# Eneolitski rudnici bakra na Balkanu

## Eneolithic copper mines in the Balkans

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Balkan je tokom neolita bila gusto naseljena teritorija, možda upravo zbog velikog bogatstva u sirovinama. Cela ova oblast obiluje vodom zbog razgranate hidrološke mreže, plodnim zemljištem za zemljoradnju, šumama sa kvalitetnim drvetom, a naročito rudnim bogatstvom i ležištima kvalitetnog kamena. Verovatno da su prvi balkanski metalurzi odlično poznavali geološko bogatstvo svoje teritorije i da su znali gde treba tražiti rudu bakra za proizvodnju metala. Nema sumnje da je eksploatacija minerala i stena korišćenih u proizvodnji kamenog oruđa često vršena u neposrednoj blizini ležišta bakarne rude što je predstavljalo dobru osnovu za nastanak prve metalurgije. Da je malahit već bio poznat kao sirovina svedoče nalazi ovog minerala na više ranoneolitskih nalazišta u jugoistočnoj Evropi (Antonović 2014: 18). Zapravo, malahit i azurit su bili dobro poznati već u mezolitu Balkana kao kamen za izradu ukrasnih predmeta. Perle i privesci, kao i amorfni grumenovi od malahita i azurita otkriveni su u mezolitskom Vlascu i u ranoneolitskim slojevima Lepenskog Vira (Borić 2012: 94).

During the Neolithic, the Balkans were a densely populated territory, perhaps precisely due to their abundance of raw materials. The entire region is rich in water due to a branched-out hydrological network, has fertile agricultural land, forests with high-quality wood, and is especially rich in ore and high-quality stone deposits. The first Balkan metallurgists were probably well-acquainted with the geological richness of their territory and knew where to look for copper ore used in metal production. Undoubtedly, the exploitation of minerals and rocks used in stone tool production was often conducted in the immediate vicinity of copper ore deposits, which was an excellent basis for the creation of true metallurgy. Malachite was already a known raw material, as attested to by finds of this mineral on many Early Neolithic sites in southeastern Europe (Antonović 2014: 18). In fact, malachite and azurite were already well-known during the Mesolithic of the Balkans, and were used to produce decorative objects. Beads and pendants, as well as amorphous chunks of malachite and azurite, were discovered at the Mesolithic site of Vlasac, and in the Early Neolithic layers of Lepenski Vir (Borić 2012: 94).

Istraživanja početaka metalurgije na Balkanu rađena poslednjih godina pokazala su da je prva metalurgija u Evropi nastala upravo na Balkanu (Radivojević et al. 2010: 2779). Još uvek je veliko pitanje odakle je donošena ruda za topljenje, mada neki bakarni predmeti iz doba nastarije metalurgije daju nagoveštaje o mogućim izvorištima rude (Gale et al. 2003; Pernicka et al. 1993; Pernicka et al. 1997; Radivojević et al. 2010: 2781, 2784 Fig. 10). Ono što je poznato je to da su najstariji rudnici bakra na Balkanu istovremeni sa najstarijim predmetima od bakra, koji svedoče o već razvijenoj tehnici rudne eksploatacije. Takođe je pitanje dokle u prošlost sežu počeci rudarenja na ovoj teritoriji, ali može se pretpostaviti da je visok nivo tehnološkog znanja u okviru neolitskih kultura na tlu Balkana sasvim sigurno imao presudnu ulogu u nastanku metalurgije i sa njom tesno povezanim rudarstvom. Međutim, praistorijski kamenolomi i rudnici nemetala do sada nisu otkriveni na Balkanu pa je sasvim moguće da ovakav način pribavljanja kvalitetne sirovine za kameno oruđe nije ni postojao na Balkanu.

Research on the beginnings of metallurgy in the Balkans, conducted over the recent years, has shown that the first metallurgy in Europe appeared precisely in the Balkans (Radivojević et al. 2010: 2779). The big question remains of where the ore for melting was obtained, even though some copper finds from the period of the earliest metallurgy give hints on the possible origins of the ore (Gale et al. 2003; Pernicka et al. 1993; Pernicka et al. 1997; Radivojević et al. 2010: 2781, 2784 Fig. 10). It is well-known that the oldest copper mines in the Balkans were contemporaneous with the oldest copper finds, which indicate the existence of developed mining techniques. It is also a question of how far into the past do the beginnings of mining in this territory go, and whether it can be assumed that the high level of technological knowledge, within the frame of Neolithic cultures in the Balkans, played a crucial part in the appearance of metallurgy and mining. However, prehistoric quarries and nonmetal mines have not yet been discovered in the Balkans, so it is very likely that this type of raw material procurement for stone tool production did not exist in the Balkans.

## Ležišta bakarne rude na Balkanu

Istočni i centralni Balkan su posebno bogati ležištima bakarne rude (Sl. 1), pa zato i ne čudi rana pojava metalurgije upravo na tim prostorima. Na teritoriji Balkana se nalazi osam metalogenetskih zona sa više polja bakarnog orudnjenja u svakoj od njih (Bogdanov 1982; Gale et al. 2003: 123, Fig. 10.1, 153–154; Janković 1967). Na istočnom Balkanu to su: 1. Rodopska zona u južnoj Bugarskoj sa rudnim oblastima Osogovo-Ozgraden, Zapadni Rodopi i Istočni Rodopi; 2. Srednjogoska zona u srednjoj Bugarskoj sa rudnim oblastima Sofija, Panađurski, Jambol, Burgas i Strandža; 3. Kraištidna zona u zapadnoj Bugarskoj (ova oblast je značajna po ležištima zlata); 4. Balkanska zona sa ležištima Čiprovci, Sedmočislenici, Granipa, Luprene i Salah-Krasimir; 5. Mezijska zona u kojoj je značajna rudna oblast Varna. Sve ove zone nastavljaju se ka centralnom i zapadnom Balkanu gde postoje tri osnovne metalogenetske zone: 1. Karpato-balkanska u istočnoj Srbiji koja se na istoku nastavlja na Srednjogorsku i Balkansku zonu (ovoj zoni pripada i rudnik vinčanske kulture Rudna Glava); 2. Srpsko-Makedonska koja se proteže od centralnog Balkana duž Velike Morave i Vardara do Egejskog

