predmeti, lasinjska kultura, Pajtenica – Velike livade (nacrtala: S. Bošnjak; prema: Balen, Zorić 2020: T. 1: 1–3); E ulomak talionika, kultura Retz-Gajary, Josipovac Punitovački – Veliko polje (izvor: Čataj 2009a: T. 36: 3, uz dozvolu) (izradile: S. Bošnjak, D. Roksandić Vukadin)

Fig. 2 – Early and Middle Eneolithic metal finds and metallurgical implements from the area of northern Croatia: A cross-edge axe, Jászladány type, Pustara – Tufek (Jovanović 1979: Pl. II: 1–3); B gold discs, Stollhof-Csáford type, Tenja – Orlovnjak (drawn by: S. Bošnjak; after: Raczky 1999: Fig. 11, cat. no. 4); C inventory of metal finds from a grave, Vukovar – Velika skela (Brunšmid 1902: Fig. 19); D copper finds, Lasinja culture, Pajtenica – Velike livade (drawn by: S. Bošnjak; after: Balen, Zorić 2020; Pl. 1: 1–3); E fragment of a crucible, Retz-Gajary culture, Josipovac Punitovački – Veliko Polje (source: Čataj 2009a: Pl. 36: 3, with permission) (made by: S. Bošnjak, D. Roksandić Vukadin)

kulturi, već ih se može samo okvirno pripisati određenom razdoblju. Problem kulturne pripadnosti izražen je kod mnogobrojnih slučajnih nalaza bakrenih križnih sjekira (engl. *cross-edge axes* ili *axe-adze,* njem. *Kreuzschneidige Axt*) koje se datiraju od 4000. do 3600. g. pr. Kr. (Balen 2010: 38–39). Zbog izmjena kronologije ranog i srednjeg eneolitika preispituje se i njihovo datiranje, koje je pomaknuto u posljednju trećinu 5. tisućljeća pr. Kr. (Csányi et al. 2010; Sava 2015: 285; Hansen 2021: 43). Među mnogim slučajnim nalazima križnih sjekira trebalo bi izdvojiti jedinstveni slučajni nalaz bogato ukrašene bakrene sjekire s bakrenim drškom (tip Jászladány) pronađen prilikom oranja položaja Pustara Tufek kod Osijeka (sl. 2A) (Bulat 1962: 18–23, T. I: 6; IV–VI; Jovanović 1979: 40–41, T. II: 1–3; Heyd, Walker 2014: 681, sl. 35.3). Sjekira je većih dimenzija, sječiva dužine

(needles, awls), which are difficult to attribute to a certain culture, but can only be tentatively attributed to a certain period. The problem of cultural affiliation is pronounced in numerous chance finds of copper cross-edge axes (axe-adze, Ger. *Kreuzschneidige Axt*; Cro. *križne sjekire*) usually dated from 4000 to 3600 BC (Balen 2010: 38–39). Due to the recent changes in the chronology of the Early and Middle Eneolithic, their dating has been reconsidered and pushed back to the last third of the 5th millennium BC (Csányi et al. 2010; Sava 2015: 285; Hansen 2021: 43). Among the many chance finds of cross-edge axes, we should single out a unique richly decorated copper axe with a copper handle (Jászladány type) found during the ploughing of the Pustara-Tufek site near Osijek (Fig. 2A) (Bulat 1962: 18–23, Pl. I: 6; IV–VI; Jovanović 1979: 40–41, Pl. II: 1–3; Heyd, Walker 2014: 681, Fig. 35.3). The axe has large

41 cm s drškom dužine 72 cm, ukupne težine 18 kg, što ju čini najtežim jedinstvenim bakrenim predmetom 4. tisućljeća pr. Kr. (Heyd, Walker 2014: 681). Zbog svoje veličine i bogatog načina ukrašavanja ova sjekira je jedinstven nalaz koji upućuje na simboličnu, sakralnu funkciju. Tipološki se više može vezati uz nalaze ranijeg eneolitika, ali okolnosti i jedinstvenost ovoga nalaza ne dopuštaju preciznije interpretacije njezine kulturne i kronološke pripadnosti.

Iako zlato i zlatni nalazi nisu primarna tema ovog rada, potrebno je spomenuti neke od nalaza u kontekstu ostave zlatnih predmeta s prostora istočne Hrvatske, okolice Osijeka: Tenja – Orlovnjak i Osijek – Čepin. Prvotno se smatralo da se radi o nalazima s dva različita lokaliteta koji su kasnije rekonstruirani u jedinstvenu ostavu s približno dvadeset i pet zlatnih predmeta. Ostava se sastoji od zlatnih traka (dijadema) (2), zlatnih karika (19) i zlatnih diskova tipa Stollhof-Csáford (6) (sl. 2B) (Vinski 1959: 208; Makkay 1985: 17; Raczky 1999: 30, sl. 11, kat. br. 4; Glogović 2003; 2004: 9–10). Navedeni diskovi rijetki su i često slučajni nalazi bez jasnog konteksta, zbog čega je njihova datacija problematična. Značajan broj zlatnih diskova pronađen je u Mađarskoj, sjevernoj Hrvatskoj i donjoj Austriji. Nalazimo ih također sjeverno i zapadno od Karpatske kotline, ponekad u srebrnoj i bakrenoj varijanti (Angeli 1967; Glogović 2003: 98; 2004; Makkay 1985; Raczky 1999; Klassen 2010; Virág 2019: 197; Prokeš et al. 2020). Pripisuju se srednjem eneolitiku, razdoblju između 4000. i 3600. g. pr. Kr., što odgovara vremenu lasinjske i retz-gajarske kulture (Balen 2010: 38; 2016: 62; Čataj 2018a: 40–41; 2018b: 60; Makkay 1985: 7; Marković 1994: 57; Raczky 1995: 54–55; 1999). Zbog promjena u kronologiji, slično kao i kod križnih sjekira, njihova datacija pomaknuta je na sam kraj 5. tisućljeća pr. Kr. (Hansen 2014; 2021: 45; Virág 2019: 198–199; Prokeš et al. 2020: 115–117).

Jedan od problematičnih nalaza je inventar kosturnog groba s lokaliteta Vukovar – Velika skela otkriven 1901. godine: traka od bakrenog lima (dijadema), spiralno namotani privjesci od bakrene žice (4), spiralno namotane bakrene trake (2) i niz perlica od školjaka (spondilusa) (sl. 2C) (Brunšmid 1902: 60–62, sl. 19; Majnarić-Pandžić 1994: 66–67). Ovi nalazi pripisuju se razdoblju eneolitika, iako je njihova kulturna pripadnost nepoznata. N. Kalicz (1982: 14) pripisuje ih retz-gajarskoj kulturi, dok ih Z. Marković (1994: 97) pripisuje horizontu Vajska-

dimensions: the blade is 41 cm long and the handle is 72 cm long, with the total weight of 18 kg making it the heaviest single copper object of the 4th millennium BC (Heyd, Walker 2014: 681). The sheer size and rich decoration make this axe a unique find and indicate that it served a symbolic, sacral purpose. The axe can typologically be more closely related to the finds from the earlier Eneolithic, but the circumstances and uniqueness of this find do not allow for more precise interpretations of its cultural and chronological affiliation.

Although gold and golden finds are not the main topic of this paper, we should mention a collection of gold items from a hoard found in the area of eastern Croatia, near Osijek: Tenja – Orlovnjak and Osijek – Čepin. Originally thought to be finds from two different sites, they were later interpreted as a single hoard with approximately twenty-five gold objects. The hoard consists of gold bands (diadems) (2), gold links (19), and gold discs of the Stollhof-Csáford type (6) (Fig. 2B) (Vinski 1959: 208, Makkay 1985: 17, Raczky 1999: 30, Fig. 11, cat. no. 4; Glogović 2003; 2004: 9–10). These discs are rare and often chance finds without a clear context, which renders their dating problematic. A significant number of gold discs were found in Hungary, northern Croatia and lower Austria. They were also discovered north and west of the Carpathian Basin, sometimes in silver and copper variants (Angeli 1967; Glogović 2003: 98; 2004; Makkay 1985; Raczky 1999; Klassen 2010; Virág 2019: 197; Prokeš et al. 2020). They are attributed to the Middle Eneolithic, the period between 4000 and 3600 BC, which coincides with the time of the Lasinja and Retz-Gajary cultures (Balen 2010: 38; 2016: 62; Čataj 2018a: 40–41; 2018b: 60; Makkay 1985: 7; Marković 1994: 57; Raczky 1995: 54–55; 1999). Due to changes in chronology, similarly to cross-edge axes, their dating has been pushed to the end of the 5th millennium BC (Hansen 2014; 2021: 45; Virág 2019: 198–199; Prokeš et al. 2020: 115–117).

The problematic finds include the inventory of an inhumation burial from the Vukovar – Velika Skela site, discovered in 1901: a strip of copper sheet (diadem), pendants of spirally wound copper wire (4), spirally wound copper coils (2), and a series of shell beads (spondylus) (Fig. 2C) (Brunšmid 1902: 60–62, Fig.19; Majnarić-Pandžić 1994: 66–67). These finds are attributed to the Eneolithic period, although their cultural affiliation is unknown. N. Kalicz (1982: 14) attributes them to the Retz-Gajary culture, while Z. Marković

Hunyadi, koji se pojavljuje na prostoru Hrvatske uz Dunav. Nakon teorije Z. Markovića nije bilo daljnjih pokušaja interpretacije ovoga groba, ali u svjetlu novih nalaza nakita (od bakra, kamena i školjki) iz lasinjske ostave s lokaliteta Magyaregres – Macskalyuk u Mađarskoj (Hornok, Kiss 2017) moglo bi se reinterpretirati pitanje pripadnosti ovih nalaza kao i njihovo moguće pripisivanje lasinjskoj kulturi. Valja spomenuti da se metalni nalazi iz navedene ostave smatraju importima u Transdanubiju, a iz njihovih analiza zaključeno je da se izvor bakrene rude najvjerojatnije nalazio na području sjeverozapadnih Karpata (Siklósi et al. 2022).

Kasni eneolitik

Prava obilježja eneolitika i jasno odmicanje od neolitičkih tradicija vide se tek kroz prve indoeuropske zajednice badenske kulture, zatim kostolačke i na kraju vučedolske kulture, koja već nagovještava početak brončanoga doba (Težak-Gregl 2017: 17). Relativna i apsolutna kronologija kasnog eneolitika u sjevernoj Hrvatskoj još je predmet rasprave. Kronologija sjeverozapadne Hrvatske posebno je problematična i nema dovoljno podataka kako bi se donosili pouzdani zaključci, iako je posljednjih godina vidljiv napredak u istraživanju (za detaljnije vidi: Marković 1994: 29; Balen 2010: 48; 2016: 65; Čataj 2016). Kronologija područja istočne Hrvatske mnogo je jasnija s više istraženih kasnoeneolitičkih lokaliteta, no i dalje manjkava zbog nedovoljno sustavnih istraživanja i cjelovitih objava.

Prisutnost badenske kulture u sjevernoj Hrvatskoj odavno je prepoznata (Schmidt 1945; Dimitrijević 1979b; Balen 2010: 59–84), međutim, javlja se sve veća potreba za izdvajanjem Boleráz faze, tj. grupe (rani Baden) od badenske kulture. Do sada je objavljen malen broj lokaliteta (Čataj 2009b; 2016; Balen 2010: 66–67), a tek nekoliko apsolutnih datuma, u rasponu od 3630. do 3360. g. pr. Kr., podudara se s datumima Boleráz grupe (Čataj 2009b: tab. 1; 2016: sl. 4; Balen 2010: tab. 5; 2016: 65; 2018a: 68–69; 2018b: 66–70). Datumi klasične badenske kulture kreću se između 3360. i 2995. g. pr. Kr. i poklapaju se s apsolutnim datumima te badenske faze s područja srednje Europe (Balen 2010: tab. 5; 2016: 66; 2018a: 69; 2018b: 68–70). Samo jedan nalaz vezan uz metalurgiju iz Hrvatske pripisuje se Boleráz grupi (Čataj 2009b: 121, T. 7: 1). Zbog toga će

(1994: 97) attributes them to the Vajska-Hunyadi horizon, which appears in the Danube region of the territory of Croatia. After the theory of Z. Marković, there were no further attempts to interpret this grave, but these finds could be reinterpreted and possibly attributed to the Lasinja culture in the light of the new finds of jewellery (made of copper, stone and shells) from the Lasinja hoard from the Magyaregres – Macskalyuk site in Hungary (Hornok, Kiss 2017). It should be mentioned that the metal finds from that hoard are considered imports to Transdanubia; analyses show that the provenance of copper ore was probably the area of the northwestern Carpathians (Siklósi et al. 2022).

Late Eneolithic

The true features of the Eneolithic and a clear departure from the Neolithic traditions can only be seen in the first Indo-European communities of the Baden culture, then the Kostolac culture, and finally the Vučedol culture, which already foreshadows the beginning of the Bronze Age (Težak-Gregl 2017: 17). The relative and absolute chronology of the Late Eneolithic in northern Croatia is still a matter of debate. The chronology of northwestern Croatia is especially problematic and lacks sufficient data to deduce reliable conclusions, although progress has been made in recent years (for details, see: Marković 1994: 29; Balen 2010: 48; 2016: 65; Čataj 2016). The chronology of eastern Croatia is clearer, with more researched Late Eneolithic sites, but it is still insufficient without enough systematic excavations and complete publications.

The presence of the Baden culture in northern Croatia was noticed a long time ago (Schmidt 1945; Dimitrijević 1979b; Balen 2010: 59–84), but there is a growing need to separate the Boleráz phase or group (early Baden) from the Baden culture. Only a small number of Boleráz sites have been published so far (Čataj 2009b; 2016; Balen 2010: 66–67), and only several absolute dates, ranging from 3630 to 3360 BC, match those of the Boleráz group (Čataj 2009b: Tab. 1; 2016: Fig. 4; Balen 2010: Tab. 5; 2016: 65; 2018a: 68–69; 2018b: 66–70). The dates of the classical Baden culture range between 3360 and 2995 BC, corresponding to the absolute dating of that Baden phase in central Europe (Balen 2010: Tab. 5; 2016: 66; 2018a: 69, 2018b: 68–70). Only one of the finds from Croatia associated with metallurgy is attributed to the Boleráz group (Čataj 2009b: 121,

se u ovom radu Boleráz grupa i klasična badenska kultura tretirati kao linearni slijed jedne kulturne cjeline pod imenom Baden.

Apsolutni datumi kostolačke kulture kreću se od 3300. do 2700. g. pr. Kr. (Benkö et al. 1989: tab. 1; Balen 2010: 89, tab. 6; 2011: 158–159, tab. 13: 1). Početkom vučedolske kulture smatra se vremenski okvir 3000. – 2900. g. pr. Kr. s trajanjem do 2600. – 2500. g. pr. Kr. ili čak i dulje, do 2400. g. pr. Kr. (Benkö et al. 1989: tab. 1; Durman, Obelić 1989; Horvatinčić et al. 1990; Forenbaher 1993: 247; Balen 2010: 110–112, tab. 8; 2018a: 70). Očito je da se trajanje kostolačke kulture preklapa s klasičnom badenskom kulturom te se čini da ona traje neobično dugo, i ulazi u vremenski okvir vučedolske kulture. To se često objašnjava pojavom dva značajna „koljena" u kalibracijskoj krivulji: između 3300. – 3100. i 2900. – 2600. g. pr. Kr., što čini apsolutne datume manje pouzdanima (Bojadžijev 1992: 397; Forenbaher 1993: 246). Stoga je predloženo kraće trajanje kostolačke kulture. Dio autora je smješta između 3000. – 2900. i 2800. – 2700. g. pr. Kr. (Bojadžijev 1992: 397), dok drugi smatraju da je kostolačka kultura dijelom suvremena s klasičnom badenskom kulturom, u trajanju od 3300. – 3200. do 3000. – 2900. g. pr. Kr. (Nikolić 2000: 78–79; Balen 2010: 91; 2011: 160). Definiranje kasnoeneolitičke kronologije sjeverne Hrvatske otežano je nedostatkom objavljene građe i malim brojem apsolutnih datuma. Opće je prihvaćeno da pojava badenske kulture kronološki određuje početak kasnog eneolitika, dok sam završetak tog razdoblja obilježava kraj vučedolske kulture (sl. 7) (Marković 1994: 28–29; Balen 2010: 11; 2016: 59–66; 2018a: 65).

Badenska kultura

Prvom pravom metalurškom kulturom na prostoru Hrvatske smatra se badenska kultura. Zauzima široko područje rasprostiranja preko teritorija današnje sjeverne i istočne Austrije, Moravske, Češke, južne Poljske i Slovačke, čitave Mađarske, sjeveroistočne Hrvatske i dijelova Vojvodine u Srbiji (Dimitrijević 1979b: 184–185; Balen 2010: 59; 2018b: 65). U vrijeme badenske kulture zamijećen je pad brojnosti metalnih nalaza, izrađuju se jednostavniji oblici te se stvara privid opadanja metalurške proizvodnje (Dimitrijević 1979b: 220; Durman 1983: 20; Težak-Gregl 1987: 73; Siklósi et al. 2018: 68). Međutim, upravo s badenskom kulturom dola-

Pl. 7: 1). Therefore, for the purposes of this paper, the Boleráz group and the classical Baden culture will be treated as a linear sequence of a single cultural unit called Baden.

The absolute dates of the Kostolac culture range from 3300 to 2700 BC (Benkö et al. 1989: Tab. 1; Balen 2010: 89, Tab. 6; 2011: 158–159, Tab. 13: 1). It is considered that the Vučedol culture began in the 3000–2900 BC timeframe and lasted until 2600–2500 BC or even longer, until 2400 BC (Benkö et al. 1989: Tab. 1; Durman, Obelić 1989; Horvatinčić et al. 1990; Forenbaher 1993: 247; Balen 2010: 110–112, Tab. 8; 2018a: 70). The Kostolac culture clearly overlaps with the classical Baden culture and seems to have lasted unusually long, well into the timeframe of the Vučedol culture. This is often explained by the occurrence of two significant "wiggles" in the calibration curve, between 3300–3100 and 2900–2600 BC, which make absolute dates less reliable (Bojadžijev 1992: 397; Forenbaher 1993: 246). Hence, a shorter duration of the Kostolac culture has been suggested. Some authors place it between 3000–2900 and 2800–2700 BC (Bojadžijev 1992: 397), while others suggest that part of the Kostolac culture is contemporary with the classical Baden culture, lasting from 3300–3200 to 3000–2900 BC (Nikolić 2000: 78–79; Balen 2010: 91; 2011: 160). Late Eneolithic chronology of northern Croatia is harder to establish due to the lack of published materials and the small number of absolute dates. It is commonly accepted that the appearance of the Baden culture chronologically determines the beginning of the Late Eneolithic, while the end of the Late Eneolithic period is determined by the end of the Vučedol culture (Fig. 7) (Marković 1994: 28–29; Balen 2010: 11; 2016: 59–66; 2018a: 65).

Baden culture

The Baden culture is considered to be the first real metallurgical culture in Croatia. It has a wide area of distribution over the territory of present-day northern and eastern Austria, Moravia, the Czech Republic, southern Poland and Slovakia, all of Hungary, northeastern Croatia, and parts of Vojvodina in Serbia (Dimitrijević 1979b: 184–185; Balen 2010: 59; 2018b: 65). During the Baden culture, the number of metal finds decreases, simpler forms are made, and there seems to be a decline in metallurgical production (Dimitrijević 1979b: 220; Durman 1983: 20; Težak-Gregl 1987: 73; Siklósi et al. 2018: 68). Nevertheless, the Baden

zi do široke upotrebe arsenskog bakra, vidi se razvoj metalurške tehnologije, koriste se nove sirovine – rude – te konačni proizvod ima bolje karakteristike (Durman 1997: 7; 2006: 31; Hansen 2011: 137; Siklósi, Szilágyi 2019: 5276).

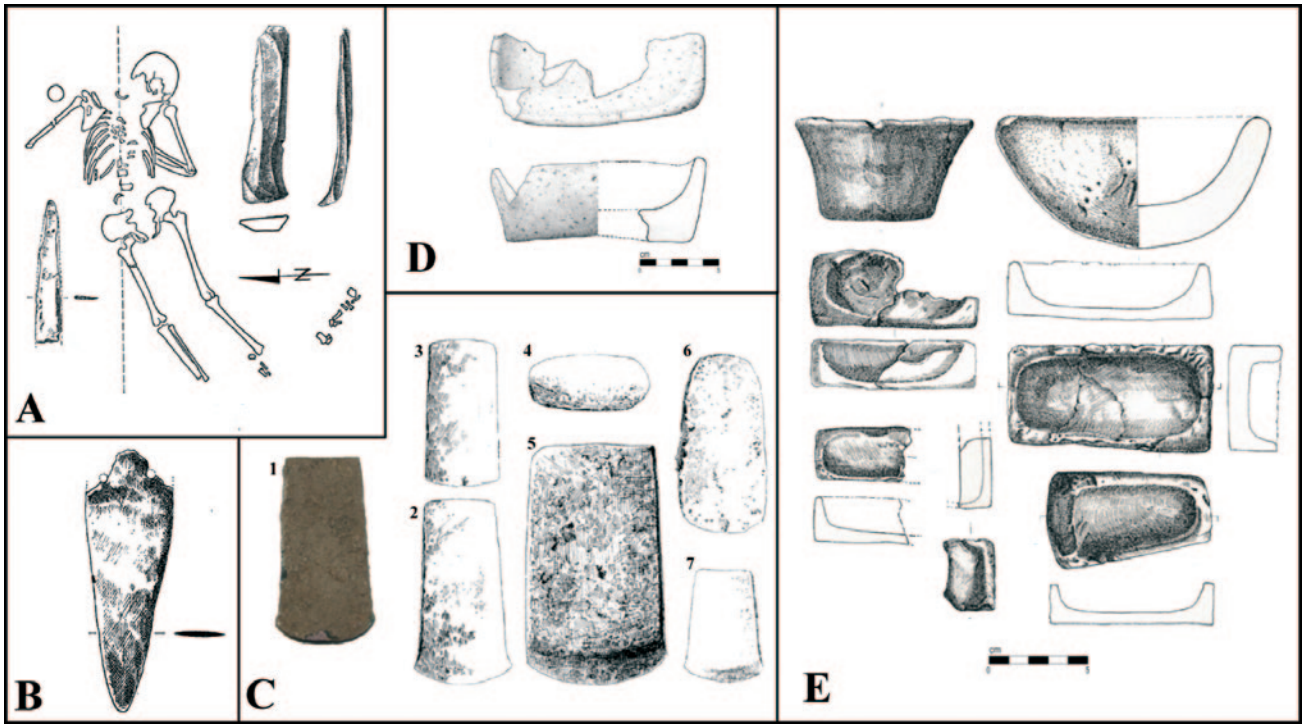
Nalazi s prostora Hrvatske koje pripisujemo badenskoj kulturi su plosnate sjekire, šila i mali triangularni bodeži. Sjekire su pravokutnog ili elipsastog oblika, jedna strana im je zaobljena, druga je ravna, što je posljedica lijevanja u jednodijelnim kalupima. Najveći broj takvih sjekira slučajni su nalazi s prostora Slavonije i Srijema. Pet takvih nalaza, koji se pripisuju badenskoj kulturi, pronađeno je u Sotinu, Oroliku, Boboti i Kutjevu (Mihalje i Brdo) (sl. 3C: 2–7) (Durman 2000: 91–92; 2006: kat. br. 9–17). Ovim nalazima možemo pridružiti i sjekiru s lokaliteta Sarvaš – Gradac koja se čuva u Gradskom muzeju Vukovar (Balen 2005: 56; Durman 2006: kat. br. 18) te sjekiru pronađenu tijekom probnih arheoloških istraživanja lokaliteta Sotin – Trojstvo (sl. 3C: 1) (Ložnjak Dizdar, Dizdar 2015: sl. 3). Istraživanjima lokaliteta Vučedol – Vinograd Streim pronađena su dva triangularna bodeža tipa lamele bez pojačanog središnjeg rebra. Jedan je imao oštećene rupice za nasad drška (sl. 3B), dok je drugi pronađen kao prilog badenskom ukopu (sl. 3A). Analizama sastava metala razvidno je da je riječ o predmetima od arsenskog bakra (Težak-Gregl 1985: 24, 30–32, sl. 2; 1987: 74, sl. 1; 2017: 157; Durman 2000: 95). Bodež iz fundusa Arheološkog muzeja u Zagrebu koji potječe s lokaliteta Sarvaš (Vinski 1961: 4–5) također ima sastav koji pokazuje velik udio arsena, što se može povezati s primjercima s lokaliteta Vučedol, stoga ga pripisujemo badenskoj kulturi (Balen 2005: sl. 43, kat. br. 229). J. Balen (2005: 56) pretpostavlja da dva navedena metalna nalaza iz Sarvaša (sjekira i bodež), usprkos nedostatku stratigrafskih podataka, dokazuju postojanje metalurške proizvodnje badenske kulture na tom lokalitetu. Zaista ne možemo isključiti mogućnost metalurgije na lokalitetu Sarvaš – Gradac, ali samo metalni nalazi nisu dovoljan dokaz takve djelatnosti, pogotovo bez ikakvih drugih nalaza metalurške aktivnosti.