## Copper deposits in the Balkans

The eastern and central Balkans are exceptionally rich in copper ore deposits (Fig. 1), so it is not surprising that early metallurgy appeared precisely in these regions. There are eight metallogenetic zones on Balkan territory, each of which includes several copper ore deposits (Bogdanov 1982; Gale et al. 2003: 123, Fig. 10.1, 153–154; Janković 1967). In the eastern Balkans, these include: 1. The Rhodope zone in southern Bulgaria with the mining areas of Osogovo-Ozgraden, western Rodopi and eastern Rodopi; 2. The Srednogorie zone in central Bulgaria with the mining areas of Sofia, Panagyurishte, Jambol, Burgas and Strandzha; 3. The Kraishtide zone in western Bulgaria (this region is significant due to gold deposits); 4. The Balkan zone with mines at Chiprovtsi, Sedmochislenitsi, Granipa, Luprene and Salah-Krashimir; 5. The Moesian zone with the important mining area of Varna. All of these zones spread out towards the central and western Balkans where three basic metallogenetic zones are recorded: 1. The Carpathian-Balkan zone in eastern Serbia that is connected with the Srednegorie and Balkan zones in the east (this zone includes the mine of the Vinča culture at Rudna Glava); 2. The Ser-

mora; 3. Dinarska koja se proteže kroz jugozapadnu Srbiju, Crnu Goru, Bosnu i Hercegovinu, Hrvatsku i Sloveniju. Rudne zone u Karpato-balkanskoj provinciji (metalogenetske zone Bor, Banat – Ridanj – Krepoljin i Poreč – Stara Planina) spadaju u neka od najbogatijih rudišta u svetu, pa se i danas intezivno eksploatišu. Nije naodmet napomenuti da se u ovoj provinciji nalaze bogata ležišta zlata, ali nema podataka o njihovoj eksploataciji tokom praistorije. U Srpsko-makedonskoj provinciji se nalaze dva arheometalurški najznačajnija rudišta bakra - polimetalično ležište na Rudniku u centralnoj Srbiji, sa eneolitskim rudnikom na Malom Šturcu, i Lece, c. 40 km južno od Pločnika. U Lecu je tokom rimskog perioda eksploatisano zlato. U blizini ovog rudnika su početkom XX veka nađene sekirečekići tipa Pločnik (Antonović 2014: 64), na osnovu čega se pretpostavlja da je rudnik bio aktivan već u doba eneolita. U Dinarskoj provinciji nalazi se, kao izolovana pojava bakarne rude, Jarmovac, praistorijski rudnik eksploatisan od vremena vinčanske kulture. U ovoj provinciji postoje značajna ležišta u srednjoj Bosni, Mračaj i Maškara, zapadno od Sarajeva, u kojima glavno orudnjenje predstavlja tetraedrit.

Male pojave bakarne rude postoje i na krajnjem zapadu Balkanskog poluostrva. U Hrvatskoj to su Trgovska gora kod Dvora na Uni, Samobor kod Zagreba, Zagrebačka gora i Tršće kod Rijeke, a u Sloveniji u okolini grada Škofja Loka i kod mesta Blagovica. Tamo je ruda bakra eksploatisana tek od 15. veka i tragovi praistorijskog rudarenja do sada nisu detektovani (Simić 1951: 99–101, 102–107). Ipak, može se pretpostaviti da su sva ta rudišta bila poznata i tokom praistorije, ali da su tragovi tog ranog rudarenja uništeni tokom eksploatacije rude u kasnijim epohama.

## Praistorijski rudnici bakra na Balkanu

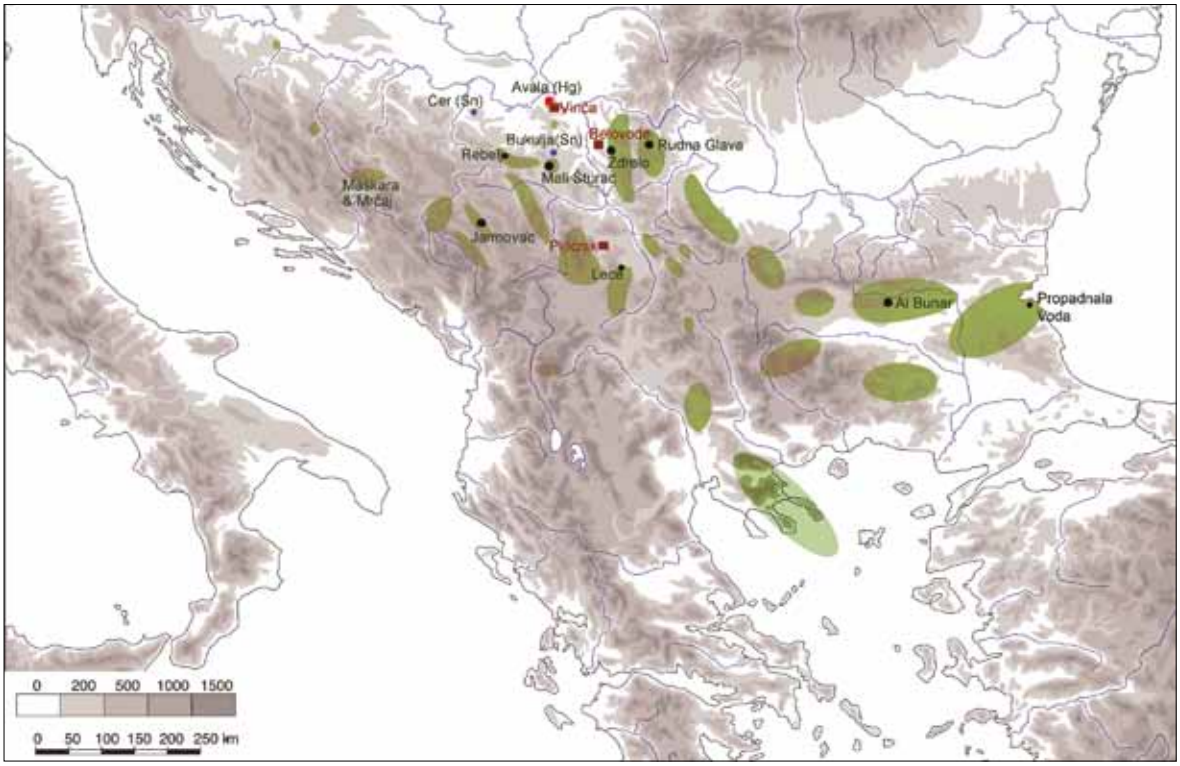
Početkom sedamdesetih godina XX veka Evgenij Černyh je sproveo bugarsko-sovjetski projekat istraživanja eneolitskog rudarenja u Bugarskoj. U okviru tog projekta zabeleženo je 103 sigurnih i potencijalnih starih rudnika: 33 nije imalo nikakve tragove stare rudarske eksploatacije, šest je imalo neke naznake starog rudarenja koje bi trebalo proveriti, a 65 ih je bilo eksploatisano u prošlosti