Nalazi badenskih metalurških radionica u sjevernoj Hrvatskoj najviše su doprinijeli mijenjanju percepcije „metalurške sposobnosti" badenske kulture. Prva radionica badenske metalurške djelatnosti zabilježena je na lokalitetu Okukalj – Gornja Bebrina tijekom manjih probnih istraživanja 1962. godine (Petrović, Belić 1971: 12). Istražen je objekt (zemunica) s ovalnim ognjištem oko kojeg su se nalazili

culture brought the widespread use of arsenical copper, a continued development of metallurgical technology, and new raw materials – ores; therefore, the final product had better characteristics (Durman 1997: 7; 2006: 31; Hansen 2011: 137; Siklósi, Szilágyi 2019: 5276).

The finds from Croatia attributed to this culture are flat axes, awls, and small triangular daggers. Axes are rectangular or elliptical in shape, one side is rounded and the other is flat, which is the result of casting in one-piece moulds. The largest number of such axes are chance finds from the area of Slavonia and Syrmia. Five such finds attributed to the Baden culture were found in Sotin, Orolik, Bobota, and Kutjevo (Mihalje and Brdo) (Fig. 3C: 2–7) (Durman 2000: 91–92; 2006: cat. no. 9–17). We can add to these finds the axe from the Sarvaš – Gradac site that is kept in the Vukovar Municipal Museum (Balen 2005: 56; Durman 2006: cat. no. 18) and the axe found during the trial archaeological excavations of the Sotin – Trojstvo site (Fig. 3C: 1) (Ložnjak Dizdar, Dizdar 2015: Fig. 3). The excavations of the Vučedol – Vinograd Streim site revealed two triangular butt daggers of the lamella type without a reinforced central rib. One had damaged rivet-holes near to the hilt-line (Fig. 3B), while the other was found as part of a Baden burial (Fig. 3A). The analysis of the metal composition showed that these objects are made of arsenical copper (Težak-Gregl 1985: 24, 30–32, Fig. 2; 1987: 74, Fig. 1; 2017: 157; Durman 2000: 95). A dagger from the collection of the Archaeological Museum in Zagreb originating from Sarvaš (Vinski 1961: 4–5) also has a composition with a large proportion of arsenic, like the ones from the Vučedol site; therefore, it can be attributed to the Baden culture (Balen 2005: 56, Fig. 43, cat. no. 229). J. Balen (2005: 56) postulates that the two metal finds from Sarvaš (the axe and the dagger), despite the lack of stratigraphical data, prove the existence of Baden culture metallurgical production at that site. Indeed, we cannot rule out the possibility of metallurgy at Sarvaš – Gradac, but metal finds alone are not sufficient proof of such production, especially without any other finds of metallurgical activity.

The discovery of Baden metallurgical workshops changed the perception of the "metallurgical ability" of the Baden culture in northern Croatia. The first discovery of Baden metallurgical activities was at the site of Okukalj – Gornja Bebrina during the small probe excavations in 1962 (Petrović, Belić 1971: 12). A structure (pit-dwelling) was found, with an oval hearth surrounded by



Sl. 3 – Metalurški pribor i metalni nalazi badenske kulture s područja sjeverne Hrvatske: A grob s triangularnim bodežom, Vučedol – Vinograd Streim (izvor: Težak-Gregl 1985: sl. 2, uz dozvolu); B triangularni bodež, Vučedol – Vinograd Streim (izvor: Težak-Gregl 1987: sl. 1, uz dozvolu); C pojedinačni nalazi plosnatih sjekira: 1 Sotin – Trojstvo (izvor: Ložnjak Dizdar, Dizdar 2015: sl. 3: 1, uz dozvolu); 2 Orolik; 3 Bobota; 4 Kutjevo – Mihalje; 5 Sotin; 6 Kutjevo – Brdo; 7 nepoznato nalazište (Brunšmid 1902: sl. 9: 2–7); D kalup ili talionik, Josipovac Punitovački – Veliko polje (izvor: Čataj 2009b: 121, T. 7: 1, uz dozvolu); E kolekcija jednodijelnih kalupa i talionika, Donja Vrba – Saloš (izvor: Durman 2000: T. 1–2, uz dozvolu) (izradile: S. Bošnjak, D. Roksandić Vukadin)

Fig. 3 – Baden culture metallurgical implements and metal finds from the area of northern Croatia: A grave with triangular butt dagger, Vučedol – Vinograd Streim (source: Težak-Gregl 1985: Fig. 2, with permission); B triangular butt dagger, Vučedol – Vinograd Streim (source: Težak-Gregl 1987: Fig. 1, with permission); C single finds of flat axes: 1 Sotin – Trojstvo (source: Ložnjak Dizdar, Dizdar 2015: Fig. 3: 1, with permission); 2 Orolik; 3 Bobota; 4 Kutjevo – Mihalje; 5 Sotin; 6 Kutjevo – Brdo; 7 unknown site (Brunšmid 1902: Fig. 9: 2–7); D mould or crucible, Josipovac Punitovački – Veliko Polje (source: Čataj 2009b: 121, Pl. 7: 1, with permission); E collection of one-piece moulds and crucibles, Donja Vrba – Saloš (source: Durman 2000: Pl. 1–2, with permission) (made by: S. Bošnjak, D. Roksandić Vukadin)

komadi metalne troske te ulomci posuda za taljenje s tragovima naslage metala na unutrašnjoj stijenci. Prema analizama troske zaključeno je da je ona ostatak neuspješnog pokušaja taljenja bakrene rude, nakon čega je ovaj objekt definiran kao metalurška radionica (Lozuk 1995: 56; Durman 2000: 95–96). Lokalitet Donja Vrba – Saloš, istraživan 1989. godine, najopsežnije je objavljena metalurška radionica badenske kulture u Hrvatskoj. Tijekom iskopavanja pronađena su četiri objekta (zemunice) s kompletom metalurškog pribora (sl. 3E) i otpada: kalupi, talionici, komadi rude, jalovina, metal i peći[3] (Lozuk 1995; 2004; 2006; Durman 2000).

pieces of metal slag and remnants of a smelting vessel with traces of metal on the inner walls. The analysis led to the conclusion that the slag was the product of an unsuccessful attempt to smelt copper ore, so this structure was defined as a metallurgical workshop (Lozuk 1995: 56; Durman 2000: 95–96). The Donja Vrba – Saloš site, excavated in 1989, represents the most extensively published metallurgical workshop of the Baden culture in Croatia. During the excavations, four structures (pit dwellings) were found with a set of metallurgical equipment (Fig. 3E) and waste: moulds, crucibles, pieces of ore, gangue, metal, and furnaces[3] (Lozuk 1995: 2004; 2006; Durman 2000).

3 Autorice ovog rada izvršile su reviziju arheološke građe s lokaliteta Donja Vrba – Saloš. Uz objavljene nalaze, izdvojena je veća količina neobjavljenih nalaza metalurškog pribora i otpada.

3 The authors of this paper recently did a review of the archaeological material from the Donja Vrba – Saloš site. Along with the published finds, they singled out a large quantity of unpublished metallurgical implements and waste.

Analize materijala s lokaliteta pokazale su da pronađena ruda sadrži visoke postotke željeza bez arsena, koji se mogu pripisati grupi sulfidnih ruda kao što su halkopirit, pirotin ili kubatin, dok je analiza metalnog ulomka pokazala da je riječ o arsenskoj bronci (za detaljnije vidi: Durman 2000: 97–98). Ovakvi rezultati analiza postavljaju u fokus istraživanja jedan od ključnih problema metalurgije obrade arsenskog bakra ili bronce, te pitanje je li arsen ili nije namjerno dodavan u svrhu dobivanja slitine. Analize provedene na metalnim predmetima i metalurškom priboru pokazuju da su zajednice badenske kulture ovladale eksploatacijom i metalurgijom sulfidne bakrene rudače iz serije tenantita-tetraedrita, sinjavaca. A. Durman zalaže se za tezu da arsen u badenskom metalu nije namjerno dodan element, već on slučajno ostaje u spoju zbog nedovoljno razvijene tehnologije taljenja bakrene rude (Durman 2000; Lazić et al. 2010: 56).

Recentnijim zaštitnim arheološkim istraživanjima na području Brodskog Posavlja otkriveno je nekoliko lokaliteta badenske kulture s tragovima metalurške aktivnosti. Nažalost, većina materijala nije objavljena ili je objavljena samo preliminarno. Zaštitnim arheološkim istraživanjem lokaliteta Donja Vrba – Saloš iz 2010. godine pronađen je ulomak kalupa, metalna troska i mogući talionik (Miklik-Lozuk 2011: 122–123). Tijekom 2011. i 2015. godine istražene su pozicije Ruščica – Glogove-Praulje i Ruščica – Praulje (Bednjanec 2012a: 128; 2012b: 129–130; 2012c: 132; Mihaljević et al. 2018: 5–10). Nalazi s lokaliteta Ruščica–Glogove–Praulje djelomično su objavljeni u sklopu izložbe „Zaštitna arheološka istraživanja Ruščica–Glogove–Praulje", prvenstveno zbirka jednodijelnih kalupa za lijevanje plosnatih sjekira (Mihaljević et al. 2018: 14–15, kat. br. 49–53). Navedeni lokaliteti na povišenim pozicijama uz lijevu obalu rijeke Save naselja su badenske kulture s vrlo izraženim dokazima metalurških aktivnosti, te bismo ih ovom prilikom mogli izdvojiti kao jedinstvenu mikroregionalnu metalursku pojavu (karta 1). Odabir ovog područja za uspostavu metalurških radionica ne iznenađuje. Područje Brodskog Posavlja važna je strateška točka s mogućnošću prijelaza preko rijeke Save do bakrom bogatih rudišta u Bosni i Hercegovini. Važnost područja hrvatske Posavine kao metalurške regije istaknuta je kasnije, tijekom brončanog doba, nalazima brojnih ostava i tragovima metalurških aktivnosti (Karavanić 2005; 2006; Vrdoljak 2021).

The analysis of the materials from the site showed that the found ore contains high percentages of iron without arsenic, which can be attributed to a group of sulphide ores such as chalcopyrite, pyrrhotite or cubatin, while the analysis of the metal fragment showed that it is arsenical copper (for more details, see: Durman 2000: 97–98). These results put in focus one of the key issues with the arsenical copper or bronze metallurgy: was arsenic intentionally added to obtain the alloy or not? Analyses carried out on metal objects and metallurgical tools indicate that prehistoric communities of the Baden culture mastered the exploitation and the metallurgy of sulphide copper ore from the series of tennantite-tetrahedrite, fahlore ores. A. Durman supports the thesis that the arsenic in the Baden metal was not intentionally added, but accidentally remained in the compound due to insufficiently developed ore smelting technology (Durman 2000; Lazić et al. 2010: 56).

The recent archaeological rescue excavations in the area of Brodsko Posavlje discovered more Baden culture sites with traces of metallurgical activities. Unfortunately, most of that material is either unpublished or published only in preliminary reports. The rescue excavation at the Donja Vrba – Saloš site in 2010 revealed a piece of mould, metal slag, and a possible crucible (Miklik-Lozuk 2011: 122–123). The sites of Ruščica – Glogove-Praulje and Ruščica – Praulje were excavated in 2011 and 2015 (Bednjanec 2012a: 128; 2012b: 129–130; 2012c: 132; Mihaljević et al. 2018: 5–10). Finds from Ruščica – Glogove-Praulje site were partially published as part of an exhibition, "Zaštitna arheološka istraživanja Ruščica-Glogove-Praulje"(Archaeological Rescue Excavations of Ruščica-Glogove-Praulje) – most notably, a collection of one-piece moulds for casting flat axes (Mihaljević et al. 2018: 14–15, cat. no. 49–53). These sites on the elevated positions along the left bank of the River Sava are Baden culture settlements with strong evidence of metallurgical activities, so they could be singled out as a unique microregional metallurgical phenomenon (Map 1). Selecting this area for the purpose of establishing metallurgical workshops is no surprise. Brodsko Posavlje is an important strategic position that allows for crossing the River Sava to reach the copper-rich deposits of Bosnia and Herzegovina. The importance of Croatian Posavina as a metallurgical region is highlighted later, during the Bronze Age, with the finds of numerous hoards and traces of metallurgical activities (Karavanić 2005; 2006; Vrdoljak 2021).

Izvan spomenutog područja znatno je manje dokaza metalurgije badenske kulture. Nalaz keramičke posude iz badenskog naselja Boleráz grupe na lokalitetu Josipovac Punitovački – Veliko polje iz okolice Đakova mogao bi se definirati kao talionik (sl. 3D) (Čataj 2009b: 121, T. 7: 1) ili kalup (Balen 2018b: 80). Kalup za lijevanje pronađen je i tijekom zaštitnog istraživanja lokaliteta Štrosmajerovac – Pustara kod Đakova, naselja koje vjerojatno pripada Boleráz grupi i klasičnoj badenskoj kulturi, međutim nedostaju detaljni podatci o kontekstu nalaza (Balen 2010: 70, bilj. 28; 2018b: 74, sl. 7).

Badenske metalurške radionice potječu i s prostora Srbije, Slovačke i Mađarske: Novačka Ćuprija, Slepčany, Lánycsók, Zók – Várhegy (Ecsedy 1990: 221–224; Durman 2000: 95; Sava 2015: 277). Valjalo bi spomenuti i jedan stari nalaz iz Dobanovaca (Srbija) – peć potkovastog oblika (Tasić 1959: 229) s kupolom i temeljnim popločenjem od kamena čija bi se funkcija možda mogla povezati s metalurškom djelatnošću (Durman 1983: 23). Istovremeni dokazi o metalurgiji bakra potječu iz Slovenije, s prostora Ljubljanskog barja u vrijeme kulturne grupe Stare gmajne. Pronađena su dva cijela keramička talionika kao i nekoliko fragmentiranih s tragovima bakra na njihovoj unutarnjoj stijenci (Milić, Velušček 2009; Velušček 2009: 18–25). Grupa Stare gmajne datira se u drugu polovicu 4. tisućljeća pr. Kr. i povezuje se s grupom Boleráz i klasičnom badenskom kulturom (Velušček 2009: 18–25).

Kostolačka kultura

Kostolačka kultura je bila rasprostranjena na prostoru istočne Slavonije, Srijema, sjeverne Bosne, središnje Srbije i Pomoravlja, odakle se širi na prostor Karpatske kotline, srednjega Balkana i rumunjskoga Podunavlja, odnosno na današnji prostor istočne Hrvatske, središnje i istočne Srbije, sjeverne Bosne, Rumunjske, Mađarske i dijelova Slovačke (Tasić 1979: 237–238; Balen 2010: 85; Đukić 2018: 87). Pitanje podrijetla te kulture problematično je od početka njezinog definiranja, međutim, prihvaćeno mišljenje je da nastaje djelovanjem badenske kulture na neolitičku osnovu na prostoru istočne Slavonije i Srijema te traje do formiranja vučedolske kulture (Dimitrijević 1979b: 230; Durman 1988a: 13; Balen 2010: 87–89; Đukić 2018: 88–89). Smatra se, također, da je kostolačka kultura mogla nastati istovremeno s baden-

Outside this area, there are fewer finds of Baden culture metallurgy. The find from the Baden settlement that was occupied during the Boleráz group at the Josipovac Punitovački – Veliko polje site near Đakovo could be a crucible (Fig. 3D) (Čataj 2009b: 121, Pl. 7: 1) or a mould (Balen 2018b: 80). A casting mould was found during the rescue excavations of the Štrosmajerovac – Pustara site near Đakovo, which could be a Boleráz and classical Baden settlement, but there is no additional information regarding the context of the find (Balen 2010: 70, n. 28; 2018b: 74, Fig. 7).

Other Baden metallurgical workshops were found in Serbia, Slovakia, and Hungary: Novačka Ćuprija, Slepčany, Lánycsók, Zók – Várhegy (Ecsedy 1990: 221–224; Durman 2000: 95: Sava 2015: 277). We should also mention one old find: a horseshoe-shaped furnace from Dobanovci (Serbia) (Tasić 1959: 229) with a dome and stone paving, the function of which could perhaps be connected with metallurgical activity (Durman 1983: 23). Contemporary evidence of copper metallurgy comes from the area of Ljubljansko Barje in Slovenia, belonging to the Stare Gmajne group, which included two whole crucibles and a few fragmented ones with copper traces on the inner wall (Milić, Velušček 2009; Velušček 2009: 18–25). The group is dated to the second half of the 4th millennium BC and has connections to both the Boleráz group and the classical Baden culture (Velušček 2009: 18–25).

Kostolac culture

The Kostolac culture was spread over the area of eastern Slavonia, Syrmia, northern Bosnia, central Serbia, and the Morava region, from where it spread to the area of the Carpathian Basin, the central Balkans, and the Romanian Danube, i.e., to the present-day area of eastern Croatia, central and eastern Serbia, northern Bosnia, Romania, Hungary, and parts of Slovakia (Tasić 1979: 237–238; Balen 2010: 85; Đukić 2018: 87). The question of the origin of this culture has been problematic from the beginning, but the accepted opinion is that it was created by the influence of the Baden culture on a Neolithic base in the area of eastern Slavonia and Syrmia and lasted until the formation of the Vučedol culture (Dimitrijević 1979b: 230; Durman 1988a: 13; Balen 2010: 87–89; Đukić 2018: 88–89). It is also believed that the Kostolac culture might have been created simultaneously with the Baden culture, but in a different area: south of the Rivers Sava and the Danube, on

skom, ali na drugom prostoru: južno od Save i Dunava, na osnovi kompleksa Boleráz-Cernavodă III (Nikolić 2000: 60–63, 69).

Metalni nalazi i tragovi metalurške djelatnosti u kontekstu ove kulture su rijetki. Na lokalitetu Đakovo – Franjevac pronađeno je šest bakrenih predmeta, od kojih su tri šila četvrtastog presjeka s kratkim trnom, dio bodeža sa zaobljenom prikovnom pločicom s tri zakovice, i dva nedefinirana komada bakra. Sastav tih predmeta pokazuje udio arsena između 1,5 i 4 % (Balen 2011: 121–125, kat. br. 1–6). Oni se uklapaju u okvire ostalih istovremenih nalaza i karakteristični su za badensku metalurgiju. Još jedan važan nalaz je četvrtasti keramički kalup za lijevanje dlijeta s lokaliteta Osijek – Frigis 1 (Tresić Pavičić 2014: 24; Đukić 2018: 103, sl. 4). Ostali metalni nalazi u kontekstu kostolačke kulture nađeni su na području Srbije i Bosne i Hercegovine. Radi se o objavljenim nalazima bakrenih šila s Gomolave te nekoliko fragmenata šila četvrtastog presjeka s trnom za nasad s lokaliteta Pivnica kod Odžaka (Benac 1962: 27, T. X: 11; Tasić 1979: 257–258).

Kostolačka kultura imala je bliske veze s dvjema metalurški naprednim kulturama, badenskom i vučedolskom, stoga ne možemo isključiti da je mogla imati udio u razvoju metalurške tehnologije. Međutim, nedovoljna istraženost i izuzetno mali broj metalnih predmeta otežava definiranje uloge kostolačke kulture u metalurgiji kasnog eneolitika.

Vučedolska kultura

Završetkom eneolitika postoji već razvijena metalurgija bakra na prostoru međuriječja Save, Drave i Dunava s nalazima radionica badenske, a kasnije i vučedolske kulture (Durman 1983; 1984; 2000; 2006; Sava 2015: 277). Mnogi autori, od samog početka istraživanja vučedolske kulture, bavili su se njezinom metalurgijom, naročito u regionalnom i u širem europskom kontekstu (izabrana literatura: Jovanović 1971; 1979; Čović 1976; 1984; Dimitrijević 1979c: 296–297, 315, 324, 329–330; Ecsedy 1990; Pravidur 2014). Najutjecajnije radove na temu vučedolske metalurgije piše A. Durman, a treba posebno izdvojiti njegov magistarski rad (1983) „Metalurgija vučedolskog kulturnog kompleksa“ i doktorsku disertaciju (1991a) „Metal u prapovijesnom društvu jugoistočne Europe“. Unatoč atraktivnosti vučedolske kulture i velikom

the basis of Boleráz-Cernavodă III (Nikolić 2000: 60–63, 69).

Metal finds and traces of metallurgical activity in the context of this culture are rare. The Đakovo – Franjevac site included six copper objects, three of which were awls with a square cross-section with a short tapering to hilt, a part of a dagger with a rounded butt with three rivets, and two undefined pieces of copper. The composition of these items shows a proportion of arsenic between 1.5 and 4% (Balen 2011: 121–25, cat. no. 1–6). They fit into the framework of other contemporaneous finds and are characteristic for Baden metallurgy. Another important find is a square ceramic mould for casting a chisel from the Osijek – Frigis 1 site (Tresić Pavičić 2014: 24; Đukić 2018: 103, Fig. 4). Other metal finds in the context of the Kostolac culture are found in the area of Serbia and Bosnia and Herzegovina. These are the finds of copper awls from Gomolava and two complete and several fragmented square-section awls with a tapering to hilt from the site of Pivnica near Odžaci (Benac 1962: 27, Pl. X: 11; Tasić 1979: 257–258).

The Kostolac culture had close connections with two metallurgically advanced cultures, Baden and Vučedol; therefore, we cannot rule out that the Kostolac culture could have had a part in the development of metallurgical technology. However, the unexplored nature of the Kostolac culture and the extremely small number of metal objects make it difficult to define its role in the metallurgy of the Late Eneolithic.