bian-Macedonian zone that spans from the central Balkans along Velika Morava and Vardar to the Aegean Sea; 3. The Dardanian zone that spans throughout southwestern Serbia, Montenegro, Bosnia and Herzegovina, Croatia and Slovenia. The mining areas in the Carpathian-Balkan province (the metallogenetic zones of Bor, Banat-Ridanj-Krepoljin and Poreč-Stara Planina) are among the richest mining areas in the world, and are being exploited to the present day. It does not hurt to mention that this province includes rich gold deposits, but there is no data about them being exploited in prehistory. The Serbian-Macedonian province includes two, from the perspective of archaeometallurgy, most important copper deposits – the polymetallic deposit at Rudnik in central Serbia, with the Eneolithic mine at Mali Šturc, and Lece, c. 40 km south of Pločnik. Lece was used for gold mining during Roman times. At the beginning of the 20th century, several axe-hammers of the Pločnik type were discovered near this mine (Antonović 2014: 64), based on which it was assumed that the mine was already active during the Eneolithic. The Dardanian province includes, as an isolated occurrence of copper ore, Jarmovac, a prehistoric mine used from the time of the Vinča culture. This province includes significant deposits in Bosnia, Mračaj and Maškara, west of Sarajevo, where tetrahedrite is the main ore.

Small occurrences of copper ore also exist in the westernmost parts of the Balkan Peninsula. In Croatia, these include Trgovska gora near Dvor, Samobor near Zagreb, Zagrebačka Gora and Tršće near Rijeka, and, in Slovenia, the area around the city of Škofja Loka and the village of Blagovica. There, copper ore was exploited from the 15th century, and traces of prehistoric mining have not yet been discovered (Simić 1951: 99–101, 102–107). However, it can be assumed that all of these mining zones were known in prehistory, but that traces of such early mining were destroyed when the ore was exploited in later periods.

## Prehistoric copper mines in the Balkans

At the beginning of the 1970, Evgenij Černyh conducted a Bulgarian-Soviet project that focused on Eneolithic mining in Bulgaria. Within the scope of that project, 103 confirmed and potential ancient mines were recorded: 33 did not display any traces of mining, six showed some signs of ancient mining that should be reevaluated, and 65 were exploited in the past, from the Eneolithic until the 20th centu-




Slika / Figure 1. Zone s bakarnim orudnjenjem, eneolitski lokaliteti, istraženi i potencijalni eneolitski rudnici na Balkanu / Zones with copper ore mineralization, Eneolithic sites, researched and potential Eneolithic copper mines in the Balkans: ■ eneolitski lokaliteti / copper age sites ● istraženi praistorijski rudnici / explored prehistoric mines • potencijalni praistorijski rudnici / potential prehistoric mines

od eneolita do XVII veka. Samo nekoliko rudnika, osim Ai Bunara, je imalo neke znake, ali ne i jasne arheološke dokaze da su bili eksploatisani tokom eneolita (Черньх 1978: 18). Kao eneolitski rudnici, pored Ai Bunara, označeni su Kristjene i Timijanka. U Kristjene, kod Stare Zagore, nađeno je rudno okno koje po svom obliku liči na tipične eneolitske rudarske radove (Черньх 1978: 42–43, sl. 23), ali nisu otkriveni arheološki nalazi koji bi to potvrdili. I u Timijanka su otkriveni rudarski radovi tipični za eneolit, kao i jedan grob iz bronzanog doba, pa je na osnovu svega toga, ali i zbog blizine ovog rudnika Ai Bunaru, zaključeno da je i na tom mestu u eneolitu eksploatisana ruda bakra (Черньх 1978: 43–44).

Rekognosciranjem rozenskog rudnog polja obavljenim od 2013. do 2015. godine obuhvaćeno je više starih rudarskih radova, poznatih od ranije – Medni rid, Propadnala voda (Sl. 2), Čiplaka, Alepu, Alefo Tumba – ali nigde nisu otkriveni pouzdano datovani eneolitski tragovi rudarenja u tom kraju (Kunze et al. 2018). Međutim, u obližnjim praistorijskim naseljima Budžak kod Sozopola i Akladi Čeiri, u slojevima sa kasnoneolitskim i ranoeneolitskim materijalom (5400 – 4900 BC) otkriveno je dosta kory. Only several mines, other than Ai Bunar, revealed some traces, but not clear archeological evidence, of being used during the Eneolithic (Черньх 1978: 18). Kristjene and Timijanka were, along with Ai Bunar, defined as Eneolithic mines. Kristjene, near Stara Zagora, yielded a mining shaft that resembles typical Eneolithic mining activities (Черньх 1978: 42–43 fig. 23), but no archeological finds that could confirm this hypothesis were recovered. Timijanka also yielded a typical Eneolithic layout, as well as a Bronze Age grave, so it was, based on these finds and the fact that this mine is close to Ai Bunar, concluded that copper ore was also exploited at this location during Eneolithic (Черньх 1978: 43–44).