Vučedol culture

At the very end of the Eneolithic, there was already developed copper metallurgy in the area between the Sava, the Drava, and the Danube, with the finds from the workshops of the Baden culture and later the Vučedol culture (Durman 1983; 1984; 2000; 2006; Sava 2015: 277). From the very beginning of research on the Vučedol culture, many authors dealt with its metallurgy, especially in the regional and wider European contexts (selected literature: Jovanović 1971; 1979; Čović 1976; 1984; Dimitrijević 1979c: 296–297, 315, 324, 329–330; Ecsedy 1990; Pravidur 2014). The most influential works on the topic of Vučedol metallurgy were written by A. Durman, most notably his master's thesis (1983) "Metallurgy of the Vučedol cultural complex" and his doctoral dissertation (1991a) "Metal in the Prehistoric Society of Southeast Europe". In spite of

interesu za njezino proučavanje, metalni nalazi i metalurgija najčešće se spominju u širem kontekstu kulture, razdoblja ili geografskog područja, te danas nema većih pomaka u istraživanju te problematike (Marković 1994: 111–114; Jovanović 2002; Marijanović 2003; Balen 2005; 2010; Rajković, Balen 2016; Težak-Gregl 2017; Miloglav 2018).

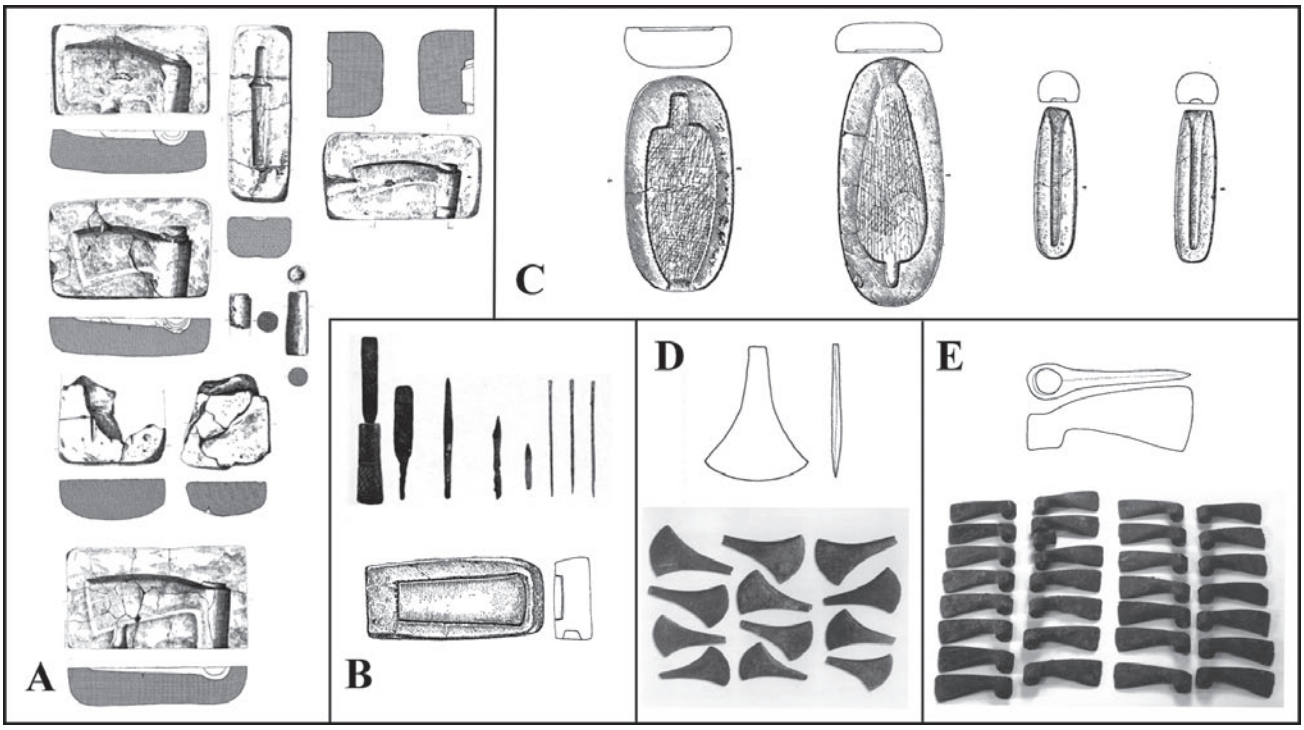
Unutar vučedolskoga kulturnog kompleksa pronađeni su razni metalni predmeti i drugi nalazi koji svjedoče o metalurškim procesima. Prepoznaje se nekoliko standardnih oblika metalnih predmeta ove kulture: bodeži, šila, dlijeta, plosnate sjekire i sjekire s cilindričnim produžetkom za nasad drška (Durman 1983: 59; Pravidur 2014: 139). Nalazi kao što su keramički kalupi za lijevanje, talionici, puhaljke za raspirivanje vatre (sopalji), keramički nastavci za mjehove i metalurške peći pronalaze se u naseljima, te su pouzdani dokazi odvijanja metalurških aktivnosti. Najveći udio metalnih nalaza pripada slučajnim ili pojedinačnim nalazima i nalazima iz ostava, a prvenstveno je tu riječ o sjekirama.

Prva detaljna istraživanja vučedolskih metalnih sjekira i njihovih kalupa proveo je Durman (1983). Istraživanje je obuhvatilo plosnate trapezaste sjekire, plosnate lepezaste sjekire i sjekire s cilindričnim produžetkom za nasad drška. Proučavajući kalupe iz Vinkovaca i sjekiru iz Sotina, on je među brojnim tipovima sličnih sjekira s cilindričnim produžetkom za nasad izdvojio one s više zakrivljenim gornjim dijelom oštrice, koje naziva „vučedolskim bojnim sjekirama". Durman, a kasnije i A. Pravidur, razlikuju ove sjekire od sličnih s ravnijim gornjim dijelom sječiva s područja Bosne i Hercegovine (Durman 1983: 60–63, 67; Pravidur 2014: 140–146). U literaturi se one nazivaju sjekirama tipa Kozarac s cilindričnim nastavkom za nasad drška (Vulpe 1970; Kuna 1981), a ime su dobile prema najreprezentativnijoj ostavi ovih sjekira iz Bosne i Hercegovine. Datiraju se u 3. tisućljeće pr. Kr. i pripisuju se vučedolskoj kulturi. Postojanje podtipova sjekira tipa Kozarac uočili su mnogi autori koji su pisali o kronologiji i tipologiji sjekira (Žeravica 1993: 24–28; Bátora 2003; Hansen 2011: 142–143; 2021: 65–67; Dani 2013; Szeverényi 2013: 664–666; Heyd, Walker 2014; Apakidze, Hansen 2020: 48). Lepezaste plosnate sjekire tipa Griča dobile su ime po ostavi iz Bosne i Hercegovine i smatraju se lokalnim proizvodom vučedolske kulture (Durman 1983; Dani

the attractiveness of the Vučedol culture and the great interest in its study, its metal finds and metallurgy are most often mentioned in the broader context of its culture, period, or geographical area, and today there are no major advances in the research of this issue (Marković 1994: 111–114; Jovanović 2002; Marijanović 2003; Balen 2005; 2010; Rajković, Balen 2016; Težak-Gregl 2017; Miloglav 2018).

There are various metal objects and other finds pointing to the metallurgical processes of the Vučedol cultural complex. Several standard forms of metal objects of this culture are recognized: daggers, awls, chisels, flat axes, and shaft-hole axes (Durman 1983: 59; Pravidur 2014: 139). The settlements included other finds – ceramic moulds for casting, crucibles, blowers for fanning the fire, ceramic attachments for bellows (tuyeres), and metallurgical furnaces – which are reliable evidence of metallurgical activities. Most of the metal finds belong to chance or single finds and finds from hoards, primarily axes.

Durman (1983) carried out detailed research on the metal axes of the Vučedol culture and their moulds. His study included flat axes of trapezoidal form, fan-shaped flat axes, and single-edged shaft-hole axes. By studying the casting moulds from Vinkovci and an axe from Sotin, he distinguished what he called a "Vučedol battleaxe", with the upper part of the blade that is more curved than the numerous other types of similar shaft-hole axes. Durman, and later A. Pravidur, distinguished these axes from similar ones with a more flattened upper part of the blade that were found in Bosnia and Herzegovina (Durman 1983: 60–63, 67; Pravidur 2014: 140–146). In literature, both of these types are considered the Kozarac type axes with a cylindrical extension for the handle attachment (Vulpe 1970; Kuna 1981), named after the most representative hoard of these axes from Bosnia and Herzegovina. They are dated to the 3rd millennium BC and attributed to the Vučedol culture. The existence of the Kozarac type axes subtypes was observed by many authors that have written about the chronology and typology of axes (Žeravica 1993: 24–28; Bátora 2003; Hansen 2011: 142–143; 2021: 65–67; Dani 2013; Szeverényi 2013: 664–666; Heyd, Walker 2014; Apakidze, Hansen 2020: 48). Fan-shaped flat axes of the Griča type are named after the hoard from Bosnia and Herzegovina and considered to be a local product of the Vučedol culture (Durman 1983;



Sl. 4 – Metalurški pribor i metalni nalazi vučedolske kulture s područja sjeverne Hrvatske: A kolekcija dvodijelnih kalupa, Vinkovci – Tržnica (izvor: Durman 1983: 23–24, T. 1–3, uz dozvolu); B metalni nalazi (Schmidt 1945: T. 48: 21–26; 49: 1–2) i višenamjenski kalup (izvor: Durman 1983: T. 4: 1, uz dozvolu), Vučedol – Gradac; C kolekcija dvodijelnih kalupa, Sarvaš – Gradac (izvor: Durman 1983: T. 4: 2–5, uz dozvolu); D ostava plosnatih sjekira, tip Griča, Vinkovci – Borinci (izvor: Durman 1983: T. 11: 3; 2006: 64, uz dozvolu); E ostava sjekira s cilindričnim produžetkom za nasad drška, tip Kozarac, Pakrac – Brekinska (izvor: Durman 1983: T. 10: 1; 2006: 65, uz dozvolu) (izradile: S. Bošnjak, D. Roksandić Vukadin)

Fig. 4 – Vučedol culture metallurgical implements and metal finds from the area of northern Croatia: A collection of two-piece moulds, Vinkovci – Tržnica (source: Durman 1983: 23–24, Pl. 1–3, with permission); B metal finds (Schmidt 1945: Pl. 48: 21–26; 49: 1–2) and a multi-purpose mould (source: Durman 1983: Pl. 4: 1, with permission), Vučedol – Gradac; C collection of two-piece moulds from Sarvaš – Gradac (source: Durman 1983: Pl. 4: 2–5, with permission); D hoard of flat axes, Griča type, Vinkovci – Borinci (source: Durman 1983: Pl. 11: 3; 2006: 64, with permission); E hoard of shaft-hole axes, Kozarac type, Pakrac – Brekinska (source: Durman 1983: Pl. 10: 1; 2006: 65, with permission) (made by: S. Bošnjak, D. Roksandić Vukadin)

2013; Pravidur 2014). One su ujednačene po obliku, veličini i težini, a pronalaze se gotovo isključivo u ostavama, s izuzetkom pojedinačnih slučajnih nalaza. Zbog njihove uniformnosti, predložena je mogućnost njihove funkcije kao ingota ili kao poluproizvoda (Durman 1983: 43).

Od metalnih predmeta koji se pronalaze u naseljima najčešće je riječ o „sitnim" alatkama kao što su igle, šila i spatule. Takvi sitni predmeti, s obzirom na impozantne nalaze sjekira, često su bili zanemarivani. Šila i igle te kalupi za njihovo lijevanje često se spominju u literaturi, ali nikad nisu tipološki definirani te često dolazi do njihovog miješanja. Za razliku od njih, predmeti tipa spatula gotovo su nepoznati u literaturi.

Dani 2013; Pravidur 2014). They have a uniform shape, size, and weight, and are almost exclusively found within hoards, with the exception of some single chance finds. Because of their uniformity, it has been proposed that they served as an ingot or a semi-finished product (Durman 1983: 43).

The most commonly found metal objects excavated in settlements are "small" tools such as needles, awls, and spatulas. Compared to imposing axe finds, such small objects are often neglected. Awls and needles, as well as moulds for casting them, are known in the literature, although these two types have never been clearly defined and are often mixed up. Unlike them, finds of spatula types are almost unknown in the literature.

Metalurške djelatnosti u vučedolskim naseljima – metalurške radionice

Specifične strukture unutar naselja (nadzemni i jamski objekti, peći), metalni predmeti, dijelovi metalurškog pribora i otpada nedvojbeno su ostatci metalurških aktivnosti koje su se mogle odvijati na lokalitetu. Upravo su takvi nalazi omogućili da se već tijekom prvih istraživanja vučedolskih lokaliteta prihvati teza o samostalnoj metalurškoj djelatnosti (Schmidt 1945; Benac 1959; Korošec, Korošec 1969; Dimitrijević 1979c: 296–297, 315, 324, 329–330; Ecsedy 1983). Metalurške radionice klasične faze vučedolske kulture na području istočne Hrvatske nalaze se unutar naselja s čvrstim dokazima metalurških aktivnosti. To su Vučedol – Gradac (Vučedol B1 i B2) s gotovo kompletnim inventarom metalurške radionice (Schmidt 1945; Dimitrijević 1979c: 296–297; Durman 1983: 31), Sarvaš – Gradac (Vučedol B1 i B2) s nalazima kalupa (sl. 4C) (Schmidt 1945: 141–142; Dimitrijević 1979c: 296–297; Durman 1983: 31; Balen 2005: 51), Vinkovci – Tržnica (Vučedol B2) s nalazom ostave kalupa u tzv. „jami ljevača bakra" (sl. 4A) i dva bakrena predmeta (Dimitrijević 1979c: 296–297; Durman 1983: 23–24; 1984), Zók – Várhegy (Vučedol B1 i B2) s nalazima kalupa i posuda za taljenje/lijevanje (Ecsedy 1983), a novijim istraživanjima mogu im se pridružiti potencijalne radionice na lokalitetu Vinkovci – Ervenica (Vučedol B2) s nalazima kalupa (Gale 2002: 57, T. 5: 5) i Vučedol – Kukuruzište Streim (Bošnjak 2021; Durman et al. 2015; 2016; 2017a; 2018; Hutinec, Roksandić 2019; 2020; Hutinec, Roksandić Vukadin 2021a). Vučedolske metalurške radionice kasnoklasične i kasne faze pronađene su na prostoru Bosne i Hercegovine. To su Zecovi kod Prijedora s nalazima ognjišta/peći, metalnih predmeta, kalupa i puhaljki (Benac 1959; Čović 1976: 106–107, T. 1; Durman 1983: 32, 34–36; Pravidur 2014: 124–127), Debelo Brdo s nalazima puhaljki i tipološki najraznolikijim repertoarom kalupa (Čović 1976: 107–110, T. 1; Durman 1983: 32; Pravidur 2014: 129), Velika Gradina u Varvari s nalazima kalupa i puhaljki (Durman 1983: 32; Čović 1984: 121; Ludajić 2005: 67, T. IV: 1; Pravidur 2014: 129–130), Gradina u selu Alihodže s nalazima kalupa (Čović 1976: 111; Durman 1983: 32; Pravidur 2014: 133–135), Podastinje kod Kiseljaka s nalazom posude za taljenje (Pravidur 2014: 134) i Donje Moštre, uz lijevu obalu rijeke Bosne kod Visokog, s nalazi-

Metallurgical activities in Vučedol settlements – metallurgical workshops

Specific structures inside the settlement (aboveground and underground objects, furnaces), metal finds, metallurgical implements, and waste – these are the remains of metallurgical activities that took place on the site. Such finds from the first investigations of the Vučedol sites led to the early acceptance of the thesis about its independent metallurgical activity (Schmidt 1945; Benac 1959; Korošec, Korošec 1969; Dimitrijević 1979c: 296–297, 315, 324, 329–330; Ecsedy 1983). Workshops of the classical phase are found inside the settlements of the Vučedol culture in the area of eastern Croatia where there is evidence of metallurgical activities. These are Vučedol – Gradac (Vučedol B1 and B2), with an almost complete inventory of a metallurgical workshop (Schmidt 1945; Dimitrijević 1979c: 296–97; Durman 1983: 31); Sarvaš – Gradac (Vučedol B1 and B2), with finds of moulds (Fig. 4C) (Schmidt 1945: 141– 42; Dimitrijević 1979c: 296–297; Durman 1983: 31; Balen 2005: 51); Vinkovci – Tržnica (Vučedol B2), with the discovery of moulds stored in the "copper caster's pit" (Fig. 4A) and two copper objects (Dimitrijević 1979c: 296–297; Durman 1983: 23–2, Pls. 1–3; 1984); Zók – Várhegy (Vučedol B1 and B2), with finds of moulds and vessels for melting/casting (Ecsedy 1983); and the potential workshops from the recent excavations of Vinkovci – Ervenica (Vučedol B2), with mould finds (Gale 2002: 57, Pl. 5: 5), and Vučedol – Kukuruzište Streim (Bošnjak 2021; Durman et al. 2015; 2016; 2017a; 2018; Hutinec, Roksandić 2019; 2020; Hutinec, Roksandić Vukadin 2021a). Vučedol metallurgical workshops of the late classical phase and the late phase were found on the territory of Bosnia and Herzegovina. These are Zecovi near Prijedor, with finds of a hearth/furnace, metal objects, moulds, and ceramic parts of pipe blowers (Benac 1959; Čović 1976: 106–107, Pl. 1; Durman 1983: 32, 34–36; Pravidur 2014: 124–127), Debelo Brdo, with the finds of ceramic parts of pipe blowers and the typologically most diverse repertoire of moulds (Čović 1976: 107–110, Pl. 1; Durman 1983: 32; Pravidur 2014: 129); Velika Gradina in Varvara, with finds of moulds and ceramic parts of pipe blowers (Durman 1983: 32; Čović 1984: 121; Ludajić 2005: 67, Pl. IV: 1; Pravidur 2014: 129–130); Gradina in the village of Alihodže, with finds of moulds (Čović 1976: 111; Durman 1983: 32; Pravidur 2014: 133–135); Podastinje near Kiseljak, with a find of smelting pots

ma kalupa i bakrenog šila (Pravidur 2014: 135). Metalurška radionica na Ljubljanskom barju geografski i arheološki je izdvojena pojava vučedolske kulture na prostoru današnje Slovenije i ne može se uklopiti u tipične radionice kasne vučedolske faze.

Najpotpuniji dokazi o vučedolskoj metalurškoj djelatnosti potječu iz istraživanja lokaliteta Vučedol – Gradac iz 1938. godine pod vodstvom R. R. Schmidta, kada je pronađen nadzemni objekt građen u dvije faze. Prvi građevinski horizont datira se u rani klasični stupanj (Vučedol B1) s definiranom metalurškom radionicom – „Megaron ljevača bakra" ili „Megaron I" s pet peći (Schmidt 1945: 21–23, sl. 10–11; T. 9: 2–3; Dimitrijević 1979c: 282; Durman 1983: 33–34, T. 7: 1–2). Drugi građevinski horizont s objektom „Megaron II" datira se u kasnoklasični stupanj (Vučedol B2) i pokazuje nešto veću kultnu namjenu od radioničkog „Megarona I" (Dimitrijević 1979c: 332). Uz peći „Megarona I" pronađen je višenamjenski kalup za lijevanje plosnatih sjekira i dlijeta te jedna plosnata sjekira koja odgovara spomenutom kalupu (sl. 4B) (Schmidt 1945: T. 49: 1–2; Durman 1983: 31, T. 4: 1; 9: 1). Sastav spomenute sjekire je 99 % čistog bakra s neznatnim tragovima srebra (Durman 1983: 47, inv. br. 1196). Nešto više metalnih predmeta pripada sitnom oruđu (sl. 4B). Pronađena su tri predmeta, štapića bakra četvrtastog presjeka, koje je Schmidt (1945: 103–104, T. 48: 21–23) smatrao ingotima, a Durman klinovima (1983: 37). Pronađene su tri igle/šila četvrtastog presjeka (Schmidt 1945: 104, T. 48: 24–26), jedna bakrena spatula nasađena u ukrašeni koštani držak iz prve faze gradnje (Schmidt 1945: T. 48, Abb. 19) i druga spatula bez drška koja pripada drugoj fazi gradnje (Schmidt 1945: T. 48: 20). Još je Schmidt uvidio da inventar nalaza ukazuje na postojanje metalurške djelatnosti u naselju i svjedoči o funkciji ove vučedolske pozicije kao metalurške radionice. Međutim, je li se ovdje odvijala metalurška djelatnost, je li riječ o ekstraktivnoj metalurgiji ili prerađivačkoj, ljevačkoj industriji, još ostaje sporno pitanje i zahtijeva reviziju sačuvanog materijala i moderan interdisciplinarni pristup.

Važno je spomenuti i nove preliminarne rezultate sustavnog istraživanja lokaliteta Vučedol – Kukuruzište Streim (2012. – 2022.). Na ovoj lokaciji evidentirano je nekoliko kulturnih horizonata, od kojih je najdominantniji horizont klasične vučedolske kulture (Vučedol B1 i B2) (Bošnjak 2021; Hutinec, Roksandić Vukadin

(Pravidur 2014: 134); and Donje Moštre, along the left bank of the River Bosnia near Visoko, with finds of moulds and a copper awl (Pravidur 2014: 135). The metallurgical workshop in Ljubljansko Barje is a geographically and archaeologically isolated Vučedol phenomenon in the territory of present-day Slovenia and cannot be integrated into the typical workshops of the late Vučedol phase.

Comprehensive evidence of Vučedol metallurgical activity comes from the excavation of the Vučedol – Gradac site by R. R. Schmidt in 1938, when an aboveground structure built in two phases was found. The first construction phase, dated to the early classical stage (Vučedol B1), includes a metallurgical workshop centre defined as the "Megaron-like house of the copper caster" or "Megaron I", with five furnaces (Schmidt 1945: 21–23 Figs. 10–11, Pl. 9: 2–3; Dimitrijević 1979c: 282; Durman 1983: 33–34, Pl. 7: 1–2). The second construction phase of the structure "Megaron II" dates back to the late classical period (Vučedol B2) and shows a more pronounced cult purpose than the workshop of "Megaron I" (Dimitrijević 1979c: 332). A multi-purpose mould for casting flat axes and chisels and one flat axe that corresponds to that mould (Fig. 4B) were found next to the "Megaron I" furnace (Schmidt 1945 Pl. 49: 1–2; Durman 1983: 31, Pl. 4: 1; 9: 1). The composition of the axe is 99% pure copper with minute traces of silver (Durman 1983: 47, inv. no. 1196). Among the metal objects, small tools are slightly more numerous (Fig. 4B). The finds include three copper rods with a square cross-section, which were considered ingots by Schmidt (1945: 103–104, Pl. 48: 21–23) and wedges by Durman (1983: 37); three needles/awls with a square cross-section (Schmidt 1945: 104, Pl. 48: 24–26); one copper spatula embedded in a decorated bone handle from the first phase of construction (Schmidt 1945: Pl. 48, Abb. 19); and another spatula without a handle from the second phase of construction (Schmidt 1945: Pl. 48: 20). Schmidt first realized that the inventory of finds indicates metallurgical activity in the settlement and testifies that this Vučedol location served as a metallurgical workshop. However, it is still uncertain whether a metallurgical activity was performed there and whether it was extractive metallurgy or the processing casting industry; this requires a review of the preserved material and a modern interdisciplinary approach.

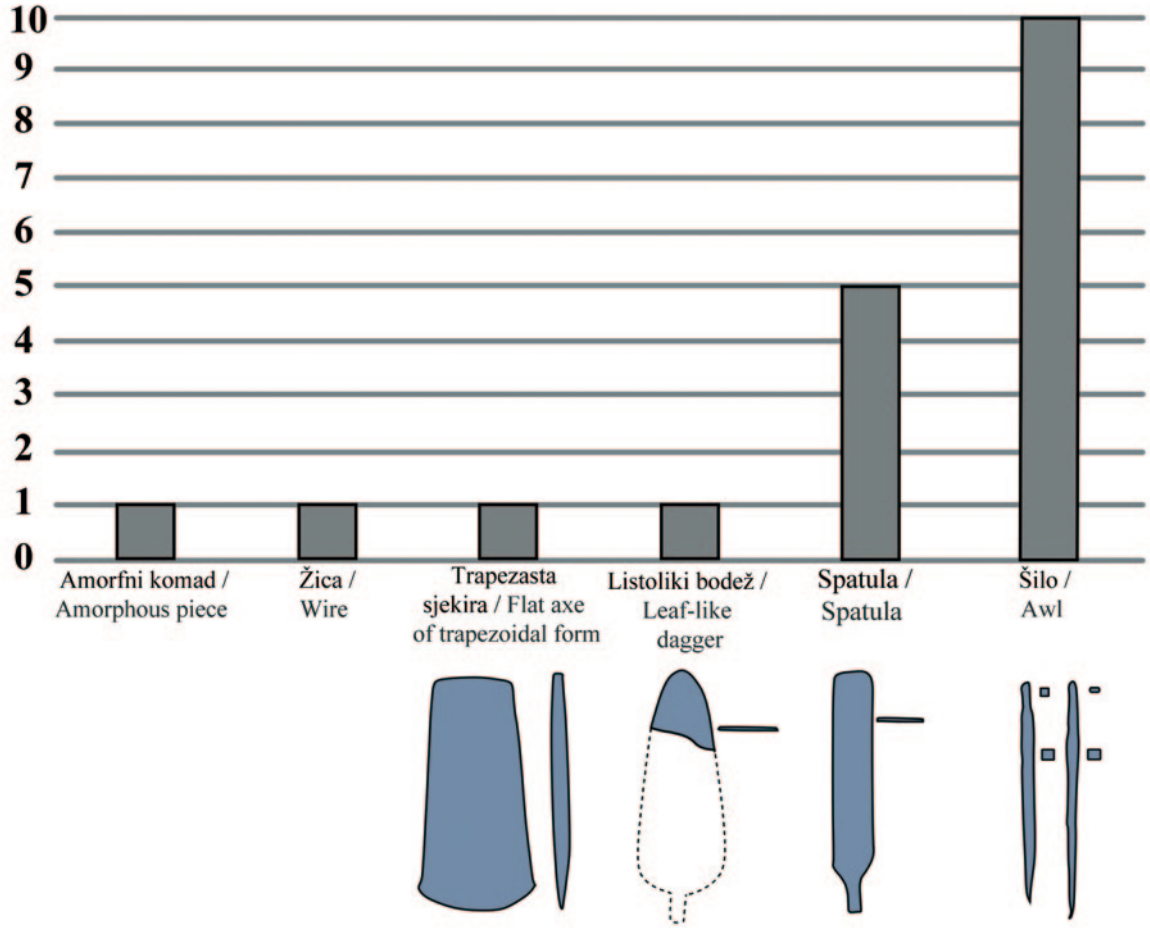
Here it is important to mention the new preliminary results of the Cornfield Streim excavations (2012–2022). Among the several cultural

2021b: 8; Roksandić Vukadin 2021: 15). Prema podatcima s terenskih istraživanja, nalazima, ali i prostornom rasporedu i organizaciji objekata i odnosima među njima, istraživači upućuju na radionički karakter ovoga dijela vučedolskog naselja (Roksandić Vukadin 2021; 2022). Kukuruzište Streim može se položajem i materijalnim ostatcima blisko vezati uz Gradac. Između njih možemo vidjeti i tipološku poveznicu s nalazima struktura – peći, metalnim nalazima i ostalim metalurškim inventarom. Sveukupno je u istraživanjima od 2012. do 2022. godine pronađeno osam peći nepoznate namjene. Nalaze se u vrlo jasnim kontekstima unutar nadzemnih objekata (kuća) s tipičnim vučedolskim inventarom. Prostorni raspored upućuje na njihovu grupiranost na jugoistočnom rubu platoa u objektima koji se nalaze u blizini fortifikacije. Neke peći su preliminarno okarakterizirane kao metalurške. Sveukupno je u istraživanjima Kukuruzišta Streim između 2012. i 2022. pronađeno 19 metalnih predmeta koji se mogu pripisati vučedolskoj kulturi (Bošnjak 2021). Od ukupnog broja ističu se šila (10), od kojih je jedno nađeno u koštanim koricama, spatule (5), trapezasta sjekira (1), komad žice (1), vrh bodeža (1) i amorfni komadić metala (1) (sl. 5). Šila i spatule najčešći su metalni nalazi na Kukuruzištu Streim, a jedine poznate paralele spatulama jesu dva nalaza s Gradca (Schmidt 1945: 29, 103, T. 48: 19–20). Svi predmeti su neobjavljeni i još su u procesu obrade. Većina ovoga metalnog inventara potječe iz jasnih konteksta objekata kao što su kuće i jame, a nešto manji broj iz sloja te jedan iz groba (Bošnjak 2021; Durman et al. 2015; 2016; 2017a; 2017b; 2018; Hutinec, Roksandić 2019; 2020; Hutinec, Roksandić Vukadin 2021a; 2022; Roksandić Vukadin 2022).

Još je jedno metalurško središte s područja Slovenije bilo iznimno važno za karakteriziranje i shvaćanje metalurške djelatnosti vučedolske kulture. Riječ je o naselju u blizini sela Ig u Ljubljanskom barju gdje je pronađen cijeli repertoar bakrenih predmeta i metalurškog pribora koji se usprkos nedostatku stratigrafskih podataka može povezati s vučedolskom kulturom. Od bakrenih predmeta izdvojeni su: sjekira (1), bodeži (6), šila četvrtastog presjeka (5) i narukvice od bakrenog lima (2) (Korošec, Korošec 1969: 20–21, T. 105). Pronađeni su jednodijelni kalupi za lijevanje plosnatih trapezastih sjekira i četiri kalupa za lijevanje sjekira s jednom oštricom i cilindričnim produžetkom za nasad drška

horizons recorded on this location, the horizon of the classical Vučedol culture is the most dominant (Vučedol B1 and B2) (Bošnjak 2021; Hutinec, Roksandić Vukadin 2021b: 8; Roksandić Vukadin 2021: 15). The data from the field research, the finds, the spatial layout and organization of the objects, and the relationships between them, all point to the workshop character of this part of Vučedol site (Roksandić Vukadin 2021; 2022). The Cornfield Streim can be closely connected to Gradac due to its location and the material remains. A typological connection can be seen in the structures (furnaces), metal finds, and other metallurgical inventory. Overall, the excavations between 2012 and 2022 found eight furnaces of an unknown purpose. They are located in very clear contexts within the aboveground buildings (houses) with a typical Vučedol inventory. The spatial arrangement indicates that they were grouped on the southeastern edge of the plateau in the buildings located near the fortification. Some of the furnaces were preliminarily characterized as metallurgical. A total of 19 metal objects that can be attributed to the Vučedol culture were found during the excavations of the Cornfield Streim between 2012 and 2022 (Bošnjak 2021). These include awls (10), one of which was found in a bone sheath, spatulas (5), a flat axe (1), a piece of wire (1), the tip of a dagger (1), and an amorphous piece of metal (1) (Fig. 5). Awls and spatulas are the most common metal finds on the Streim Cornfield, and the only known parallels to spatulas are two finds from Gradac (Schmidt 1945: 29, 103, Pl. 48: 19–20). All the objects are unpublished and are still being processed. The majority of this metal inventory comes from clear contexts of objects such as houses or pits, a slightly smaller number comes from a layer, and one comes from a grave (Bošnjak 2021; Durman et al. 2015; 2016; 2017a; 2017b; 2018; Hutinec, Roksandić 2019; 2020; Hutinec, Roksandić Vukadin 2021a; 2022; Roksandić Vukadin 2022).

Another metallurgical centre from Slovenia was extremely important for the characterization and understanding of the Vučedol culture and its metallurgical activity. That centre is a settlement near the village of Ig in Ljubljansko Barje, containing the entire repertoire of copper objects and metallurgical implements, which, despite the lack of stratigraphic data, can be associated with the Vučedol culture. These copper objects are an axe (1), daggers (6), awls with a square cross-section (5), and bracelets made of copper sheet



Sl. 5 – Metalni nalazi prema količini i tipu s nalazišta Vučedol – Kukuruzište Streim (2012. – 2022.) (nacrtale i izradile: S. Bošnjak, D. Roksandić Vukadin)
Fig. 5 – Metal finds by number and type from the Vučedol – Cornfield Streim site (2012–2022) (drawn and made by: S. Bošnjak, D. Roksandić Vukadin)

(Durman 1983: 32–33, T. 6: 1–7). Većina kalupa su višenamjenski jednodijelni kalupi. Od pet zdjela za taljenje/lijevanje metala, sve su imale cjevasti nastavak za držak, dok jedan primjer ima očuvan i kljunasti izljev (Durman 1983: 37, T. 8: 8). Analiza sastava dijela bakrenih predmeta s istraživanja Ig pokazala je da je riječ o antimonskom bakru s visokim udjelom srebra kakav je i tipičan za razdoblje kasnoga eneolitika i 3. tisućljeća pr. Kr. na prostoru od istočnih Alpa do Karpatske kotline (Durman 1983: 54–56; 1988b: 35; Trampuž Orel, Heath 2008). Prva intenzivna metalurška aktivnost na prostoru Ljubljanskoga barja zabilježena je ranije, već tijekom 4. tisućljeća pr. Kr., nakon čega dolazi do napuštanja ovoga prostora. Tijekom 3. tisućljeća pr. Kr. (2900./2800. do 2400. g. pr. Kr.), istovremeno s vučedolskom kulturom, obnavlja

(2) (Korošec, Korošec 1969: 20–21, Pl. 105). The finds include one-piece moulds for casting flat trapezoidal axes and four moulds for casting axes with a single blade and a cylindrical extension for the attachment of the handle (shaft-hole axes) (Durman 1983: 32–33, Pl. 6: 1–7). Most moulds are multi-purpose one-piece moulds. Five vessels for melting/casting metal were also found, all of them with a tubular extension for the handle, and one with a preserved spout (Durman 1983: 37. Pl. 8: 8). The analysis of the composition of some of the copper objects from Ig showed that the objects were made of antimony copper with a high content of silver, which is typical for the Late Eneolithic period and the 3rd millennium BC in the area from the eastern Alps to the Carpathian Basin (Durman 1983: 54–56; 1988b: 35; Trampuž Orel, Heath 2008). First intensive metallurgi-

se metalurška djelatnost, a razvitak ovog prostora nastavlja se i u ranom brončanom dobu (Velušček, Čufar 2003; Velušček 2008). Naselje Ig na osnovi tipoloških obilježja keramičkih posuda povezano je s vučedolskom kulturom, za koju se smatralo da dolazi na taj prostor u potrazi za bakrenom rudom (Dimitrijević 1979c: 307; Durman 1983: 32–37). Danas prevladava mišljenje da ovaj prostor ima lokalni razvoj autohtone kulture koja održava intenzivnu komunikaciju i bliske veze s vučedolskom kulturom (Velušček 2004c: 78–79).

Ostave

Metalurške ostave su fenomen koji se u intenzivnom obliku prvi put na našim prostorima javlja u okviru vučedolske kulture. Ostave vučedolske kulture pronađene na tlu Hrvatske jesu Brekinska kod Pakraca (sl. 4E) i Borinci kod Vinkovaca (sl. 4D), a njima pridružujemo ostavu iz Topolja kod Knina (Durman 1983: 39–43, T. 10: 1, 5; 11: 3). Nešto veći broj ostava pronađen je na području današnje Bosne i Hercegovine na lokalitetima Griča, Vranovići, Lohinje i Kozarac, a nažalost danas je sačuvan samo polovičan inventar njihova izvornog sadržaja (Durman 1983: 40–42, T. 10: 2–4; 11: 1; Pravidur 2014: 148, T. 9–16; 23–30: 69–92; 31: 93–96). Na prostoru današnje Srbije pronađena je ostava Legeta (Durman 1983: 42, T. 11: 2). U vrijeme vučedolske kulture počinje serijska proizvodnja i pojava ostava identičnih bakrenih predmeta (Jovanović 1979: 48; Durman 1983: 31; 1988b: 32; 2006: 49), što se odražava na materijalu u ostavama kao što su Brekinska i Borinci (sl. 6). Ostave na prostoru Hrvatske su uniformne, dok su na području Bosne i Hercegovine često sadržavale predmete različitih dimenzija i tipova (sl. 6).

Grobovi

Većina poznatih i istraženih lokaliteta vučedolske kulture odnosi se na naselja, bez podataka o nekropolama. O pogrebnim običajima nosilaca vučedolske kulture doznajemo iz malog uzorka kosturnih ukopa unutar naselja (Dimitrijević 1979c: 284). Svi pronađeni ukopi jedinstveni su slučajevi, a zajednička komponenata im je ukop u duboke jame u zgrčenom ili drugim položajima (Durman 2009: 252–254). Izgleda da prilaganje metalnih nalaza kao grob-

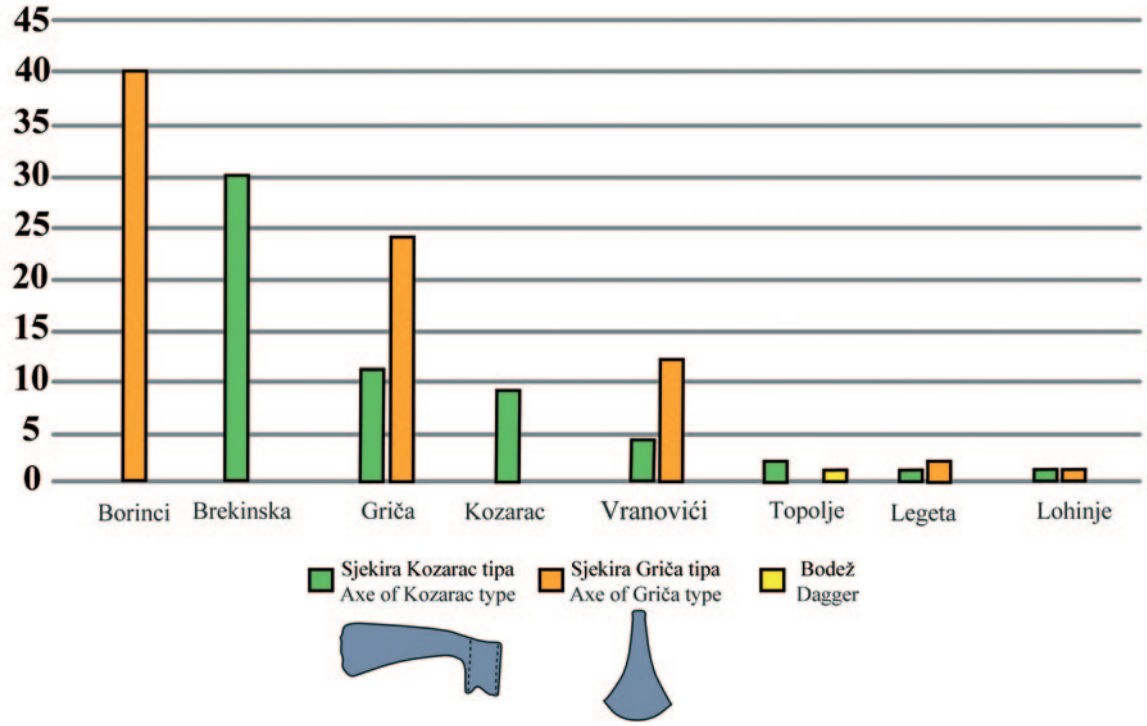
cal activity in the area of Ljubljansko Barje was recorded earlier, during the 4th millennium BC, after which this area was abandoned. Metallurgical activity was renewed during the 3rd millennium BC (2900/2800 to 2400 BC), contemporary with the Vučedol culture, and the development of this area continued into the Early Bronze Age (Velušček, Čufar 2003; Velušček 2008). Based on the typological features of the pottery, the Ig settlement is associated with the Vučedol culture, which was thought to have come there in search of copper ore (Dimitrijević 1979c: 307; Durman 1983: 32–37). Today, the prevailing opinion is that this area had a locally developed autochthonous culture that maintained intensive communication and close ties with the Vučedol culture (Velušček 2004c: 78–79).

Hoards

Metallurgical hoards are a phenomenon that appeared for the first time in our region as an intensive form within the Vučedol culture. The Vučedol culture hoards found on the Croatian territory are Brekinska near Pakrac (Fig. 4E) and Borinci near Vinkovci (Fig. 4D), with the addition of Topolje near Knin (Durman 1983: 39–43, Pl. 10: 1, 5; 11: 3). A slightly larger number of hoards were found in the territory of present-day Bosnia and Herzegovina, in the sites of Griča, Vranovići, Lohinje, and Kozarac, but only half of their original contents have been preserved today (Durman 1983: 40–42, Pl. 10: 2–4; 11: 1; Pravidur 2014: 148, Pls. 9–16; 23–30; 31: 93–96). A Legeta hoard was found on the territory of present-day Serbia (Durman 1983: 42, Pl. 11: 2). The Vučedol culture saw the beginning of serial production and the appearance of hoards of identical copper objects (Jovanović 1979: 48; Durman 1983: 31; 1988b: 32; 2006: 49), which can be seen in the inventory of hoards such as Brekinska and Borinci (Fig. 6). The inventory of hoards in Croatia is uniform, while hoards in Bosnia and Herzegovina often contain objects of different dimensions and types (Fig. 6).

Graves

Most of the known sites of the Vučedol culture in northern Croatia are settlements without necropolises. Funerary practices of the Vučedol culture are known from a small number of inhumation burials within the settlements (Dimitrijević 1979c: 284). All the found burials are unique cases; their common component is the burial in deep



Sl. 6 – Metalni nalazi iz ostava vučedolske kulture (nacrtale i izradile: S. Bošnjak, D. Roksandić Vukadin, prema: Durman 1983: T. 11)
Fig. 6 – Metal finds from Vučedol culture hoards (drawn and made by: S. Bošnjak, D. Roksandić Vukadin, after: Durman 1983: Pl. 11)

nih priloga među vučedolskim grobovima unutar naselja nije uobičajena praksa. Iznimku čini dvojni ukop s lokaliteta Vučedol – Vinograd Streim (V-87), uz koji je između ostalih nalaza pronađen ulomak zlatnog lima (okova) sa zakovicom od slitine zlata i srebra i kalup za lijevanje dlijeta (Hoti 1994: 183–184). Osim njega, na Kukuruzištu Streim 2021. godine (V-17/21) otkriven je kolektivni grob u kojemu je uz mnoštvo nalaza pronađeno i bakreno šilo (Hutinec, Roksandić Vukadin 2021a; 2022; Roksandić Vukadin 2022). Tijekom istraživanja istog položaja 2015. godine (V-12/15) pronađen je uništeni kolektivni grob gdje je na kostima jednoga od pokojnika primijećen intenzivan zeleni trag. Pretpostavlja se da je riječ o bakrenoj patini koja je obojila kost uz koju se predmet nalazio (Durman et al. 2015).

Drugačija situacija vidljiva je na području izvan matičnog područja vučedolske kulture. Pojavljuju se paljevinski i kosturni ukopi pod tumulima uz keramiku vučedolskih karakteristika gdje su prilozi metalnih predmeta češći. Riječ je o bogatim grobovima koji imaju obilježpits in a fetal or other positions (Durman 2009: 252–254). It seems that adding metal as a grave good was not a common practice for the graves within Vučedol culture settlements. An exception is the double burial from Vučedol – Vineyard Streim (V-87) that contained a piece of gold sheet with a rivet made of a gold and silver alloy and a mould for casting a chisel (Hoti 1994: 183–184). Also, among numerous finds, a copper awl was found in a collective grave at the Cornfield Streim site (V-17/21) in 2021 (Hutinec, Roksandić Vukadin 2021a; 2022; Roksandić Vukadin 2022). The excavations at the same location in 2015 (V-12/15) found a destroyed collective grave where an intense green mark was noticed on the bone of one of the deceased. It is assumed that this was caused by copper patina colouring the bone next to which the object was placed (Durman et al. 2015).

A different situation can be seen outside the original area of the Vučedol culture. There are cremation and inhumation burials under tumuli along with Vučedol-style pottery, where metal grave goods are more common. These rich graves

ja tzv. kneževskih tumula (Dimitrijević 1979c: 285; Primas 1996; Guštin 2006; Govedarica 2021). Iako na području Hrvatske nije pronađen nijedan vučedolski tumul, slučajni nalazi para srebrnih sjekira iz Starih Jankovaca otvaraju mogućnost postojanja najvjerojatnije uništenog monumentalnog ukopa (Balen, Mihelić 2003; Težak-Gregl 2017: 161–162).

Valja spomenuti još jedan slučajni nalaz kao mogući grobni prilog s područja Slovenije. Riječ je o sjekiri s cilindričnim produžetkom za nasad drška (tip Kozarac) s lokaliteta Raven kod Zagorja ob Savi (Gabrovec 1966: 22, T. 2: 6; Šinkovec 1996: 130, T. 1: 2; Draksler 2007: 127–128). Iako je kontekst ovog nalaza nejasan, može se povezati s eneolitičkim kosturnim ukopima toga područja. Spomenuta sjekira vrlo rano se dovodi u vezu s kalupima metalurške radionice 3. tisućljeća pr. Kr. na Ljubljanskom barju (Gabrovec 1966: 20–22; Šinkovec 1996: 130). Sjekire s cilindričnim produžetkom za nasad drška 3. tisućljeća pr. Kr. se na području Kavkaza često nalaze u grobovima, dok se u jugoistočnoj Europi najčešće nalaze u ostavama ili kao pojedinačni nalazi (Bátora 2003; Hansen 2021).

Razvoj metalurške tehnologije u okviru vučedolske kulture

Analize metalnog sastava sjekira iz ostava, uz brojne pojedinačne i slučajne metalne nalaze, navele su Durmana (1983: 53) na zaključak da se u okviru vučedolske kulture pojavljuju tri osnovna tipa metalnih predmeta. Radi se predmetima koji osim bakra imaju značajan udio srebra, antimona i/ili arsena. Sjekire tipa Baniabic iz Šarengrada pored Iloka jedine su sjekire s cilindričnim produžetkom za nasad drška koje sadrže arsen i stoga se smatraju importima iz istočnih radionica. Isprva Durman (1983: 53–54) ove nalaze grupira zajedno sa slučajnim nalazima plosnatih sjekira, dok u kasnijim radovima plosnate sjekire pripisuje badenskoj kulturi (Durman 2000: 91–92). Vučedolskoj kulturi pripisuju se sjekire s visokim udjelima srebra i antimona. U vrijeme klasične faze kulture pojavljuju se isključivo bakreni predmeti s udjelom srebra, dok se u kasnijoj fazi uz njih javljaju i oni s udjelom antimona. Takva situacija vjerojatno je rezultat prerade oksidne rude tijekom klasične faze, dok se tijekom kasne faze uz nju počinju taliti i kompleksnije (sulfidne) rude (Durman 1983: 54–56; 1988b: 35). Pre-

have the characteristics of the "princely" tumuli (Dimitrijević 1979c: 285; Primas 1996; Guštin 2006; Govedarica 2021). Although no Vučedol tumuli have been found in Croatia, the chance find of a pair of silver axes from Stari Jankovci opens up the possibility of a monumental burial that was most likely already destroyed (Balen, Mihelić 2003; Težak-Gregl 2017: 161–162).