The field survey of the Rosen Ore Field, conducted in the period between 2013 and 2015, encompassed several mining zones, including the previously known medni rid, Propadnala voda (Fig. 2), Chiplaka, Alepu and Alefo Tumba, but no definitive traces of Eneolithic mining activities were discovered in the area (Kunze et al. 2018). However, the layers that contained Late Neolithic and Early Eneolithic material (5400-4900 BC) at the nearby prehistoric settlements of Budžak near Sozopol and Akladi Čeiri yielded many copper ore fragments, malachite

mada rude bakra, nakita od malahita i poneki metalni predmet na osnovu čega je pretpostavljena eneolitska eksploatacija rude na okolnim rudištima (Leshtakov 2010; Kunze et al. 2018).

Ai Bunar

Najstariji i najbolje istraženi eneolitski rudnik bakra u Bugarskoj je za sada samo Ai Bunar, otkriven 1971. godine (Черньх 1978: 56). Nalazi se 8 km severozapadno od Stare Zagore u centralnoj Bugarskoj. To je polimetalično ležište hidrotermalnog tipa, sa olovom, cinkom i bakrom kao osnovnom mineralizacijom. Na više mesta karbonatna ruda bakra (malahit i azurit) izbija na površinu što je i dovelo do veoma rane rudarske eksploatacije na ovom mestu. Orudnjenje koje seže do 25 – 30 m u dubinu se pojavljuje u žilama širokim od 0,5 m do 5 m, a na mestima gde se one sastaju debljina dosеže do 10 – 15 m .

Istraženo je 11 rudarskih okana, neka od njih sa više ulaza. Njihova dužina se kreće od 10 do 111 m, širina od 2 do 10 m, a u dubinu idu do 20 m. Eneolitska keramika Karanovo VI – Gumelnița kulture otkrivena je u oknima 1, 2, 3 i 4. Okno 3 je dalo najviše arheoloških nalaza (Sl. 3). Pored eneolitske keramike tu je nađeno i 15 rudarskih alatki od roga (Черньх 1978: 58, 61, 62, 64, 67).

jewelry and some metal finds, so it was proposed that Eneolithic mining took place in the nearby ore fields (Leshtakov 2010; Kunze et al. 2018).

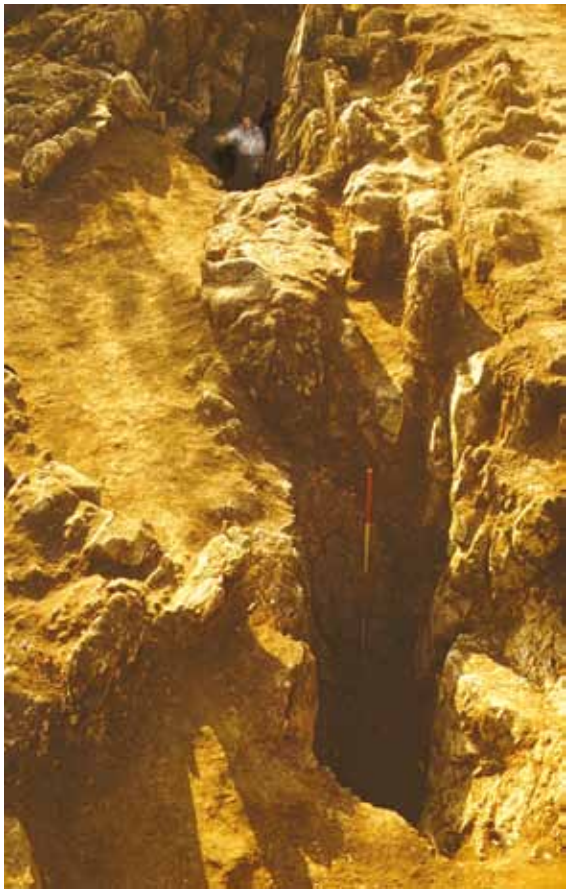
Ai Bunar

The oldest and most researched Eneolithic copper mine in Bulgaria is Ai Bunar, discovered in 1971 (Черньх 1978: 56). It is situated 8 km northwest of Stara Zagora in central Bulgaria. It is a polymetallic hydrothermal deposit, where lead, zinc and copper make up the basic mineralization. The carbonate minerals of copper (malachite and azurite) appear on the surface at several places, which was what caused the very early exploitation at this location. The ore deposit, that is 25-30 m deep, appears in lodes that are 0.5-5 m thick, and which reach a thickness of 10-15 m at the points of intersection.

A total of 11 mining shaft were researched, some of them at several entrances. Their length varies from 10 to 111m, their width from 2 to 10m, and they can go up to 20m in depth. Eneolithic pottery of the Karanovo VI Gumelnița culture was discovered in shafts 1, 2, 3 and 4. Shaft 3 yielded the most archaeological finds (Fig. 3). Apart from Eneolithic pottery, it also yielded 15 mining tools made of antlers (Черньх 1978: 58, 61, 62, 64, 67).

Slika / Figure 2. Propadnala Voda, rudno polje Rozen / Propadnala Voda, the Rosen Ore Field (foto dobijena ljubaznošću / photo obtained by courtesy of P. Leshtakov).

Slika / Figure 3. Ai Bunar, Okno 3 / Ai Bunar, Shaft 3 (foto dobijen ljubaznošću / photo obtained by courtesy of E. Černih).



Slika / Figure 4. Ai Bunar, Okno 4 / Ai Bunar, Shaft 4 (foto dobijen ljubaznošću / photo obtained by courtesy of from E. Černih).