We should mention another chance find from Slovenia that is a possible grave good. It is a shaft-hole axe (Kozarac type) from the site of Raven near Zagorje ob Savi (Gabrovec 1966: 22, Pl. 2: 6; Šinkovec 1996: 130, Pl. 1: 2; Draksler 2007: 127–128). Although the context of this find is uncertain, it can be associated with Eneolithic inhumation burials in that area. The axe was connected to the casting moulds of metallurgical workshop from the 3rd millennium BC in Ljubljansko Barje (Gabrovec 1966: 20–22; Šinkovec 1996: 130). Shaft-hole axes of the 3rd millennium BC in the Caucasus region are frequently found in graves, while in southeastern Europe they are most often found in hoards or as single finds (Bátora 2003; Hansen 2021).

Development of metallurgical technology within the Vučedol culture

The analysis of the metal composition of axes from hoards, along with the numerous single and chance metal finds, led Durman (1983: 53) to conclude that the framework of the Vučedol culture includes three basic types of metal objects. Aside from copper, these objects have significant traces of silver, antimony, and/or arsenic. The Baniabic-type axes from Šarengrad near Ilok in Syrmia are the only shaft-hole axes that contain arsenic and therefore are considered imports from eastern workshops. Initially, Durman (1983: 53–54) grouped these finds with the chance finds of flat axes; in later works, he attributed flat axes to the Baden culture (Durman 2000: 91–92). Axes with high proportions of silver and antimony are attributed to the Vučedol culture. The classical phase of that culture included only copper objects with silver content, while the later phase included copper objects with both silver and antimony content. This is probably due to the fact that only oxide ore was used during the classical phase, and more complex (sulphide) ores began to be smelted during the late phase (Durman 1983: 54–56; 1988b: 35). The dominance of antimony copper is also visible in the composition of the group of metal finds from Ljubljansko Barje – Ig site (Trampuž Orel, Heath 2008).

vlast antimonskog bakra vidljiva je i u sastavu skupine metalnih nalaza s lokaliteta Ljubljansko barje – Ig (Trampuž Orel, Heath 2008).

Durman (1988b) predlaže rekonstrukciju razvoja procesa taljenja i lijevanja tijekom vučedolske kulture na osnovi arheoloških nalaza i sastava bakrenih predmeta. Obradu oksidnih ruda datira u vrijeme klasične faze, a rekonstruira po nalazima peći s vučedolskog Gradca. Prvotno se u zatvorenoj peći sa zaobljenim dnom talila oksidna ruda. Rezultat je relativno čist bakar, koji bi se potom topio u posebnoj posudi unutar peći s ravnim dnom te bi se dalje lijevao u kalupe (za detaljnije vidi: Durman 1988b). Tijekom kasnijih faza obrađuju se kompleksnije rude čija obrada ostavlja veću količinu otpada. Upravo to objašnjava intenzivnu ekspanziju vučedolske kulture i razvoj novih naselja koja su bliža izvorištima ruda (Durman 1983: 67). Metalurške aktivnosti kasnije vučedolske kulture rekonstruira po nalazima s bosanskohercegovačkih gradina. Obrada sulfidne rude je kompleksnija, na otvorenim ognjištima, te je zahtijevala veliku količinu kisika upuhivanjem zraka puhaljkama ili mjehovima. Rezultat takve obrade je bakrenac, a njegovom daljnjom obradom dobivao se čisti bakar za lijevanje u kalupe (za detaljnije vidi: Durman 1988b). Isprva Durman za sve sulfidne rude opisuje jedan proces taljenja i posebno se fokusira na arsenske i antimonske bakrene sulfosoli (Durman 1983: 57–58; 1988b), dok u kasnijim radovima izdvaja obradu halkopirita kao zasebnu (Durman 1997: 12; 2006: 79–80). Obrada halkopirita vrlo je kompleksna i zahtjevna zbog velike količine željeza u rudi, što zahtijeva jako visoke temperature (oko 1500 °C) za taljenje, a kod neuspješnog taljenja velika količina željeza ostaje u metalu. Na samom kraju postojanja vučedolske kulture pripisana joj je i upotreba halkopiritne rude na osnovi nalaza metalnih predmeta iz istraživanja lokaliteta Vinkovci – Tržnica u sloju koji dijeli fazu B2 vučedolske kulture od faze A vinkovačke kulture. Pronađena su četiri metalna predmeta: amorfni komad lijeva, jedno šilo, izduženi predmet zašiljen s obje strane i tanka pločica (Durman 1997: 12, tab. 1). Njihov sastav pokazuje značajan udio željeza i namjerno dodavanje kositra (za detaljnije vidi: Durman 1997: 12). Takvi nalazi kositrene bronce odraz su razvoja metalurške tehnologije i trgovine, a karakteristika su brončanoga doba.

Durman (1988b) proposes a reconstruction of the development of the smelting and casting process during the Vučedol culture based on archaeological finds and the composition of copper objects. He dates the processing of oxide ores to the classical phase, and reconstructs it based on the finds of furnaces from Vučedol – Gradac. First, oxide ore was smelted in a closed furnace with a rounded bottom. The result would be relatively pure copper, which would then be melted in a special vessel and inside a flat-bottomed furnace so that it could be further cast into moulds (for more details, see: Durman 1988b). During the later phases, the Vučedol culture began to process more complex ores, which leaves more waste. That would explain the intensive expansion of the Vučedol culture and the development of new Vučedol settlements closer to the ore sources (Durman 1983: 67). The reconstruction of the metallurgical activities of the later Vučedol culture is based on the finds from hillforts in Bosnia and Herzegovina. The processing of sulphide ore is more complex; it took place on open hearths and required a large amount of oxygen, which would be provided by pipe blowers or bellows. The result of such processing is copper matte; its further processing yields pure copper for casting into moulds (for more details, see: Durman 1988b). At first, Durman described a single smelting process for all sulphide ores and focused especially on arsenic and antimony copper sulfosalts (Durman 1983: 57–58; 1988b); in later works, he separated the processing of chalcopyrite (Durman 1997: 12; 2006: 79–80). The processing of chalcopyrite is very complex and demanding due to the large amount of iron in the ore, which requires very high temperatures (about 1500°C) for melting; in case of unsuccessful smelting, a large amount of iron remains in the metal. The use of chalcopyrite was attributed to the very end of the Vučedol culture, based on the finds of metal objects from the excavations in Vinkovci – Tržnica, in the layer that separates the B2 phase of the Vučedol culture from the A phase of the Vinkovci culture. Four metal objects were found: an amorphous piece of casting, an awl, an elongated object pointed on both sides, and a thin plate (Durman 1997: 12, Tab. 1). Their composition shows a significant proportion of iron and the intentional addition of tin (for more details, see: Durman 1997: 12). Such finds of tin bronze reflect the development of metallurgical technology and trade, and are characteristic of the Bronze Age.

RASPRAVA

Prapovijesna metalurgija bakra jedan je dugotrajan i kompliciran proces koji je trajao najmanje tri tisućljeća od prve upotrebe elementarnog bakra do pojave njegovog lijevanja (sl. 1). Za razvoj metalurgije bio je potreban cijeli paket novih tehnologija, a ne samo jedna tehnološka inovacija. Termodinamička ograničenja dovela su do toga da će proći još tri tisućljeća od prvog lijevanog bakra do lijevanja željeza (Killick; Fenn 2012: 563). Prostor jugoistočne Europe obiluje izvorima bakra i ostalih ruda koje i danas imaju važnu ulogu u industriji metala. Zato su prapovijesne zajednice ovoga prostora bile jedne od prvih koje su ovladale rudarstvom i metalurgijom, prvo bakra i zlata, a kasnije i drugih plemenitih i obojenih metala. Tehnologija obrade rude do konačnog proizvoda vrlo je kompleksna, a ovladavanje njome moralo je biti dugotrajan i kompliciran proces ovisan o mnogo raznih čimbenika. Iz današnje perspektive teško je percipirati i još teže rekonstruirati procese i promjene te razvoj metalurgije.

Prostor sjeverne Hrvatske u ranome i srednjem eneolitiku gotovo da ne poznaje metaluršku tehnologiju i nema ulogu u njezinu širenju i razvoju. Istovremeno kulture susjednih područja, naročito Srbije, Slovenije i Mađarske, razvijaju metaluršku tehnologiju i proizvodne centre te stvaraju distribucijske mreže kojima cirkulira velika količina metala. Kasnije usvajanje metalurške tehnologije ovoga prostora objašnjava se nedostatkom izvora metalnih ruda, naročito bakra.

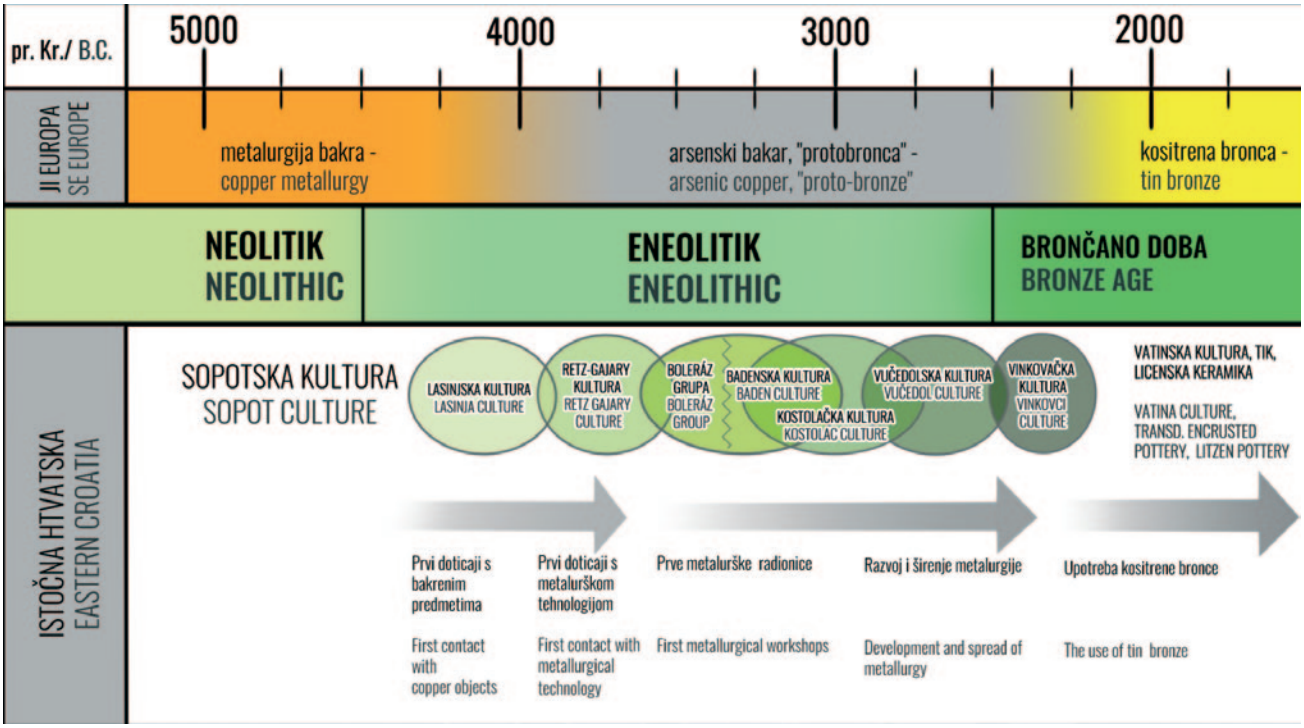
Jedine metalne nalaze i tragove metalurških aktivnosti ranoga i srednjega eneolitika nalazimo na lokalitetima u Slavoniji i Srijemu. Uzrok tome može biti stanje istraženosti ili činjenica da je taj prostor pod većim utjecajem metalurški razvijenih kultura zbog povoljnih prirodnogeografskih čimbenika i razvijenih komunikacijskih putova. Metalni nalazi srednjega eneolitika sjeverne Hrvatske ukazuju na to da su se tadašnje zajednice susrele s metalom najvjerojatnije putem trgovine, ali teško je reći koliki je bio opseg i intenzitet te komunikacije. Najstariji dokaz metalurškog postupka u Hrvatskoj je posuda za taljenje iz Josipovca Punitovačkog kraj Đakova datirana u vrijeme kulture Retz-Gajary (Čataj 2009a: 47–48, sl. 37–40, T. 36: 3). Međutim, bez obzira na provedene analize, točna funkcija tog predmeta u metalurškom postupku ostaje nejasna. Važnost tog nalaza ukazuje

DISCUSSION

Prehistoric copper metallurgy was a long and complicated process which lasted at least three millennia, from the first use of elemental copper until the appearance of its casting (Fig. 1). Instead of a single technological innovation, the development of metallurgy required a whole package of new technologies. Thermodynamic constraints meant that another three millennia would pass from the first casting of copper to the casting of iron (Killick, Fenn 2012: 563). Southeastern Europe has many sources of copper and other ores that still play an important role in the metal industry. That is why the prehistoric communities of this area were among the first to master mining and metallurgy, first of copper and gold, and later of other precious and non-ferrous metals. The technology required to process ore to the final product is very complex, and its mastering must have been a long and complicated process dependent on many different factors. It is difficult to perceive, and even more difficult to reconstruct, processes and changes in the development of metallurgy from today's perspective.

During the Early and Middle Eneolithic, the area of northern Croatia had almost no metallurgy and played no role in the expansion and development of metallurgical technology. At the same time, the cultures of neighbouring areas, especially Serbia, Slovenia, and Hungary, developed metallurgical technology and production centres and created distribution networks through which a large amount of metal circulated. The later adoption of metallurgical technology in this area is explained by the lack of sources of metal ores, especially copper.

The only metal finds and traces of metallurgical activities of the Early and Middle Eneolithic can be found at the Slavonian and Syrmian sites. This may be the result of the state of research or because this area was more influenced by metallurgically developed cultures due to favourable natural or geographical factors and developed communicational routes. Metal finds from the Middle Eneolithic in northern Croatia show that these communities most likely encountered metal through trade, but it is difficult to estimate the extent and intensity of this communication. The oldest evidence of metallurgical activity in Croatia is a smelting vessel from Josipovac Punitovački near Đakovo, attributed to the Retz-Gajary culture (Čataj 2009a: 47–48, Fig. 37–40, Pl. 36: 3). Despite the analyses, the exact function of that item in the metallurgical process is



Sl. 7 – Pojednostavljeni prikaz razvoja metalurgije bakra na prostoru istočne Hrvatske u kontekstu jugoistočne Europe (izradile: S. Bošnjak, D. Roksandić Vukadin)
Fig. 7 – Simplified representation of the development of copper metallurgy in eastern Croatia in the context of southeastern Europe (made by: S. Bošnjak, D. Roksandić Vukadin)

na potrebu prapovijesnih zajednica da eksperimentiraju s tehnologijom obrade ili prerade bakra. Trenutna saznanja će se najvjerojatnije promijeniti obradom materijala sa srednjoeneolitičkog nalazišta retz-gajarske kulture, Medvođe – Glogovica. Nalazište ima značajan potencijal, sadrži sve elemente potencijalne metalurške radionice te bi moglo biti ključno za razumijevanje njihovog tehnološkog dosega. Usprkos ovim podatcima, u ranome i srednjem eneolitiku ne možemo govoriti o značajnoj uporabi metalnih predmeta ni poznavanju metalurške tehnologije na području sjeverne Hrvatske.

O pravoj razvijenoj metalurgiji na tom području zasad možemo govoriti tek u vrijeme badenske kulture i pojave arsenskog bakra. Mnoge spoznaje o obradi bakra na prostoru jugoistočne Europe savladane su prije nego što badenska kultura donosi metaluršku tehnologiju na naše prostore (obrada bakra kovanjem, taljenje, lijevanje metodom izgubljenog voska i u jednodijelne kalupe). Dosadašnji nalazi pokazuju da zajednice badenske kulture svoju rudu tale u jednostavnim keramičkim posudama debelih stijenki (talionicima) čije tipološke odlike pokazuju ujednačenost u svim radionicama still unknown. This find indicates the need of prehistoric communities to experiment with the copper processing technology. The current perception will most likely change with a proper study of the Middle Eneolithic Retz-Gajary site of Medvođe – Glogovica. The site exhibits great potential and contains all the elements of a metallurgical workshop. Thus, it could be of great importance for understanding their technological level. In spite of this, we cannot claim there was a significant use of metal objects or metallurgical technology in the area of northern Croatia during the Early and Middle Eneolithic.

For the time being, we can only discuss the developed metallurgy when talking about the Baden culture and the onset of arsenic copper. Different kinds of copper processing in southeastern Europe were mastered before the Baden culture brought its metallurgical technology to the area (copper processing by forging, smelting, casting with the lost wax method and one-piece moulds). Finds indicate that the communities of the Baden culture processed their ore in thick-walled, simple ceramic vessels (crucibles) that show typological uniformity throughout the workshops (Ecsedy 1990). Moulds do vary in size, but only one-piece

(Ecsedy 1990). Svi pronađeni kalupi su jednodijelni, za lijevanje plosnatih sjekira, iako se razlikuju po veličini (Durman 2000; Lozuk 1995; Mihaljević et al. 2018). Stoga se može zaključiti da je metalurška proizvodnja badenske kulture u Hrvatskoj bila ograničena na samo jedan proizvod, jednostavnu plosnatu sjekiru. Treba imati na umu da se neki metalni predmeti mogu izraditi kovanjem i temperiranjem. Takav proces ne zahtijeva visoke temperature ni pribor za lijevanje, stoga ne ostavlja mnogo dokaza u arheološkom zapisu.

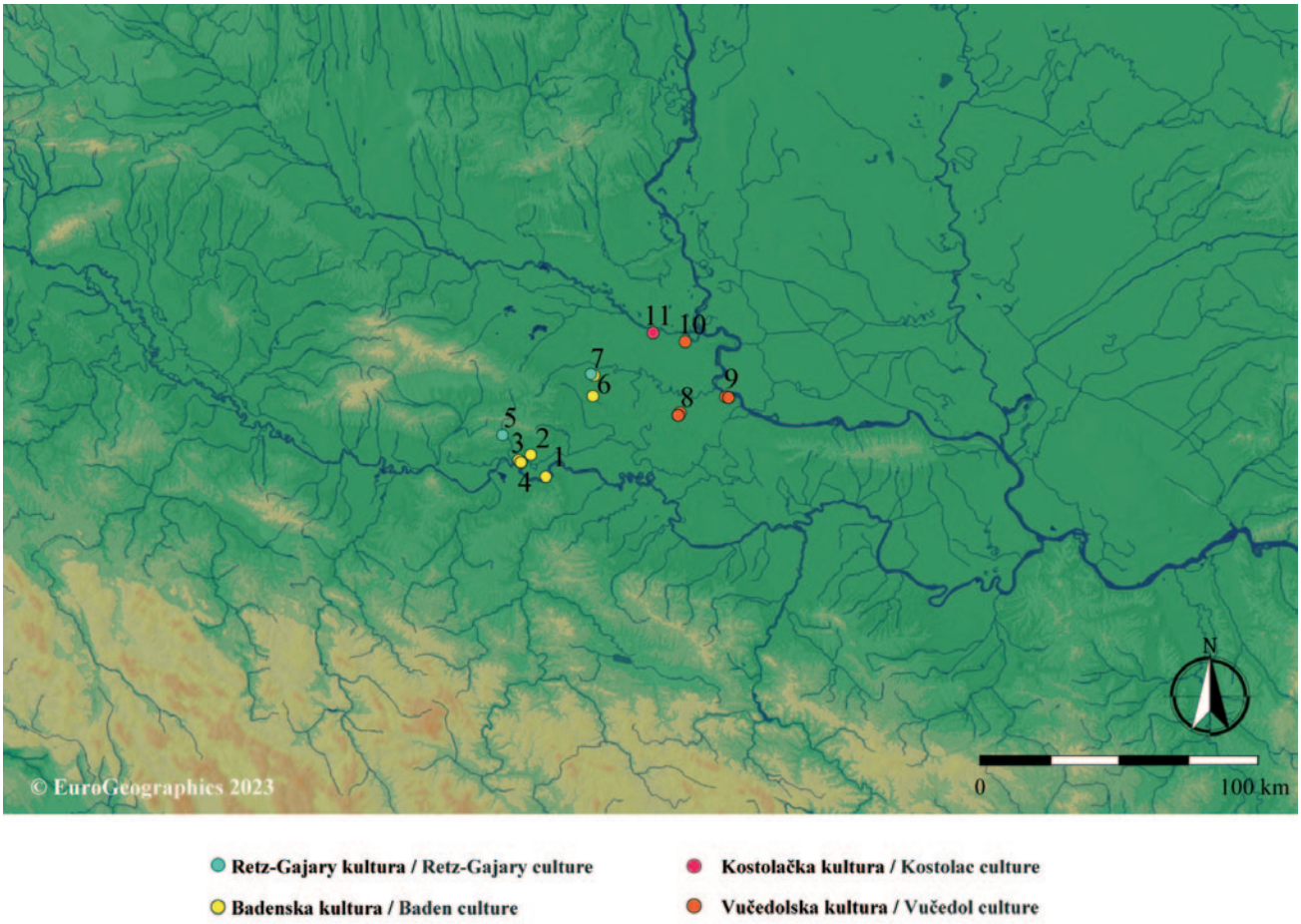
Primjećuje se da se metalurške radionice badenske kulture u Hrvatskoj grupiraju na području Brodskog Posavlja (karta 1). S obzirom na opseg metalurške aktivnosti badenske kulture na tom području, pouzdano ga možemo okarakterizirati kao lokaliziranu metaluršku pojavu. Ipak, treba očekivati nalaze metalurške djelatnosti badenske kulture i na ostalim područjima Hrvatske. S područja Posavine, dolinama rijeka Vrbasa i Bosne pruža se glavni komunikacijski pravac prema rudno bogatim srednjobosanskim planinama. Ta komunikacija između Bosne i Hercegovine, preko Posavine do istočne Slavonije, Srijema i rijeke Dunav morala je nastati vrlo rano, još tijekom neolitika, sa svrhom nabave i distribucije kamene sirovine. Razvojem metalurgije i sve većom potražnjom bakrene rude tijekom eneolitika rastao je i značaj takve komunikacije. Takva situacija očita je tijekom razdoblja badenske kulture. Ruda se najvjerojatnije nabavljala s područja Bosne i Hercegovine, prerađivala u radionicama Brodskog Posavlja te distribuirala dalje (Durman 2000). Nadalje, lokalitet Medvođe – Glogovica otvara mogućnost da je distribucija rude iz Bosne i Hercegovine počela i nešto ranije, tijekom srednjeg eneolitika. Komunikacijski pravac mogao se nastaviti razvijati u vrijeme kostolačke kulture, uzimajući u obzir da se nekoliko važnih lokaliteta nalazi na desnoj, bosanskoj strani rijeke Save. Metalni sastav nalaza kostolačke kulture ukazuje na vezu s metalurškim krugom badenske kulture i poznavanje arsenskog bakra. Mali broj istraženih lokaliteta i objavljenog materijala te nedefiniran odnos s badenskom i vučedolskom kulturom onemogućavaju shvaćanje njezine kompletne uloge u razvoju metalurgije kasnoga eneolitika.