Rudne žile u Ai Bunaru se pružaju horizontalno po površini i vertikalno u dubinu kao uske žile. Nakon vađenja rude i njihovog iscrpljivanja ostali su nepravilni kanali (Sl. 4) koji se danas smatraju rudarskim oknima iako po izgledu i obliku znatno odudaraju od okana koja nastaju u organizovanoj rudnoj eksploataciji što odlikuje rudarstvo iz kasnijih perioda.

Nalazi keramike Karanovo VI – Gumelnica grupe u oknima Ai Bunara sigurno datuje ovaj rudnik u kraj ranog halkolita. Ipak ruda iz Ai Bunara otkrivena na nekim okolnim lokalitetima (Stara Zagora Bolnica, Bereketska Mogila) u slojevima sa keramikom Karanovo V – Marica III grupe, pa čak i u ranijim slojevima sa Marica II keramikom, potvrđuje da je eksploatacija bakarne rude u Ai Bunaru počela već na kraju neolita i početkom ranog halkolita (oko 5100 BC; Gale et al. 2003: 161), a to znači paralelno sa radom Rudne Glave koja je bila eksploatisana u isto vreme.

The lodes of ore at Ai Bunar spread horizontally on the surface, and narrow down vertically. The extraction of the ore and the emptying of the lodes left irregularly-shaped canals (Fig. 4) that are now thought to be mining shafts, even though their layout and shape differ significantly from shafts made through organized mining which is a feature of mining activities from later periods.

The find of Karanovo VI-Gumelnica group pottery in the shafts at Ai Bunar definitively date this mine to the end of the Early Eneolithic. However, ores from Ai Bunar that were discovered at some sites in the vicinity (Stara Zagora Bolnica, Bereketska mogila), in layers that contained pottery of the Karanovo V-Marica III group, and even earlier layers with Marica II pottery, proves that the exploitation of copper ore at Ai Bunar began already at the end of the Neolithic and the beginning of Early Eneolithic (around 5100 BC; Gale et al. 2003: 161), i.e. that it was contemporaneous with the activities conducted at Rudna Glava.

Rudna Glava

Tokom kasnog neolita i ranog eneolita bakarna ruda se na centralnom Balkanu verovatno iskopavala na više mesta, ali je Rudna Glava za sada jedini potpuno potvrđeni i sistematski istražen ranoeneolitski rudnik vinčanske kulture (Sl. 5). Nalazi se 20 km jugoistočno od Majdanpeka, savremenog rudnika bakra koji je možda takođe bio eksploatisan tokom praistorije, sudeći na osnovu analize izotopa olova rađenih pre 30 godina (Pernicka et al. 1993).

Na Rudnoj Glavi je, od rimskih vremena do savremenog doba, vršena eksploatacija rude gvožđa koja predstavlja primarno orudnjenje na ovom rudištu, dok je karbonatna ruda bakra (malahit i azurit) sekundarna pojava.

Rudna Glava je istraživana od 1968. do 1987. godine (Jovanović 1982; Antonović 2014: 8). Tom prilikom je istraženo 8 pristupnih platformi, svaka sa više rudnih kanala tako da je skupa istraženo 30 kanala/okana. Zapravo ne može da se govori o oknima u pravom smislu već o kanalima koji su nastali kao rezultat iskopavanja rudnih žila (Sl. 6-7). Rudnik je bio otkriven tokom raščišćavanja terena i pripremanja lokacije za otvaranje savremenog rudnika gvožđa. Nekoliko praistorijskih okana je tada presečeno po dužini (Sl. 8) čime su bili otkriveni oblik i dimenzije starih rudarskih radova (Јовановић 1972: 5, T II/2, TIV/1).

Rudna Glava

During the Late Neolithic and Early Eneolithic, copper ore was probably exploited at several places in the central Balkans, but Rudna Glava is, so far, the only confirmed and systematically excavated Early Eneolithic mine of the Vinča culture (Fig. 5). It is situated 20 km southeast of Majdanpek, a modern-day copper mine that might have, based on isotope analyses that were conducted 30 years ago, also been used during prehistory, (Pernicka et al. 1993).

From Roman to modern times, Rudna Glava was used for extracting iron, which is the main ore at this shoot, while carbonate copper ore (malachite and azurite) are a secondary feature.

Rudna Glava was excavated from 1968 to 1987 (Jovanović 1982; Antonović 2014: 8). At the time, 8 access platforms were excavated, and each had several mining canals, meaning that a total of 30 canals/shafts were researched. These cannot be defined as proper shafts, but rather as canals that were created as a result of mining lodes (Fig. 6-7). The mine was discovered when the area was being cleared and prepared for the construction of a modern-day iron mine. Several prehistoric shafts were then bisected lengthwise (Fig. 8), thereby revealing the shape and dimensions of ancient mining shafts (Јовановић 1972: 5, T II/2, TIV/1).

Slika / Figure 5. Rudna Glava, pogled sa zapada / Rudna Glava, a view from the west (foto / photo: B. Jovanović, dokumentacija AI, Beograd / documentation of the IA, Belgrade).

Prosečna dubina kanala, odnosno okana, bila je 8 m, ali su neka bila i do 15 m duboka (Jovanović 1982: 4–16). Eksploatacija rude je počinjala od horizontalne platforme – mesta gde je ruda izlazila na površinu i gde se na površini spajalo nekoliko rudnih žila.

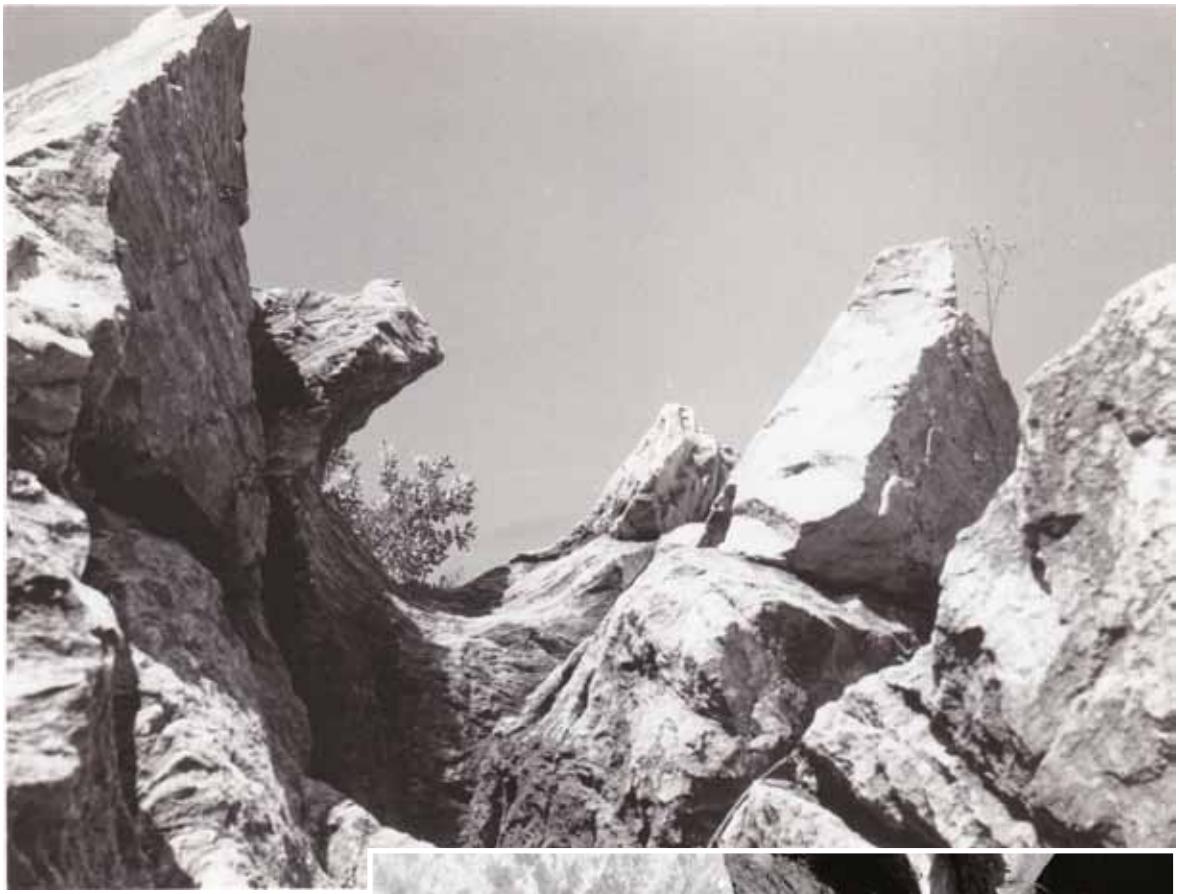
Tokom iskopavanja otkriven je veliki broj kamenih i koštanih rudarskih alatki i keramike vinčanske kulture koji su prikupljeni ispred i u ispunama rudarskih okana. Neke alatke su bile ostavljene na dnu rudarskih okana, ali najveći broj ih je bio verovatno upotrebljavan van okana radi površinske eksploatacije rude. Keramika je bila otkrivena na nekoliko mesta, a najviše u okviru pet ostava otkrivenih na pristupnim platformama okana 2 i 6 (Sl. 9). Keramika zastupljena na Rudnoj Glavi pripada mlađim fazama vinčanske kulture (Gradačka faza – Vinča Pločnik I) (Jovanović 1982: 91–96). Prema apsolutnim datumima Rudna Glava je bila eksploatisana tokom cele vinčanske kulture od 5400 do 4650 BC (Borić 2009: 205 f).

The average depth of the canals, i.e. shafts, was 8 m, but some were up to 15 m deep (Jovanović 1982: 4–16). The extraction of ore started at the access platform – the place where the ore was visible on the surface, and where several lodes intersected.

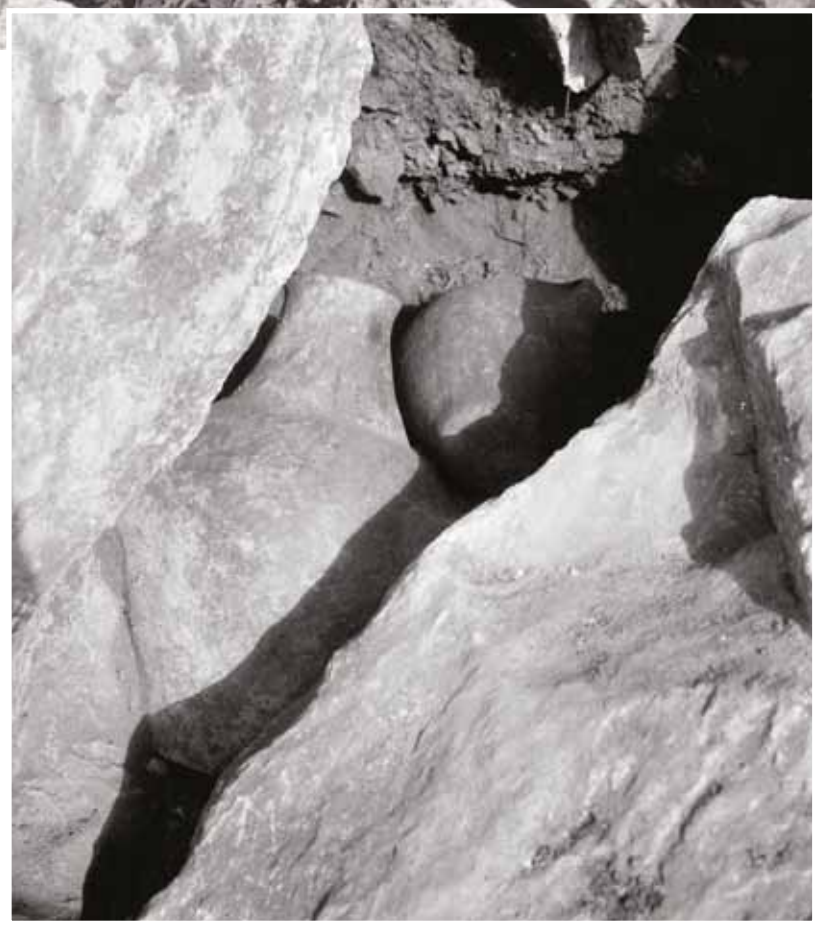
The excavations of the area around, as well as inside, the mining shafts revealed a large number of stone and bone mining tools and pottery of the Vinča culture. Some tools were left at the bottom of the shafts, but most were probably used outside, for the extraction of surface ore. Pottery was found at several places, and most of it was part of the five hoards that were discovered on the access platforms of shafts 2 and 6 (Fig. 9). The pottery from Rudna Glava belongs to the earlier phases of the Vinča culture (the Gradac phase -Vinča Pločnik I) (Jovanović 1982: 91–96). Based on radiocarbon dates, Rudna Glava was in use for the entire duration of the Vinča culture, from 5400 to 4650 BC (Borić 2009: 205 f).