Eneolitička metalurgija svoj vrhunac doživljava u vrijeme vučedolske kulture. Mnogo badenskih utjecaja i djelatnosti, naročito metalurgiju, preuzima vučedolska kultura. Lokaliteti vučedolske kulture s tragovima metalurških aktivnosti

moulds for casting flat axes were found (Durman 2000; Lozuk 1995; Mihaljević et al. 2018). This indicates that the metallurgical production of the Baden culture in Croatia was limited to only one product, a simple flat axe. We should keep in mind that some metal objects could be produced by smithing and annealing. Such practices do not require high temperatures or casting equipment, and therefore would not leave much evidence in the archaeological record.

It may be noted that the metallurgical workshops of the Baden culture in Croatia are clustered in the area of Brodsko Posavlje (Map 1). Considering the extent of the Baden metallurgical activity in that area, we can confidently consider it as a localized metallurgical phenomenon. Nevertheless, we should expect more finds of Baden culture metallurgy in other areas of Croatia. The main communication route from the area of Posavina to the ore-rich central Bosnian mountains runs through the valleys of the Vrbas and the Bosna. The communication route from Bosnia and Herzegovina across the Sava valley to eastern Slavonia and Syrmia and the Danube must have appeared very early on during the Neolithic with the purpose of obtaining and distributing stone. Its importance only grew with the development of metallurgy during the Eneolithic and a growing need for copper ore. This becomes most apparent during the Baden culture. The ore was most likely obtained from Bosnia and Herzegovina, processed at the workshops of Brodsko Posavlje, and then distributed further (Durman 2000). Furthermore, the site of Medvođe – Glogovica suggests that ore distribution from Bosnia and Herzegovina might have been established even earlier, during the Middle Eneolithic. The communication route could have continued developing during the Kostolac culture, as several important sites are located on the Bosnian side, on the right bank of the River Sava. The metal composition of the Kostolac culture finds indicates a connection with the Baden culture metallurgical circle and a familiarity with arsenic copper. The small number of explored sites and published materials, along with an undefined relationship with the Baden and Vučedol cultures, make it impossible to fully understand its role in the development of Late Eneolithic metallurgy.

Eneolithic metallurgy in Croatia reached its peak at the time of the Vučedol culture. Many Baden cultural influences and activities, especially metallurgy, were taken over by the Vučedol culture. Vučedol culture sites with traces of metallurgical activities (presumed workshops) are found primarily along



Karta 1 – Eneolitički lokaliteti s nalazima metalurške djelatnosti u sjevernoj Hrvatskoj (podloga: EuroDEM; preuzeto iz baze kartografskih podataka, © EuroGeographics 2023; izradile: S. Bošnjak, D. Roksandić Vukadin)
Map 1 – Eneolithic sites with finds of metallurgical activity in northern Croatia (basemap: EuroDEM; from the cartographic database, © EuroGeographics 2023; made by: S. Bošnjak, D. Roksandić Vukadin)

1 Donja Bebrina – Okukalj; 2 Donja Vrba – Saloš; 3 Ruščica – Glogove-Praulje; 4 Ruščica – Praulje; 5 Medvođe – Glogovica; 6 Štrosmajerovac – Pustara; 7 Josipovac Punitovački – Veliko polje; 8 Vinkovci – Tržnica i/and Ervenica; 9 Vučedol – Gradac i/and Kukuruzište Streim; 10 Sarvaš – Gradac; 11 Osijek – Frigis 1

(pretpostavljene radionice) nalaze se prvenstveno u blizini rijeke Dunav (karta 1) (Vinkovci, Vučedol, Sarvaš, Zók) te u blizini izvora bakra u sjevernoj, sjeveroistočnoj i srednjoj Bosni i Hercegovini (Debelo Brdo, Zecovi kod Prijedora, Velika Gradina u Varvari, Gradina Alihodže, Donje Moštre). Izgleda da je kultura preuzela i nastavila razvijati put distribucije rudne sirovine od prethodnica, a pritom je izbjegla naseljavanje područja Posavine. Na spomenutom području nisu poznati lokaliteti vučedolske kulture[4], te izgleda da je područje Brodskog Posavlja izgubi-

and near the Danube (Map 1) (Vinkovci, Vučedol, Sarvaš, Zók) and near copper sources in northern, northeastern, and central Bosnia and Herzegovina (Debelo Brdo, Zecovi kod Prijedora, Velika Gradina in Varvara, Gradina Alihodže, Donje Moštre). This culture seems to have adopted and further developed the ore distribution route from the previous cultures, but in doing so avoided inhabiting the area of Posavina. No Vučedol culture sites are known in the area,[4] and it seems that Brodsko Posavlje lost its importance as a metallurgical centre with the end of the Baden culture, around the end of the 4th and the

4 U literaturi se na nekoliko mjesta sporadično spominju nalazi vučedolske keramike s područja Brodskog Posavlja. Radi se o fragmentiranim, nedijagnostičkim ulomcima bez jasnog konteksta koji se mogu pripisati i drugim eneolitičkim kulturama.

4 Finds of Vučedol pottery from the area of Brodsko Posavlje are sporadically mentioned in several places in the literature. These are fragmented, non-diagnostic sherds without a clear context that can also be attributed to other Eneolithic cultures.

lo svoju važnost kao metalurško središte krajem badenske kulture, odnosno krajem 4. i početkom 3. tisućljeća pr. Kr., da bi se ponovno obnovilo i aktiviralo tijekom brončanog doba. Ovaj fenomen može se usporediti s područjem Ljubljanskog barja. Metalurška proizvodnja tamo je započela tijekom druge četvrtine 4. tisućljeća pr. Kr. i trajala do zadnje četvrtine 4. tisućljeća pr. Kr. nakon čega dolazi do prekida u naseljavanju i metalurškoj proizvodnji sve do sredine 3. tisućljeća pr. Kr. (Velušček 2008). Još jedan čimbenik koji treba uzeti u obzir pri izostanku naselja vučedolske kulture u savskom prostoru jest i sklonost vučedolskih zajednica da svoja naselja grade na zaštićenim dominantnim uzvišenjima (uzdignute lesne zaravni ili gradine). Područje Ljubljanskog barja predstavlja izuzetak i vrlo je izoliran vučedolski fenomen, zbog neposredne blizine izvorišta bakrene rude.

Vučedolska kultura počinje samostalni lokalni razvoj tehnologije obrade i prerade bakra te izradu vlastitih tipova metalnih predmeta. Razvija se tzv. „serijska proizvodnja", pojavljuju se dvodijelni i višenamjenski kalupi te ostave identičnih bakrenih predmeta (Durman 1983; 1988a). Smatra se da su sjekire s cilindričnim produžetkom za nasad drška odraz vrhunca metalurgije bakra. Pomicanje rupe za nasad drška sa središta na rub predmeta omogućilo je lakše rukovanje sjekirom i veću probojnu snagu. Istovremeno, zbog toga su podložnije pucanju kod rupe za nasad, naročito ako se ne lijevaju pravilno. Njihovo lijevanje zahtijeva značajnu vještinu i kvalitetan metal (bakar ili bakrena legura) (Hansen 2021). Poznati su brojni nalazi sjekira s cilindričnim produžetkom za nasad drška tipa Kozarac i njihovih kalupa. Opće je prihvaćeno da su one lokalni proizvod zajednica vučedolske kulture, zajedno s plosnatim sjekirama tipa Griča. Važno je napomenuti da sjekire tipa Kozarac ne nalazimo izvan šireg područja Karpatske kotline, jugoistočne Europe (Dani 2013), a da sjekire tipa Griča ne pronalazimo izvan okvira vučedolske kulture (Durman 1983: 60).

Tijekom ranijih faza najviše se koriste oksidne i karbonatne rude, dok kasnije počinje upotreba sulfidnih bakrenih ruda iz serije tenantit-tetraedrit i razvija se upotreba antimonskog bakra (Durman 1983). Otvorena je i mogućnost da je vučedolska kultura na kraju svojega postojanja upoznata i s kompleksnijim sulfidnim rudama te kositrenom broncom, ali to je još predmetom rasprave (Durman 1997).

start of the 3rd millennium BC, only to regain it during the Bronze Age. Something of a parallel might be drawn with the area of Ljubljansko Barje. Metallurgical production there started during the second quarter of the 4th millennium BC and lasted until the last quarter of the 4th millennium BC. Subsequently, there was a hiatus in inhabitation and metallurgical production until the middle of the 3rd millennium BC (Velušček 2008). Considering the lack of Vučedol culture settlements in the area of the Sava, another factor must be taken into account: the tendency of Vučedol communities to build their settlements on protected and dominant highlands (elevated loess plateaus or hillforts). The area of Ljubljansko Barje is an exception and a very isolated Vučedol phenomenon, because of its copper ore source.

The Vučedol culture began the independent local development of copper processing technology and the production of its own types of metal objects. "Serial production" began, two-part and multi-purpose moulds started to be used, and hoards of identical copper objects appeared (Durman 1983; 1988a). Shaft-hole axes are thought to be the peak of copper metallurgy. The transfer of the shaft-hole from the centre to the edge of the object made axes easier to handle with more penetrative power. However, it made them more susceptible to breakage at the neck if not cast properly. Therefore, casting them required great skill and quality metal (copper or copper alloy) (Hansen 2021). There are numerous finds of Kozarac-type shaft-hole axes and their casting moulds. It is widely accepted that Vučedol culture communities produced them locally along with flat axes of the Griča type. It is important to note that Kozarac-type axes did not spread outside the area of the wider Carpathian Basin, southeastern Europe (Dani 2013), and that Griča-type axes did not spread outside of the Vučedol culture (Durman 1983: 60).

During the earlier stages, oxide and carbonate ores were mostly used, but later, the use of sulphide copper ores from the tennantite-tetrahedrite series began and the use of antimony copper developed (Durman 1983). There is also the possibility that the Vučedol culture at the end of its existence was familiar with more complex sulphide ores and tin bronze, but that is still a matter of debate (Durman 1997).

Metallurgical workshops of the Vučedol culture in Slavonia and Syrmia were most likely casting workshops for melting ingots and/or remelting objects, where only processing metallurgy was done. Almost no waste or other evidence

Metalurške radionice vučedolske kulture u Slavoniji i Srijemu najvjerojatnije su ljevačke radionice za taljenje ingota i/ili pretaljivanje predmeta, gdje se odvijala samo prerađivačka metalurgija. Gotovo da nema nalaza otpada ni drugih dokaza prerade rude i odvijanja ekstraktivne metalurgije. Pretpostavljeno je da su radionice ekstraktivne metalurgije premještene bliže izvorima rude u Bosni i Hercegovini (Durman 1983), odakle su distribuirani ingoti ili poluproizvodi. Možda je moguće pretpostaviti da je vučedolska kultura organizirala i razvila mrežu specijaliziranih radionica i putova za proizvodnju i distribuciju metalnih predmeta na velikim udaljenostima. Ipak, ovakva situacija je teorijska, te je potrebno detaljno interdisciplinarno istraživanje nove i revizija stare građe kako bi se bolje razumjela prava funkcija svih metalurških radionica vučedolske kulture.

Razvoj metalurgije u sjeverozapadnoj Hrvatskoj tijekom razdoblja eneolitika još je nepoznanica. Dostupno je malo podataka, a mnogi u potpunosti nedostaju, kao na primjer za period između retz-gajarske i vučedolske kulture. Ako uzmemo u obzir razvoj metalurške tehnologije u obližnjim područjima poput Slovenije, možemo pretpostaviti da je metalurgija na tom području bila poznata ako ne i prakticirana prije dolaska vučedolske kulture. Vučedolska kultura prisutna je i na području Požeške kotline i okolice Moslavine. Značajan nalaz s tog područja je ostava iz Brekinske u kojoj su pronađene brojne sjekire tipa Kozarac. S tog područja vučedolska kultura se širila prema sjeverozapadu, prema Bilogori i Kalniku. Vrlo je vjerojatno da se kultura širila i zauzela današnje sisačko-banovinsko područje (Durman 1991b; Madiraca 2012) s obzirom na blizinu rudama bogatog područja sjeverozapadne Bosne i Hercegovine gdje su između ostalih lokaliteta pronađene metalurška radionica Zecovi i ostava Kozarac. Spomenuta područja dijele mnoga prirodna i zemljopisna obilježja, uključujući i izvore bakrene rude, ali u smislu arheometalurgije su nedovoljno istražena te zahtijevaju opsežnu sustavnu studiju.

ZAKLJUČAK

Prema dosadašnjem stanju istraženosti, područje sjeverne Hrvatske nije sudjelovalo u najranijem razvoju europske metalurgije, ali je tom tehnologijom u potpunosti ovladalo prije početka brončanog doba (sl. 7). Prvi tragovi metalurgije javljaju se tijekom srednjeg eneolitika, of ore processing or extractive metallurgy has been found. It is presumed that they moved the workshops for extractive metallurgy closer to the ore sources in Bosnia and Herzegovina (Durman 1983), from where they distributed ingots or half-finished products. Perhaps it can be assumed that the Vučedol culture developed and organised a long-distance network of specialised workshops and routes for the purpose of producing and distributing metal objects. Nevertheless, this scenario remains theoretical, needing detailed interdisciplinary research of recent material and a review of old material to better understand the true nature of all Vučedol culture metallurgical workshops.

The Eneolithic development of metallurgy in northwestern Croatia is still a mystery. Very little data is available, and there is no data for the period between the Retz-Gajary and Vučedol cultures. If we take into account the development of metallurgical technology in the nearby areas like Slovenia, we can assume that metallurgy was already at least familiar if not practised there by the time the Vučedol culture reached that area. The Vučedol culture is present in the area in and around Požega Valley and the region of Moslavina. An important find from that area is the Brekinska hoard, where numerous Kozarac-type axes were discovered. From there, the Vučedol culture spread to the northwest towards the mountains of Bilogora and Kalnik. It is also likely that it spread towards Sisak and the Banovina region (Durman 1991b; Madiraca 2012), considering the ore-rich area of northwestern Bosnia and Herzegovina with sites like the metallurgical workshop of Zecovi and the Kozarac hoard. The mentioned areas share many natural and geographical features, including sources of copper ore, but in terms of archaeometallurgy, they are insufficiently researched and require extensive systematic study.

CONCLUSION

The current state of research indicates that the area of northern Croatia did not participate in the earliest development of European metallurgy but fully mastered that technology before the onset of the Bronze Age (Fig. 7). The first evidence of metallurgy appears during the Middle Eneolithic, when the area of eastern Croatia became involved in the metallurgical development. Still, there has been neither targeted archaeometallurgical study that would allow for a better understanding of the technological level they mastered nor the metal-

kada se područje istočne Hrvatske uključuje u metalurški razvoj. Ipak, do sada nije napravljeno ciljano arheometalurško istraživanje koje bi omogućilo bolje razumijevanje ovladane tehnološke razine i metalurških procesa koji su se tada odvijali. Tijekom kasnog eneolitika metalurška proizvodnja u Hrvatskoj doživljava procvat s badenskom kulturom, a nastavlja svoj razvoj s vučedolskom kulturom. Zbog nedostatnih podataka ne možemo utvrditi kada i gdje su se počeli odvijati metalurški procesi u sjeverozapadnoj Hrvatskoj, ali možemo pretpostaviti da je tehnologija barem bila poznata lokalnim zajednicama tijekom kasnog eneolitika.

Možemo izdvojiti jedno metalurški razvijeno područje u Posavini koje je djelovalo tijekom druge polovice 4. tisućljeća pr. Kr., u okviru badenske kulture, a možda i ranije u okviru retzgajarske kulture. U to vrijeme uspostavljen je opskrbni put od izvora bakra u Bosni i Hercegovini te je započela samostalna proizvodnja bakrenih predmeta. Metalurška tehnologija nastavila se razvijati, moguće s kostolačkom, ali zasigurno s vučedolskom kulturom. Zajednice vučedolske kulture nastavile su metaluršku proizvodnju i razvile su vlastite tipove metalnih predmeta. Također, moguće je da su tijekom vučedolske kulture bila organizirana specijalizirana naselja za određeni dio metalurške proizvodnje. Tehnološki napredak i sve veća potražnja bili su poticaj za širenje, razvoj trgovine na velike udaljenosti, stvaranje komunikacijskih mreža i kolonizaciju novih područja. Takvi procesi najizraženiji su širenjem vučedolske kulture južno od Save te prema zapadu i alpskom prostoru, gdje zaposjeda glavne komunikacijske putove, važne strateške pozicije i ležišta bakra.

Metalurška tehnologija razvija se kao važna gospodarska grana koja rezultira nizom ekonomskih i društvenih promjena. Zajednice koje su kontrolirale trgovinske putove i izvore bakra uživale su veliku moć i bogatstvo, što je omogućilo izdizanje pojedinca unutar društva njegovom moći, statusom i bogatstvom. Upravo je razvoj metalurške produkcije, koja je postala centralna odlika vučedolske kulture, doveo do jasne stratifikacije društva, obilježio tranzicijski period i stvorio poveznicu između kasnoga eneolitika i ranoga brončanog doba.

lurgical processes that occurred. During the Late Eneolithic, metallurgical production in Croatia flourished with the Baden culture, and it continued its development with the Vučedol culture. Due to insufficient data, we cannot establish when and where metallurgy began to be practised in northwestern Croatia, but we can assume that it was at least known to the local communities during the Late Eneolithic.

We can pinpoint one metallurgically developed area in Posavina that was active during the second half of the 4th millennium BC within the framework of the Baden culture, or maybe even earlier, in the Retz-Gajary culture. During that time, a supply network from the copper sources in Bosnia and Herzegovina was established, and independent production of copper objects began. The metallurgical technology continued developing, possibly in the Kostolac culture, but surely in the Vučedol culture. Vučedol culture communities continued their metallurgical production and even developed their own types of metal objects. It is also possible that specialized settlements for particular segments of metallurgical production were organized during the Vučedol culture. Technological progress and increasing demand were the incentives for expansion, the development of long-distance trade, the creation of communication networks, and the colonization of new areas. Such processes were most pronounced during the expansion of the Vučedol culture south of the Sava and towards the west and the Alpine area, where it occupied the main communication routes, important strategic positions, and copper deposits.

Metallurgical technology developed as an important economic branch that resulted in a series of economic and social changes. The communities that controlled the trade routes and sources of copper enjoyed great power and wealth, which made it possible for individuals to rise within the society with their own power, status, and wealth. It was the development of metallurgical production, which became a central feature of the Vučedol culture, that led to a clear stratification of society, marked the transitional period, and created a link between the Late Eneolithic and the Early Bronze Age.

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INTERNETSKI IZVORI INTERNET SOURCES

EuroDEM – Euro digital elevation model, © EuroGraphics 2023, https://www.mapsforeurope.org (accessed 25. 06. 2024)

LITERATURA BIBLIOGRAPHY

Amzallag, N. 2009, From Metallurgy to Bronze Age Civilizations: The Synthetic Theory, *American Journal of Archaeology*, Vol. 113(4), 497–519. https://doi.org/10.3764/aja.113.4.497

Angeli, W. 1967, Der Depotfund von Stollhof, *Annalen des Naturhistorischen Museums Wien,* Vol. 70 (1966), 491–496.

Antonović, D. 2002, Copper processing in Vinča. New contributions to the thesis about metallurgical character of Vinča culture, *Starinar*, Vol. LII, 27–45. https://doi.org/10.2298/STA0252027A

Antonović, D. 2006, Malachite finds in Vinča culture: evidence of early copper metallurgy in Serbia, *Metalurgija*, Vol. 12(2–3), 85–92.

Antonović, D. 2018, Eneolitski rudnici bakra na Balkanu / Eneolithic copper mines in the Balkans, in: *Povratak u prošlost. Bakreno doba u sjevernoj Hrvatskoj / Back to the past. Copper Age in northern Croatia*, Balen J., Miloglav I., Rajković D. (eds.), Arheološki muzej u Zagrebu, Filozofski fakultet Sveučilišta u Zagrebu, Arheološki muzej Osijek, Zagreb, 187–209. https://doi.org/10.17234/9789531758185-10

Apakidze, J., Hansen, S. 2020, Two Bronze Age Hoards with Shaft-Hole Axes from West Georgia. Materials for Communication Between Central and Eastern Europe, in: *Ultra velum temporis. Venované Jozefovi Bátorovi k 70. Narodeninám*, Kozubová A., Makarová E., Neumann M. (eds), Slovenská archeológia LXVIII (Supplementum 1), 39–52. https://doi.org/10.31577/slovarch.2020.suppl.1.1

Balen, J. 2005, *Sarvaš – neolitičko i eneolitičko naselje / Sarvaš – Neolithic and Eneolithic settlement*, Musei Arcaeologici Zagrabiensis Catalogi et Monographiae II, Arheološki muzej u Zagrebu, Zagreb.

Balen, J. 2010, *Eneolitičke kulture na prostoru istočne Hrvatske*, Unpublished PhD Thesis, University of Zagreb, Zagreb.

Balen, J. 2011, *Đakovo – Franjevac: kasno bakrenodobno naselje / Đakovo – Franjevac: late eneolithic settlement*, Musei Arcaeologici Zagrabiensis Catalogi et Monographiae VII, Arheološki muzej u Zagrebu, Zagreb.

Balen, J. 2016, The development of Eneolithic cultures between the Sava and Drava rivers, in: *Croatia at the Crossroads. A consideration of archaeological and historical connectivity*, Proceedings of conference held at Europe House, Smith Square, London, 24-25 June 2013 to mark the accession of Croatia to the European Union, Davidson D., Gaffney V., Miracle P., Soafer J. (eds.), Archaeopress Publishing Ltd, Oxford, 59–74.

Balen, J. 2018a, Eneolitičke kulture na prostoru istočne Hrvatske, in: *Arheologija na Dunavu*, znanstveni skup, Vukovar, 7. do 11. listopada 2013, Tončinić D. (ed.), Izdanja Hrvatskog arheološkog društva 31 (2017), Hrvatsko arheološko društvo, Gradski muzej Vukovar, Zagreb – Vukovar, 65–74.

Balen, J. 2018b, Badenska kultura / The Baden culture, in: *Povratak u prošlost. Bakreno doba u sjevernoj Hrvatskoj / Back to the past. Copper Age in northern Croatia*, Balen J., Miloglav I., Rajković D. (eds.), Arheološki muzej u Zagrebu, Filozofski fakultet Sveučilišta u Zagrebu, Arheološki muzej Osijek, Zagreb, 65–85. https://doi.org/10.17234/9789531758185-05

Balen, J., Mihelić, S. 2003, Par srebrnih sjekira iz Starih Jankovaca, *Opvscvla archaeologica*, Vol. 27(1), 85–96.