Slika / Figure 6. Rudna Glava, Okno 2f / Rudna Glava, Shaft 2f (foto / photo: B. Jovanović, dokumentacija AI, Beograd / documentation of the IA, Belgrade).

Slika / Figure 7. Rudna Glava, Okno 2d / Rudna Glava, Shaft 2d (foto / photo: B. Jovanović, dokumentacija AI, Beograd / documentation of the IA, Belgrade).



Slika / Figure 8. Rudna Glava, Okno 6 / Rudna Glava, Shaft 6 (foto / photo: B. Jovanović, dokumentacija AI, Beograd / documentation of the IA, Belgrade).



Slika / Figure 9. Rudna Glava, Ostava 2 / Rudna Glava, Hoard 2 (foto / photo: B. Jovanović, dokumentacija AI, Beograd / documentation of the IA, Belgrade).

Jarmovac

Jarmovac je jedinstven kompleks ranog rudarstva smešten u jugozapadnoj Srbiji, na južnoj periferiji Priboja. Poznat je kao praistorijski rudnik još od tridesetih godina 20. veka na osnovu sumarnih opisa dva stara rudarska okna i nalaza kamenog rudarskog čekića sa žlebom ispred jednog od njih (Davis 1937). Rudarski kompleks Jarmovac je 5 km duga zona orudnjenja.

Iskopavanja su započeta 2003. godine (Дерикоњић 2005; Derikonjić et. al. 2011). Izvode se na dva lokaliteta, Majdan i Curak, kao i na obližnjem lokalitetu Kaluđersko Polje van rudne oblasti. Na ovom poslednjem je pronađeno naselje kasne faze vinčanske kulture. Iako još uvek nije otkrivena direktna veza tog vinčanskog naselja i rudnika na Jarmovcu, pretpostavlja se da je ovo vinčansko naselje u tesnoj vezi sa rudarenjem na obližnjim lokalitetima Majdan i Curak i određuje datum početka rudarske aktivnosti u Jarmovcu u sredinu petog milenijuma pre nove ere (Derikonjić et al. 2011).

Na lokalitetu Majdan otkriveni su vertikalno okno, horizontalno okno i pristupna platforma, što je, sve skupa, navelo istraživače da prepoznaju bar dve faze rudarenja. Položaj horizontalnog okna i

Jarmovac

Jarmovac is a unique mining complex situated on the southern periphery of Priboj in southwestern Serbia. It has been known as a prehistoric ever since the 1930 based on the scarce descriptions of two old mining shafts and a mining hammer with a gauge that was discovered in front of one of them (Davis 1937). The Jarmovac mining complex includes a 5 km-long mining zone.

Excavations at the sites of Majdan and Curak, as well as at the nearby site of Kaluđersko Polje that is outside the mining zone began in 2003 (Дерикоњић 2005; Derikonjić et. al. 2011). The latter yielded a settlement dated to the late phase of the Vinča culture. Even though no direct link between this settlement of the Vinča culture and the mine at Jarmovac was found, it was assumed that this settlement of the Vinča culture was closely related to the mining activities that took place at the nearby sites of Majdan and Curak, and that it dates the beginning of mining activities at Jarmovac into the middle of the fifth millennium BC (Derikonjić et al. 2011).

The site of Majdan yielded a vertical shaft, a horizontal shaft, and an access platform which led the researchers to differentiate between at least two

Slika / Figure 10. Jarmovac, Majdan, horizontalno okno / Jarmovac, Majdan, horizontal shaft (foto / photo: J. Pendić, ljubaznošću / by courtesy of S. Derikonjić, Zavičajni muzej Priboj / Homeland Museum, Priboj).

Slika / Figure 11. Jarmovac, Curak, otvoreni kop, pogled sa jugoistoka / Jarmovac, Curak, open pit, a view from the southeast (foto / photo: Jugoslav Pendić, ljubaznošću / with courtesy by S. Derikonjić, Zavičajni muzej Priboj / Homeland Museum, Priboj).

prisustvo drvenih greda u njemu stavljaju to okno u mlađu, drugu fazu eksploatacije na Majdanu, koja je i dalje bila zasnovana na praćenju bogatih malahitnih žila (Sl. 10). Vertikalno okno predstavlja početnu rudarsku fazu, ali i ono je nastalo tek posle ranog eneolita sudeći na osnovu četvorougaonog oblika rudnog kanala i ostacima drvene potpore otkrivene na dubini od 6 m. Do sada nije nađen arheološki materijal koji bi obezbedio dokaz o hronološkoj pripadnosti ovog okna na Majdanu.

Nalazište Curak se nalazi na padini c. 50 m udaljenoj od Majdana. Na njemu su otkrivena dva vertikalna okna koja su pratila žilu bogatu malahitom i magnetitom i površinski kop ispred njih (Sl. 11). Na ovom mestu su nađene 42 kamene alatke koje sve potiču sa otvorenog kopa. Identifikovana su dva tipa alatki: veliki kameni batovi sa žlebom i mali žrvnjevi za usitanjavanje rude.