Balen, J., Zorić, J. 2020, Metalni nalazi lasinjske kulture s nalazišta Pajtenica – Velike livade, in: *HOMO UNIVERSALIS. Zbornik radova posvećen Zorku Markoviću povodom 65. obljetnice života*, Dizdar M., Botić K., Kalafatić H. (eds.), Zbornik Instituta za arheologiju 15, Institut za arheologiju, Zagreb, 187–193.

Bánffy, E. 1994, Transdanubia and eastern Hungary in the early copper age, in: *A Jósa András Múzeum Évkönyve* XXXVI, 291–296.

Bátora, J. 2003, Kupferne Schaftlochäxte in Mittel-, Ost- und Süosteuropa (Zu Kulturkontakten und Datierung - Äneolithikum/Frühbronzezeit), *Slovenská Archeólogia*, Vol. LI(1), 1–37.

Bednjanec, L. 2012a, Slavonski Brod – luka (lokalitet Ruščica – Glogove – Praulje), *Hrvatski arheološki godišnjak*, Vol. 8 (2011), 126–128.

Bednjanec, L. 2012b, Slavonski Brod – luka (lokalitet Ruščica – Glogove – Praulje), *Hrvatski arheološki godišnjak*, Vol. 8 (2011), 128–130.

Bednjanec, L. 2012c, Slavonski Brod – luka (lokalitet Ruščica – Praulje), *Hrvatski arheološki godišnjak*, Vol. 8 (2011), 130–132.

Benac, A. 1959, Slavonska i ilirska kultura na prehistorijskoj gradini Zecovi kod Prijedora, *Glasnik zemaljskog muzeja Bosne i Hercegovine u Sarajevu*, Vol. XIV, 13–51.

Benac, A. 1962, Pivnica kod Odžaka i neki problemi kostolačke kulture, *Glasnik Zemaljskog muzeja u Sarajevu*, Vol. XVII, 21–40.

Benkö, L, Horváth, F., Horvatinčić, N., Obelić, B. 1989, Radicarbon and thermoluminescence dating of prehistoric sites in Hungary and Yugoslavia, *Radiocarbon*, Vol. 31(3), 992–1002. https://doi.org/10.1017/S0033822200012637

Bojadžiev, J. 1992, Probleme der Radiokohlenstoffdatierung der Kulturen des Spätäneolithikums und der Frühbronzezeit, *Studia Praehistorica*, Vol. 11–12, 389–406.

Borić, D. 2009, Absolute dating of metallurgical innovations in the Vinča culture of the Balkans, in: *Metals and Societies. Studies in honour of Barbara S. Ottaway*, Kienlin T. L., Roberts Ben W. (eds.), Universitätsforschungen zur prähistorischen Archäologie 169, Verlag Dr. Rudolf Habelt GmbH, Bonn, 191–245.

Bošnjak, S. 2021, *Metalurgija vučedolske kulture: izvori i njihove sirovine*, Unpublished MA Thesis, University of Zagreb, Zagreb.

Brunšmid, J. 1902, Nahođaji bakrenoga doba iz Hrvatske i Slavonije i susjednih zemalja, *Viestnik hrvatskoga arheolopkoga društva*, Vol. VI, 32–67.

Bulat, M. 1962, Bakrene sjekire u Muzeju Slavonije, *Osječki zbornik*, Vol. 8, 5–36.

Csányi, M., Raczyk, P., Tárnoki, J. 2010, Das kupferzeitliche Gräberfeld von Rákóczifalva – Bagiföld in Ungarn, *Das Altertum*, Vol. 55(4), 241–270.

Čataj, L. 2009a, Retz-Gajary kultura, in: *Josipovac Punitovački – Veliko polje I. Zaštitna arheološka istraživanja na trasi autoceste A5. Eneolitičko, brončanodobno i srednjovjekovno naselje*, Čataj L. (ed.), Hrvatski restauratorski zavod, Zagreb, 23–103.

Čataj, L. 2009b, Badenska kultura, in: *Josipovac Punitovački – Veliko polje I. Zaštitna arheološka istraživanja na trasi autoceste A5. Eneolitičko, brončanodobno i srednjovjekovno naselje*, Čataj L. (ed.), Hrvatski restauratorski zavod, Zagreb, 104–139.

Čataj, L. 2016, Lasinja, Retz-Gajary and Boleráz? Radiocarbon dates and the sequence of Copper Age Cultures in Central Croatia, in: *Centenary of Jaroslav Palliardi's Neolithic and Aeneolithic Relative Chronology*, Kovárník J. (ed.), University of Hradec Králové, Philosophical Faculty, Oftis, Hradec Králové – Ústí nad Orlicí, 181–192.

Čataj, L. 2018a, Lasinjska kultura / The Lasinja culture, in: *Povratak u prošlost. Bakreno doba u sjevernoj Hrvatskoj / Back to the past. Copper Age in northern Croatia*, Balen J., Miloglav I., Rajković D. (eds.), Arheološki muzej u Zagrebu, Filozofski fakultet Sveučilišta u Zagrebu, Arheološki muzej Osijek, Zagreb, 25–47. https://doi.org/10.17234/9789531758185-03

Čataj, L. 2018b, Kultura Retz-Gajary / The Retz-Gajary culture, in: *Povratak u prošlost. Bakreno doba u sjevernoj Hrvatskoj / Back to the past. Copper Age in northern Croatia*, Balen J., Miloglav I., Rajković D. (eds.), Arheološki muzej u Zagrebu, Filozofski fakultet Sveučilišta u Zagrebu, Arheološki muzej Osijek, Zagreb, 49–63. https://doi.org/10.17234/9789531758185-04

Čataj, L. 2020, *Geneza i razvoj lasinjske kulture na području središnje i gorske Hrvatske*, Unpublished PhD Thesis, University of Zagreb, Zagreb.

Černych, E. N. 1978, Aibunar – a Balkan copper mine of the fourth millennium BC (Investigations of the years 1971, 1972 and 1974), *Proceedings of the Prehistoric Society*, Vol. 44, 203–217. https://doi.org/10.1017/S0079497X00010136

Childe, V. G. 1944, Archaeological ages as technological stages, *The Journal of the Royal Anthropological Institute of Great Britain and Ireland*, Vol. 74(1–2), 7–24. https://doi.org/10.2307/2844291

Čović, B. 1976, Metalurška djelatnost vučedolske grupe u Bosni, *Godišnjak Centra za balkanološka ispitivanja*, Vol. XIII(11), 105–116.

Čović, B. 1984, Praistorijsko rudarstvo i metalurgija u Bosni i Hercegovini – Stanje i problemi istraživanja, *Godišnjak Centra za balkanološka ispitivanja*, Vol. XXII(20), 111–144.

Dani, J. 2013, The significance of metallurgy at the beginning of the third millennium BC in the Carpathian Basin, in: *Transition to the Bronze Age. Interregional Interaction and Socio-Cultural Change in the Third Millenium BC Carpathian Basin and Neighbouring Regions*, Heyd V., Kulcsár G., Szeverényi V. (eds.), Archaeolingua, Budapest, 203–231.

Dimitrijević, S. 1979a, Lasinjska kultura, in: *Praistorija Jugoslavenskih zemalja. III: Eneolitsko doba*, Benac A. (ed.), Akademija nauka i umjetnosti Bosne i Hercegovine, Centar za balkanološka ispitivanja, Sarajevo, 137–181.

Dimitrijević, S. 1979b, Badenska kultura, in: *Praistorija Jugoslavenskih zemalja. III: Eneolitsko doba*, Benac A. (ed.), Akademija nauka i umjetnosti Bosne i Hercegovine, Centar za balkanološka ispitivanja, Sarajevo, 183–234.

Dimitrijević, S. 1979c, Vučedolska kultura i vučedolski kulturni kompleks, in: *Praistorija Jugoslavenskih zemalja. III: Eneolitsko doba*, Benac A. (ed.), Akademija nauka i umjetnosti Bosne i Hercegovine, Centar za balkanološka ispitivanja, Sarajevo, 267–343.

Draksler, M. 2007, Območje Zagorja ob Savi v prazgodovini, *Arheološki vestnik*, Vol. 58, 121–155.

Durman, A. 1983, Metalurgija vučedolskog kompleksa, *Opvscvla archaeologica*, Vol. 8, 1–87.

Durman, A. 1984, Ostava kalupa vučedolskog ljevača bakra iz Vinkovaca, in: *Arheološka istraživanja u istočnoj Slavoniji i Baranji*, znanstveni skup, Vukovar 6 – 9. X. 1981, Majnarić-Pandžić N. (ed.), Izdanja Hrvatskog arheološkog društva 9, Hrvatsko arheološko društvo, Zagreb, 37–52.

Durman, A. 1988a, Metal u vučedolskom kulturnom kompleksu / Metal in the Vučedol Culture Complex, in: *Vučedol. Treće tisućljeće p. n. e. / Vučedol. Three thousand years B.C.*, Durman A. (ed.), katalog izložbe, Muzejsko-galerijski centar, Zagreb, 32–38.

Durman, A. 1988b, Vučedolska kultura / The Vučedol Culture, in: *Vučedol. Treće tisućljeće p. n. e. / Vučedol. Three thousand years B.C.*, Durman A. (ed.), katalog izložbe, Muzejsko-galerijski centar, Zagreb, 13–20.

Durman, A. 1991a, *Metal u prapovijesnom društvu jugoistočne Europe*, Unpublished PhD Thesis, University of Zagreb, Zagreb.

Durman, A. 1991b, Prilog za rekonstrukciju najranije povijesti, in: *Dvor na Uni. od prijeslavenskog doba do naših dana*, Joka M. (ed.), Skupština općine Dvor na Uni, Dvor na Uni, 89–94.

Durman, A. 1997, Tin in Southeastern Europe?, *Opvscvla archaeologica*, Vol. 21, 7–14.

Durman, A. 2000, Počeci metalurgije na brodskom području, in: *Zbornik radova sa znanstvenog skupa o Slavonskom Brodu. U povodu 750. obljetnice prvoga pisanog spomena imena Broda*, 13.–15. listopada 1994, Živaković-Kerže Z. (ed.), Bibliotheca Croatica-Slavonica, Sirmiensia et Baranxensia 2, Hrvatski institut za povijest, Podružnica za povijest Slavonije, Srijema i Baranje, Muzej brodskog Posavlja, Slavonski Brod, 91–102.

Durman, A. 2006, *Simbol boga i kralja. Prvi europski vladari / Symbol of God and King. The First European Rulers*, katalog izložbe, Galerija Klovićevi dvori, Zagreb.

Durman, A. 2009, Valja nama preko rijeke: misterij i simbolika smrti od mezolitika do brončanog doba, in: *Etnolog Vitomir Belaj. Zbornik radova povodom 70. rođendana Vitomira Belaja*, Petrović Leš T. (ed.), FF Press, Zagreb, 235–265.

Durman, A., Obelić, B. 1989, Radiocarbon Dating of the Vučedol Culture Complex, *Radiocarbon*, Vol. 31(3), 1003–1009. https://doi.org/10.1017/S0033822200012649

Durman, A., Hutinec, M., Roksandić, D. 2015, *Izvješće o rezultatima sustavnih arheoloških istraživanja nalazišta Vučedol-Kukuruzište Streim (V-12/2015)*, Muzej vučedolske kulture, Vukovar (neobjavljen izvještaj pohranjen u Konzervatorskom odjelu Ministarstva kulture Republike Hrvatske u Vukovaru, Vukovar).

Durman, A., Hutinec, M., Roksandić, D. 2016, Vučedol – Kukuruzište Streim, *Hrvatski arheološki godišnjak*, Vol. 12 (2015), 120–122.

Durman, A., Hutinec, M., Roksandić, D. 2017b, Vučedol – Kukuruzište Streim, *Hrvatski arheološki godišnjak*, Vol. 13 (2016), 105–107.

Durman, A., Hutinec, M., Roksandić, D. 2018, *Izvješće o rezultatima sustavnih arheoloških istraživanja nalazišta Vučedol-Kukuruzište Streim (V-17/2018)*, Muzej vučedolske kulture, Vukovar (neobjavljen izvještaj pohranjen u Konzervatorskom odjelu Ministarstva kulture Republike Hrvatske u Vukovaru, Vukovar).

Durman, A., Roksandić, D., Hutinec, M., Crnković, M. 2017a, *Izvješće o rezultatima sustavnih arheoloških istraživanja nalazišta Vučedol-Kukuruzište Streim (V-17/2017)*, Muzej vučedolske kulture, Vukovar (neobjavljen izvještaj pohranjen u Konzervatorskom odjelu Ministarstva kulture Republike Hrvatske u Vukovaru, Vukovar).

Đukić, A. 2018, Kostolačka kultura u kontinentalnoj Hrvatskoj / The Kostolac culture in continental Croatia, in: *Povratak u prošlost. Bakreno doba u sjevernoj Hrvatskoj / Back to the past. Copper Age in northern Croatia*, Balen J., Miloglav I., Rajković D. (eds.), Arheološki muzej u Zagrebu, Filozofski fakultet Sveučilišta u Zagrebu, Arheološki muzej Osijek, Zagreb, 87–111. https://doi.org/10.17234/9789531758185-06

Đurković, B., Vinokić, J., Vurdelja, R. 1963, Bakar, in: *Tehnička enciklopedija* sv. 1, Podhorski R. (ed.), Jugoslavenski leksikografski zavod, Zagreb, 651–665. https://tehnika.lzmk.hr/tehnicka-enciklopedija-1966-1997/

Ecsedy, I. 1983, Ásatások Zók-Várhegyen (1977–1982). Előzetes jelentés / Excavations at Zók-Várhegy (1977–1982). Preliminary report, *A Janus Pannonius Múzeum Évkönyve*, Vol. XXVII (1982), 59–105.

Ecsedy, I. 1990, On the Early Development of Prehistoric Metallurgy in Southern Transdanubia, *Godišnjak Centra za balkanološka ispitivanja*, Vol. XXII(20), 209–231.

Forenbaher, S. 1993, Radicarbon dates and absolute chronology of the central European Early Bronze Age, *Antiquity*, Vol. 67(255), 218–256. https://doi.org/10.1017/S0003598X00045336

Gabrovec, S. 1966, Zagorje v prazgodovini, *Arheološki vestnik*, Vol. 17, 19–39.

Gale, I. 2002, Vučedolsko naselje na Ervenici u Vinkovcima, *Vjesnik Arheološkog muzeja u Zagrebu*, 3.s. Vol. XXXV, 53–66.

Glogović, D. 2003, Ostava Tenja – Orlovnjak i ostali prapovijesni nalazi zlata u sjevernoj Hrvatskoj, *Opvscvla archaeologica*, Vol. 27, 97–101.

Glogović, D. 2004, O diskovima tipa Stollhof-Csaford iz Hrvatske, *Osječki zbornik*, Vol. 27, 9–13.

Govedarica, B. 2021, Monumentalni tumuli s područja Crne Gore i pitanje kontinuiteta kultnog mjesta (I dio – Primjer praistorijskih kneževskih grobova) / Monumental Tumuli from the Area of Montenegro and the Issue of the Continuity of the Cult Place (Part I – Example of Prehistoric Princely Tombs), *New Antique Doclea*, Vol. XII, 7–34.

Guštin, M. 2006, Prvi vladari između Egejskog i Jadranskog mora, in: *Simbol boga i kralja. Prvi europski vladari / Symbol of God and King. The First European Rulers*, katalog izložbe, Galerija Klovićevi dvori, Zagreb, 87–98.

Hansen, S. 2011, Metal in South-Eastern and Central Europe between 4500 and 2900 BCE, in: *Anatolian Metal V*, Yalçin Ü., Wirth C. (eds.), Der Anschnitt: Zeitscrift für Kunst und Kultur im Bergbau 24, Veröffentlichungen aus dem Deutschen Bergbau-Museum Bochum 180, Deutschen Bergbau-Museum Bochum, Bochum, 137–149.

Hansen, S. 2013, Innovative metals: copper, gold and silver in the Black Sea Region and the Carpathian Basin During the 5th and 4th Millennium BC, in: *Metal Matters. Innovative Technologies and Social Change in Prehistory and Antiquity*, Burmeister S., Hansen S., Kunst M., Müller-Scheeßel N. (eds.), Verlag Marie Leidorf GmbH, Rahden/Westfalen, 137–170.

Hansen, S. 2014, Goldene Scheiben aus der Kupferzeit, *Das Altertum*, Vol. 59, 81–108.

Hansen, S. 2021, Axes and Metal Deposits in the Caucasus from the 5th to the 2nd Millennium BCE, in: *The Caucasus. Bridge between the urban centres in Mesopotamia and the Pontic steppes in the 4th and 3rd millennium BC. The transfer of knowledge and technologies between East and West in the Bronze Age*, Proceedings of the Caucasus conference, Frankfurt am Main, November 28 – December 1, 2018, Giemsch L., Hansen S. (eds.), Schriften des Archäologischen Museums Frankfurt 34, Verlag Schnell & Steiner GmbH, Regensburg, 31–85. https://doi.org/10.11588/propylaeumdok.00005306

Heyd, V., Walker, K. 2014, The First Metalwork and Expressions of Social Power, in: *The Oxford Handbook of Neolithic Europe*, Flower C., Harding J., Hofmann D. (eds.), Oxford University Press, Oxford, 672–691. https://doi.org/10.1093/oxfordhb/9780199545841.013.035

Hornok, P., Kiss, P. 2017, A Balaton-Lasinja-kultúra települése és kincslelete Magyaregresen, *Archaeologiai Értesítö*, Vol. 142(1), 239–253.

Horvatinčić, N., Obelić, B., Srdoč, D., Durman, A., Benkö, L., Sliepčević, A. 1990, Radiocarbon and TL Dating of the Eneolithic Site Vučedol in East Croatia, Yugoslavia, in: *Proceedings of the Second International Symposium, ^{14}C and Archaeology*, Groningen 1987, Mook W. G, Waterbolk H. T (eds.), PACT: journal of the European study group on physical, chemical, biological and mathematical techniques applied to archaeology 29, Council of Europe, Strasbourg – Rixensart, 243–250.

Hoti, M. 1994, Vučedol – Streimov vinograd: magijski ritual i dvojni grob vučedolske kulture, *Opvscvla archaeologica*, Vol. 17, 183–203.

Hutinec, M., Roksandić, D. 2019, *Izvješće o rezultatima sustavnih arheoloških istraživanja nalazišta Vučedol-Kukuruzište Streim (V-17/2019, V-12/2019)*, Muzej vučedolske kulture, Vukovar (neobjavljen izvještaj pohranjen u Konzervatorskom odjelu Ministarstva kulture Republike Hrvatske u Vukovaru, Vukovar).

Hutinec, M., Roksandić, D. 2020, *Izvješće o rezultatima sustavnih arheoloških istraživanja nalazišta Vučedol-Kukuruzište Streim (V-17/2020, V-12/2020)*, Muzej vučedolske kulture, Vukovar (neobjavljen izvještaj pohranjen u Konzervatorskom odjelu Ministarstva kulture Republike Hrvatske u Vukovaru, Vukovar).

Hutinec, M., Roksandić Vukadin, D. 2021a, *Izvješće o rezultatima sustavnih arheoloških istraživanja nalazišta Vučedol-Kukuruzište Streim (V-17/2021, V-12/2021)*, Muzej vučedolske kulture, Vukovar (neobjavljen izvještaj pohranjen u Konzervatorskom odjelu Ministarstva kulture Republike Hrvatske u Vukovaru, Vukovar).

Hutinec, M., Roksandić Vukadin, D. 2021b, Uvod / Intorduction, in: *Vučedol, zapisano na kućnom broju 12 / Vučedol. Written on the house number 12*, Hutinec M., Roksandić Vukadin D., Šuljug M. (eds.), katalog izložbe, Muzej vučedolske kulture, Vukovar, 4–9.

Hutinec, M., Roksandić Vukadin, D. 2022, Izvješće o rezultatima sustavnih arheoloških istraživanja nalazišta Vučedol – Kukuruzište Streim (V-17/2022), Muzej vučedolske kulture, Vukovar (neobjavljen izvještaj pohranjen u Konzervatorskom odjelu Ministarstva kulture Republike Hrvatske u Vukovaru, Vukovar).

Jovanović, B. 1971, *Metalurgija eneolitskog perioda Jugoslavije*, Posebna izdanja 9, Arheološki institut, Beograd.

Jovanović, B. 1979, Rudarstvo i metalurgija eneolitskog perioda Jugoslavije, in: *Praistorija Jugoslavenskih zemalja. III: Eneolitsko doba*, Benac A. (ed.), Akademija nauka i umjetnosti Bosne i Hercegovine, Centar za balkanološka ispitivanja, Sarajevo, 27–85.

Jovanović, B. 1980, The Origins of Copper Mining in Europe, *Scientific American*, Vol. 242(5), 152–167. https://doi.org/10.1038/scientificamerican0580-152

Jovanović, B. 2002, Metalurgija bakra eneolitskog perioda na Centralnom i Zapadnom Balkanu, *Godišnjak Centra za balkanološka ispitivanja*, Vol. XXXII(30), 133–140.

Jovanović, B. 2009, Beginning of the metal age in the central Balkans according to the results of the archeometallurgy, *Journal of Mining and Metallurgy B: Metallurgy*, Vol. 45(2), 143–148. https://doi.org/10.2298/JMMB0902143J

Jovanović, B., Ottaway, B. S. 1976, Copper mining and metallurgy in the Vinča group, *Antiquity*, Vol. 50(198), 104–113. https://doi.org/10.1017/S0003598X00070848

Kalafatić, H. 2009, Zaštitna istraživanja lokaliteta Čepinski Martinci-Dubrava na trasi autoceste Beli Manastir-Osijek-Svilaj 2007. i 2008. g., *Annales Instituti Archaeologici*, Vol. V, 20–25.

Kalafatić, H., Hulina, M. 2016, Zaštitno arheološko istraživanje lokaliteta AN7B Čeminac-Vakanjac na dionici autoceste A5 Beli Manastir – Osijek 2014. i 2015. godine, *Annales Instituti Archaeologici*, Vol. XII, 29–35.

Kalicz, N. 1982, A Balaton-Lasinja kultúra történeti kérdései és fémleletei, *Archaeologiai Értesitő*, Vol. 109, 3–17.

Kalicz, N. 1992, A legkorábbi fémleletek Délkelet-Európában és a Kárpát-medencében az ie 6–5. évezredben, *Archaeologiai Értesitő*, Vol. 119, 3–14.

Karavanić, S. 2005, Late Bronze Age metallurgical activity in north Croatia, in: *L'âge du bronze en Europe et en Méditerranée / The Bronze Age in Europe and the Mediterranean*, Acts of the XIVth UISPP Congress, Universaity of Liege, Belgium, 2–8 September 2001, British Archaeological Report International series 1337, Archaeopress Publishing Ltd, Oxford, 63–67.

Karavanić, S. 2006, Prerada i proizvodnja metala u naselju Mačkovac-Crišnjevi (Nova Gradiška) / Metallverarbeitung und -produktion in der Siedlung Mačkovac-Crišnjevi (Nova Gradiška), *Prilozi Instituta za arheologiju u Zagrebu*, Vol. 23, 29–52.

Killick, D., Fenn, T. 2012, Archaeometallurgy: The Study of Preindustrial Mining and Metallurgy, *Annual Review of Anthropology*, Vol. 41, 559–575. https://doi.org/10.1146/annurev-anthro-092611-145719

Klassen, L. 2010, Karpaten oder Alpen? Zur Herkunft der Kupferscheibe aus Hornstaad (Lkr. Konstanz), *Archäologisches Korrespondenzblatt*, Vol. 40(1), 29–48.

Korošec, P., Korošec, J. 1969, *Najdbe s koliščarskih naselbin pri Igu na Ljubljanskem barju | Fundgut der Pfahlbausiedlungen bei Ig am Laibacher Moor,* Arheološki katalogi Slovenije III, Narodni muzej, Ljubljana.

Košćec, B., Marijanović, P., Marušić, R., Rizen, V. 1988, Rudarstvo, istražni radovi, in: *Tehnička enciklopedija* sv. 11, Požar H. (ed.), Jugoslavenski leksikografski zavod, Zagreb, 593–607. https://tehnika.lzmk.hr/tehnicka-enciklopedija-1966-1997/

Krauss, R., Pernicka, E., Kunze, R., Dimitrov, K., Leshtakov, P. (eds.) 2020, *Prehistoric Mining and Metallurgy at the Southeast Bulgarian Black Sea Coast*, Ressourcen Kulturen12, Bartelheim M., Scholten T. (eds.), Tübingen University Press, Tübingen. Kuna, M. 1981, Zur Neolithischen und Äneolithischen Kupferverarbeitung im Gebiet Jugoslawiens, *Godišnjak Centra za balkanološka ispitivanja*, Vol. XIX(17), 13–82.

Kunze, R., Abele, J., Leshtakov, P., Dimitrov, K., Krauß, R., Rödel, T. 2018, Archaeometallurgical prospections in the highlands of *Medni Rid*, southeastern Bulgaria: Preliminary report on fieldwork 2013–2015 with a focus upon remote sensing methods by means of LiDAR, *Journal of Archaeological Science: Reports*, Vol. 19, 596–617. https://doi.org/10.1016/j.jasrep.2018.03.021

Kuzmanović, M. 2010, *AN 7: Medvođe – Glogovica, Izvješće o zaštitnom arheološkom istraživanju na trasi Magistralnog plinovoda Slobodnica – Donji Miholjac*, Geoarheo d.o.o., Zagreb (neobjavljen izvještaj pohranjen u Konzervatorskom odjelu Ministarstva kulture Republike Hrvatske u Slavonskom Brodu, Slavonski Brod).

Kuzmanović, M. 2011, Glogovica – Medvođe (AN 7), *Hrvatski arheološki godišnjak*, Vol. 7 (2010), 108–111.

Lazić, L., Durman, A., Lazić, S. 2010, Povijesni pregled rudarstva i metalurgije na području Zrinske i Trgovske gore, in: *Zrinska gora. Regionalni park prirode*, Bučar M. (ed.), Grad Petrinja, Sisačko-moslavačka županija, Učiteljski fakultet Sveučilišta u Zagrebu – Odsjek u Petrinji, Matica hrvatska – Ogranak Petrinja, Zagreb 56–71.

Ložnjak Dizdar, D., Dizdar, M. 2015, Sotin i Opatovac, probna arheološka istraživanja višeslojnih nalazišta 2014. godine, *Annales Instituti Archaeologici*, Vol. XI, 9–13.

Lozuk, J. 1995, A problem of the Baden group metallurgy at the site of Saloš-Donja Vrba near Slavonski Brod, in: *Ancient Mining and Metallurgy in Southeast Europe*, International Symposium, Donji Milanovac, May 20–25 1990, Jovanović B. (ed.), Posebna izdanja 27, Archaeological Institute, Museum of Mining and Metallurgy, Beograd – Bor, 55–59.

Lozuk, J. 2004, Raster naselja badenske kulture – lokalitet Saloš kod sela Donja Vrba, *Vijesti Muzeja Brodskog Posavlja*, Vol. 9, 24–27.

Lozuk, J. 2006, Saloš kraj Donje Vrbe, in: *Stotinu hrvatskih arheoloških nalazišta*, Durman A. (ed.), Leksikografski zavod Miroslav Krleža, Zagreb, 228–229.

Ludajić, N. 2005, Metalurška radionica sa Velike gradine u Varvari, *Glasnik Zemaljskog muzeja Bosne i Hercegovine u Sarajevu: Arheologija*, Vol. 46 (1991), 59–77.

Macan, J. 2015, Imenje i nazivlje u kemiji i kemijskom inženjerstvu. U rudniku riječi, *Kemija u industriji: Časopis kemičara i kemijskih inženjera Hrvatske*, Vol. 64(5–6), 292–293.

Madiraca, V. 2012, Brekinjova kosa – kamenolom Bojna, *Hrvatski arheološki godišnjak*, Vol. 8 (2011), 297–298.

Majnarić-Pandžić, N. 1994, Sjaj bronce i željeza u praskozorju povijesti, in: *Vukovar. Vjekovni hrvatski grad na Dunavu*, Feletar D., Horvat V., Jurčević J., Karač Z., Karaman I., Majnarić-Pandžić N., Marić R., Potrebica F., Tomičić Ž., Wertheimer-Baletić A. (eds.), Nakladnička kuća dr. Feletar, Koprivnica, 65–80.

Makkay, J. 1985, Copper Age Gold Discs on the Territory of the later Pannonia Province, *Communicationes Archaeologicae Hungariae*, Vol. 1985, 5–25.

Marijanović, B. 2003, *Eneolitik i eneolitičke kulture u Bosni i Hercegovini*, Odsjek za arheologiju i povijest umjetnosti Pedagoškog fakulteta Sveučilišta u Mostaru, Mostar.

Marković, Z. 1985, Problem ranog eneolita u sjeverozapadnoj Hrvatskoj, *Vjesnik Arheološkog muzeja u Zagrebu*, 3.s. Vol. XVIII, 1–34.

Marković, Z. 1994, *Sjeverna Hrvatska od neolita do brončanog doba. Problem kontinuiteta stanovništva i kultura sjeverne Hrvatske od ranog neolita do početka brončanog doba*, Muzej grada Koprivnice, Koprivnica.

Marković, Z. 2012, Novija razmatranja o nekim aspektima sopotske kulture u sjevernoj Hrvatskoj, *Prilozi Instituta za arheologiju u Zagrebu*, Vol. 29, 57–69.

Marušić, R. 1988, Rudarstvo, in: *Tehnička enciklopedija* sv. 11, Požar H. (ed.), Jugoslavenski leksikografski zavod, Zagreb, 588–593. https://tehnika.lzmk.hr/tehnicka-enciklopedija-1966-1997/

Mihaljević, M., Podunavac, D., Matković Vrban, M. 2018, *Zaštitna arheološka istraživanja Ruščica – Glogove – Praulje*, katalog izložbe, Gradski muzej Nova Gradiška, Nova Gradiška.

Miklik-Lozuk, L. 2011, Regionalni vodovod, dionica Bicko Selo – Slavonski Brod, *Hrvatski arheološki godišnjak*, Vol. 7 (2010), 121–123.

Milić, Z., Velušček, A. 2009, Analize površja talilnih posod s Starih gmajn na Ljubljanskem barju / Analyses of surface of crucibles from Stare gmajne at the Ljubljansko barje, in: *Koliščarska naselbina Stare gmajne in njen čas. Ljubljansko barje v 2. polovici 4. tisočletja pr. Kr. / Stare gmajne pile-dwelling settlement and its era. The Ljubljansko barje in the 2nd half of the 4th millennium BC*, Velušček A. (ed.), Opera Instituti archaeologici Sloveniae 16, Inštitut za arheologijo, Založba ZRC, Ljubljana, 245–249. https://doi.org/10.3986/9789612545611

Miloglav, I. 2018, Vučedolska kultura / The Vučedol Culture, in: *Povratak u prošlost. Bakreno doba u sjevernoj Hrvatskoj / Back to the past. Copper Age in northern Croatia*, Balen J., Miloglav I., Rajković D. (eds.), Arheološki muzej u Zagrebu, Filozofski fakultet Sveučilišta u Zagrebu, Arheološki muzej Osijek, Zagreb, 113–145. https://doi.org/10.17234/9789531758185-07

Nikolić, D. 2000, *Kostolačka kultura na teritoriji Srbije*, Centar za arheološka istraživanja 19, Filozofski fakultet Univerziteta u Beogradu, Beograd.

O'Brien, W. 2013, Bronze Age copper mining in Europe, in: *The Oxford handbook of the European Bronze Age*, Harding A, Fokkens H. (eds), Oxford University Press, Oxford, 438–453. https://doi.org/10.1093/oxfordhb/9780199572861.013.0024

O'Brien, W. 2014, *Prehistoric Copper Mining in Europe. 5500 – 500 BC*, Oxford University Press, Oxford, New York. https://doi.org/10.1093/oso/9780199605651.001.0001

Ottaway, B. S. 2001, Innovation, production and specialization in early prehistoric copper metallurgy, *European Journal of Archaeology*, Vol. 4(1), 87–112. https://doi.org/10.1179/eja.2001.4.1.87

Ottaway, B. S., Roberts, B. 2008, The emergence of metalworking, in: *Prehistoric Europe. theory and practice*, Jones A. (ed.), Wiley Blackwell Studies in Global Archaeology 12, Wiley Blackwell, Chichester, 193–225.

Paulin, A. 1982, Metalurgija, in: *Tehnička enciklopedija* sv. 8, Požar H. (ed.), Jugoslavenski leksikografski zavod, Zagreb, 433–452. https://tehnika.lzmk.hr/tehnicka-enciklopedija-1966-1997/

Pernicka, E. 2014, The development of metallurgy in western Anatolia, the Aegean and southeastern Europe before Troy, in: *Western Anatolia before Troy. Proto-Urbanisation in the 4th Millennium BC?*, Proceedings of the International Symposium held at the Kunsthistorisces Museum, Wien 21–24 November 2012, Horejs B., Mehofer M. (eds.), Austrian Academy of Sciences Press, Wien, 447–461. https://doi.org/10.11588/propylaeumdok.00004660

Pernicka, E., Anthony, D. W. 2010, The invention of copper metallurgy and the Copper Age of old Europe, in: *The Lost World of Old Europe. The Danube Valley, 5000–3500 BC*, Anthony D. W. (ed.), The Institute for the Study of the Ancient World, Princeton University Press, New York – Princeton, 162–177.

Petrović, K., Belić, B. 1971, Praistorijske kulture na području brodskog posavlja, in: *Periodizacija starijeg gvozdenog doba u Jugoslaviji*, Simpozium praistorijske sekcije Arheološkog društva Jugoslavije, Slavonski Brod, 23-25 novembra 1970, Todorović J. (ed.), Materijali VII, Arheološko društvo Jugoslavije, Muzej Brodskog Posavlja, Beograd, 9–20.

Prokeš, L., Jarůšková, Z., Petřík, J., Frączek, M., Kalicki, T. 2020, Origin of a silver Stollhof-type disc excavated at Vanovice (South Moravia), *Praehistorische Zeitschrift*, Vol. 95(1), 112–127. https://doi.org/10.1515/pz-2020-0007

Pravidur, A. 2014, *Metal u životu prapovijesnih zajednica na tlu Bosne i Hercegovine*, Unpublished PhD Thesis, University of Zagreb, Zagreb.

Primas, M. 1996, *Velika Gruda I. Hügelgräber des frühen 3. Jahrtausends v. Chr. im Adriagebiet – Velika Gruda, Mala Gruda und ihr Kontext*, Universitätsforschungen zur Prähistorische Archäologie 32, Dr. Rudolf Habelt BmbH, Bonn.Raczky, P. 1995, New data on the absolute chronology of the Copper Age in the Carpathian Basin, in: *Neuere Daten zur Siedlungsgeschichte und Chronologie der Kupferzeit des Karpatenbeckens*, Kovács T. (ed.), Inventaria Praehistorica Hungariae 7, Magyar Nemzeti Múzeum, Budapest, 51–60.

Raczky, P. 1999, Goldfunde aus der Kupferzeit. Die Anfänge der Metallurgie im Karpatenbecken, in: *Prähistoriche Goldschätze aus dem Ungarischen Nationalmuseum*, Kovács T., Raczky P. (eds.), Ungarischen Nationalmuseum, Institut für Archäologie der Eötvös-Loránd-Universität, Budapest, 17–37.

Radivojević, M., Rehren, T., Pernicka, E., Šljivar, D., Brauns, M., Borić, D. 2010, On the origins of extractive metallurgy: new evidence from Europe, *Journal of Archaeological Science*, Vol. 37(11), 2775–2787. https://doi.org/10.1016/j.jas.2010.06.012

Radivojević, M., Roberts, B. W., Marić, M., Kuzmanović-Cvetković, J., Rehren, T. (eds.) 2021, *The Rise of Metallurgy in Eurasia. Evolution, Organisation and Consumption of Early Metal in the Balkans*, Archaeopress Publishing Ltd, Oxford. http://doi.org/10.32028/9781803270425

Radivojević, M., Kuzmanović-Cvetković, J. 2014, Copper minerals and archaeometallurgical materials from the Vinča culture sites of Belovode and Pločnik: overview of the evidence and new data, *Starinar*, Vol. LXIV, 7–30. https://doi.org/10.2298/STA1464007R

Radivojević, M., Rehren, T. 2016, Paint it black: the rise of metallurgy in the Balkans, *Journal of Archaeological Method and Theory,* Vol. 23(1), 200–237. https://doi.org/10.1007/s10816-014-9238-3

Rajković, D., Balen, J. 2016, *Sarvaš. Neolitičko i eneolitičko naselje II / Sarvaš. Neolithic and Eneolithic settlement II*, Arheološki muzej u Zagrebu, Arheološki muzej Osijek, Zagreb – Osijek.

Renfrew, C. 1970, The autonomy of the south-east European Copper Age, *Proceedings of the Prehistoric Society*, N.S. Vol. XXXV (1969), 12–47. https://doi.org/10.1017/S0079497X00013396

Renfrew, C., Bahn, P. G. (eds.) 2005, *Archaeology. The key concepts*, 1st Edition, Routledge, London – New York.

Roksandić Vukadin, D. 2021, Novi elementi u graditeljstvu s položaja Kukuruzište Streim / New elements in building technology from the position of Streim Cornfield, in: *Vučedol. Zapisano na kućnom broju 12 / Vučedol. Written on the house number 12*, Hutinec M., Roksandić Vukadin D., Šuljug M. (eds.), katalog izložbe, Muzej vučedolske kulture, Vukovar, 12–17.

Roksandić Vukadin, D. 2022, Posljednjih deset godina na Vučedolu: preliminarni rezultati istraživanja s lokaliteta Kukuruzište Streim (2012.-2022.) / The last ten years on Vučedol: preliminary research results from Cornfield Streim (2012-2022), in: *Vučedol/kultura: ishodište i nasljeđe / Vučedol/culture: origin and heritage*, 1st International Scientific and Expert Conference on Vučedol Culture, Vukovar, 8th and 9th of December 2022, Roksandić Vukadin D., Hutinec M. (eds), book of abstracts, Vučedol Culture Museum, Vukovar Municipal Museum, Vukovar, 31–32.

Sava, V. 2015, *Neolithic and Eneolithic in the Lower Mureş Basin*, Mega Publishing House, Cluj-Napoca.

Schmidt, R. R. 1945, *Die Burg Vučedol*, Arheološki muzej u Zagrebu, Zagreb.

Szeverényi, V. 2013, The earliest copper shaft-hole axes in the Carpathian basin: interaction, chronology and transformations of meaning, in: *Moments in Time. Papers Presented to Pál Raczky on His 60th Birthday*, Anders A., Kulcsár G., Kalla G., Kiss V., Szabó G. (eds.), Őrségészeti Tanulmányok I / Prehistoric Studies I, Őrségészeti Társaság, Eötvös Loránd University, L'Harmattan Kiadó, Budapest, 661–669.

Siklósi, Z., Szilágyi, M. 2019, New data on the provenance of copper finds from the Early-Middle Copper Age of the Great Hungarian Plain, *Archaeological and Anthropological Sciences,* Vol. 11(10), 5275–5285. https://doi.org/10.1007/s12520-019-00867-8

Siklósi, Z., Virág, Z. M., Mozgai, V., Bajnóczi, B. 2018, The spread of the products and technology of metallurgy in the Carpathian Basin between 5000 and 3000 BC – Current questions, *Dissertationes Archaeologicae*, 3.s. Vol. 5, 67–82. https://doi.org/10.17204/dissarch.2017.67

Siklósi, Z., Horváth, E., Villa, I. M., Nisi, S., Mozgai, V., Bajnóczi, B., Csippán, P., Hornok, P., Kiss, P. 2022, The provenance of the raw material and the manufacturing technology of copper artefacts from the Copper Age hoard from Magyaregres, Hungary, *PLoS ONE*, Vol. 17(11): e0278116. https://doi.org/10.1371/journal.pone.0278116

Strahm, C., Hauptmann, A. 2009, The metallurgical developmental phases in the Old World, in: *Metals and Societies. Studies in honour of Barbara S. Ottaway*, Kienlin T. L., Roberts B. W. (eds.), Universitätsforschungen zur prähistorischen Archäologie 169, Verlag Dr. Rudolf Habelt GmbH, Bonn, 116–128.

Šimić, J. 2004, Kneževi Vinogradi – Osnovna škola. Zaštitno istraživanje neolitičkog lokaliteta, *Obavijesti hrvatskog arheološkog društva*, Vol. XXXVI(2), 74–79.

Šinkovec, B. 1988, Rudna ležišta (rudišta), in: *Tehnička enciklopedija* sv. 11, Požar H. (ed.), Jugoslavenski leksikografski zavod, Zagreb, 696–705. https://tehnika.lzmk.hr/tehnicka-enciklopedija-1966-1997/

Šinkovec, I. 1996, Posamezne kovinske najdbe bakrene in bronaste dobe, in: *Depojske in posamezne kovinske najdbe bakrene in bronaste dobe na Slovenskem II*, Teržan B. (ed.), Katalogi in monografije 30, Narodni muzej, Ljubljana, 125–163.

Tasić, N. 1959, Praistorijsko naselje kod Dobanovaca i prilog proučavanju badenske grupe u Vojvodini, *Starinar*, n. s. Vol. IX–X, 227–240.

Tasić, N. 1979, Kostolačka kultura. in: *Praistorija Jugoslavenskih zemalja. III: Eneolitsko doba*, Benac A. (ed.), Akademija nauka i umjetnosti Bosne i Hercegovine, Centar za balkanološka ispitivanja, Sarajevo, 235–266.

Težak-Gregl, T. 1985, Dva nova groba badenske kulture s Vučedola, *Opvscvla archaeologica*, Vol. 10, 23–39.

Težak-Gregl, T. 1987, Prilog poznavanju metalne produkcije badenske kulture, *Opvscvla archaeologica*, Vol. 11–12, 73–81.

Težak-Gregl, T. 2017, *Hrvatske zemlje od starijega kamenog do bakrenog doba*, Leykam international, Zagreb.

Trampuž Orel, N., Heath, D. J. 2008, Copper finds from the Ljubljansko barje (Ljubljana Moor) – A contribution to the study of prehistoric metallurgy, *Arheološki vestnik*, Vol. 59, 17–29.

Tresić Pavičić, D. 2014, Osijek – Frigis 1 (AN 2), *Hrvatski arheološki godišnjak*, Vol. 10 (2013), 23–25.

Trigger, B. G. 2006, *A History of Archaeological Thought*, 2nd edition, Cambridge University Press, Cambridge. https://doi.org/10.1017/CBO9780511813016

Velušček, A. 1999, Neolithic and Eneolithic investigations in Slovenia, *Arheološki vestnik*, Vol. 50, 59–79.

Velušček, A. 2004a, Hočevarica in začetki uporabe bakra v Sloveniji / Hočevarica and the onset of copper use in Slovenia, in: *Hočevarica. Eneolitsko kolišče na Ljubljanskem barju / An eneolithic pile dwelling in the Ljubljansko barje*, Velušček A. (ed.), Zbirka Opera Instituti archaeologici Sloveniae 8, Inštitut za arheologijo, Založba ZRC, Ljubljana, 297–306. https://doi.org/10.3986/9789612545055

Velušček, A. 2004b, Hočevarica: terenske raziskave, predstavitev najdb in naravoslovne analize / Hočevarica: Field research, a presentation of the material finds and the scientific analyses, in: *Hočevarica. Eneolitsko kolišče na Ljubljanskem barju / An eneolithic pile dwelling in the Ljubljansko barje*, Velušček A. (ed.), Zbirka Opera Instituti archaeologici Sloveniae 8, Inštitut za arheologijo, Založba ZRC, Ljubljana, 33–55. https://doi.org/10.3986/9789612545055

Velušček, A. 2004c, Past and present lake-dwelling studies in Slovenia Ljubljansko barje (the Ljubljana Marsh), in: *Living on the lake in prehistoric Europe. 150 years of lake-dwelling research*, Menotti F. (ed.), Routledge, London – New York, 69–97. https://doi.org/10.4324/9780203583203

Velušček, A. 2008, Doneski k raziskovanju metalurške dejavnosti na Ljubljanskem barju / Contributions to research on metalworking in Ljubljansko barje, *Prilozi Instituta za arheologiju u Zagrebu*, Vol. 25, 33–46.

Velušček, A. 2009, Koliščarska naselbina Stare gmajne in njen čas / Stare gmajne pile-dwelling settlement and its era, in: *Koliščarska naselbina Stare gmajne in njen čas. Ljubljansko barje v 2. polovici 4. tisočletja pr. Kr. / Stare gmajne pile-dwelling settlement and its era. The Ljubljansko barje in the 2nd half of the 4th millennium BC*, Velušček A. (ed.), Opera Instituti archaeologici Sloveniae 16, Inštitut za arheologijo, Založba ZRC, Ljubljana, 11–48. https://doi.org/10.3986/9789612545611

Velušček, A., Čufar, K. 2003, Založnica pri Kamniku pod Krimom na Ljubljanskem barju – naselbina kulture Somogyvár-Vinkovci, *Arheološki vestnik*, Vol. 54, 123–158.

Vinski, Z. 1959, O prethistorijskim zlatnim nalazima iz Jugoslavije, *Arheološki radovi i rasprave*, Vol. 1, 207–236.

Vinski, Z. 1961, O oružju ranoga brončanog doba u Jugoslaviji, *Vjesnik Arheološkog muzeja u Zagrebu*, 3.s. Vol. II, 1–37.

Virág, Z. M. 2019, Data on the Copper Age metallurgy of Transdanubia, in: *„Trans Lacum Pelsonem". Prähistorische Forschungen in Südwestungarn (5500 – 500 v. Chr.) / Prehistoric Research in South-Western Hungary (5500 – 500 BC)*, Bánffy E., Barna J. P. (eds.), Castellum Pannonicum Pelsonense 7., Verlag Marie Leidorf GmbH, Rahden/Westfalen, 187–216.

Vrdoljak, S. 2021, Uljevne kape (Gusszäpfen) i značaj ostave Brodski Varoš (Slavonski Brod) / Casting jets (Gusszäpfen) and the importance of the Brodski Varoš hoard (Slavonski Brod), *Annales Instituti Archaeologici*, Vol. XVII, 193–203.

Vulpe, A. 1970, *Die Äxte und Beile in Rumänien I*, Prähistorische Bronzefunde IX(2), C. H. Beck, München.

Žeravica, Z. 1993, *Äxte und Beile aus Dalmatien und anderen Teilen Kroatiens, Montenegro, Bosnien und Herzegovina*, Prähistorische Bronzefunde IX(18), Franz Steiner Verlag, Stuttgart.