Na lokalitetu Curak se prilikom iskopavanja nailazilo na rasute fragmente vinčanske keramike,[1] hronološki opredeljujuć ovaj lokalitet. Pored toga blizina vinčanskog naselja na lokalitetu Kaluđersko polje, 300 m udaljenom od starih rudarskih radova, dodatno sugeriše kulturnu pripadnost ovog rudnika.

1 Usmeno saopštenje Save Derikonjića, Zavičajni muzej Priboj.

phases of mining activities. The position of the horizontal shaft, and the presence of wooden pillars within it, date this shaft into the younger, i.e. the second phase of exploitation at Majdan, which was still based on following the rich lodes (Fig. 10). The vertical shaft presents the initial phase of mining, but it was also created only after the Early Neolithic, as suggested by the quadratic shape of the mining canal and the remains of a wooden support system that was discovered at the depth of 6 m. So far no archaeological material was discovered that could be used to chronologically define this shaft at Majdan.

The site of Curak is situated on a slope, about 50 m from Majdan. It yielded two vertical shafts that followed the rich lode of malachite and magnetite, and an open cast mine that was in front of it (Fig. 11). The open mine yielded 42 stone tools, including two types of tools: large stone hammers with gauges and small grindstones used to grind the ore.

The excavations of Curak revealed sporadic finds of pottery ascribed to the Vinča culture,[1] thereby dating this site. Additionally, the proximity of a Vinča culture settlement at the site of Kaluđersko polje, 300 m away from the old mine, also speaks in favor of the suggested cultural attribution of this site.

1 Personal communication of Savo Derikonjić from the Homeland Museum Priboj.

Mali Šturac

Eneolitski rudnik na Malom Šturcu je otkriven 1980. godine (Јовановић 1988). Ovaj rudnik se nalazi na lokalitetu Prljuša koji je smešten na jugozapadnoj padini Malog Šturca, najnižeg vrha planine Rudnik u centralnoj Srbiji. Rudna zona površine 2,5 ha ima elipsoidni oblik i pruža se pravcem jugozapad – severoistok (Sl. 12).

Prva arheološka istraživanja obavljena su 1981. godine kada su otkriveni ulazi u dva okna (Okno 1 i 2). Istraživanja su nastavljena 1987. godine i tada je otkriveno još nekoliko okana (Okna 3, 4, 5 i 6). Više su istraženi samo Okno 5 i Okno 6 kod kojih su otkriveni ulazi u same rudne kanale. Iskopavanje Okna 6 je nastavljeno 2013–2014. godine i tada je otkrivena prostrana plitka rudna jama, a paralelno s njim je istražena površinska eksploatacija rude u zoni okna 4 veličine c. 90 m$^2$. Sakupljeni su brojni rudarski kameni batovi, dve potpuno fragmentovane alatke od jelenjeg roga i nekoliko atipičnih fragmenta eneolitske keramike.

Istraživanja na Prljuši su nastavljena 2011. godine (Antonović & Vukadinović 2012). Geofizičko ispitivanje donjeg dela padine ukazalo je na veći broj rudnih pojava i potencijalnih starih rudarskih radova pokrivenih slojem sipara i komadima raspadnutih stena iz gornjih slojeva lokaliteta debljine 2 – 10 m (Antonović et al. 2012).

Mali Šturac

The Eneolithic mine at Mali Šturac was discovered in 1980 (Јовановић 1988). This mine is situated at the Prljuša site on the southwestern side of Mali Šturac, the lowest top of the Rudnik Mountain in central Serbia. The mining area of 2.5 ha is elliptical in shape and spreads in a southwest-northeast direction (Fig. 12).

The first archaeological excavations were conducted in 1981, and yielded entrances to two shafts (Shafts 1 and 2). The research continued in 1987, when several other shafts were discovered (Shafts 3, 4, 5 and 6). Detailed research was carried out only on Shaft 5 and Shaft 6, revealing the entrances of the mining canals. The excavations of Shaft 6 resumed in 2013-2014, and yielded a wide shallow mining pit. At the same time, an area of c. 90 m2 was excavated around Shaft 4, where traces of surface exploitation were recorded. Numerous mining hammers, two completely fragmented antler tools, and several atypical Eneolithic pottery fragments were found.

The excavations of Prljuša continued in 2011 (Antonović & Vukadinović 2012). Geophysical research of the lower part of the slope points to a large number of mining traces and traces of potential ancient mining activities, covered by a 2-10 m thick layer of debris and pieces of rocks that slid from the upper layers (Antonović et al. 2012).

Slika / Figure 12. Mali Šturac, pogled odozgo / Mali Šturac, a view from above (dokumentacija AI, Beograd / documentation of the IA, Belgrade).

Slika / Figure 13. Mali Šturac, okno Objekat 1 / Mali Šturac, Shaft Object 1 (foto / photo: V. Dimić, dokumentacija AI, Beograd / documentation of the IA, Belgrade).

Rekognosciranjem samog lokaliteta 2011. i 2012. godine otkriveno je najmanje 13 grupa starih rudarskih radova u gornjem delu lokaliteta. Neka od ovih okana imaju impozantne dimenzije što dokazuje da je Prljuša pre početka rudne eksploatacije bila naročito bogata rudom koja je izbijala na površinu u obliku moćnih žila. Nakon eksploatacije rude ostajale su prostrane galerije čije su se tavanice vremenom obrušile i zatrpale ostatke praistorijskih okana (Sl. 13). Istraživanje jednog od ovih okana, smeštenog na najvišoj koti lokaliteta, započeto je 2014. godine i prvo je u čijim je slojevima otkrivena hronološki jasno definisana kasnoeneolitska keramika Bubanj-Hum kulture (Sl. 14). Ovaj nalaz iz najviših delova lokaliteta ukazuje da je na Prljuši eksploatacija karbonatne rude bakra trajala do kraja eneolita.

Tokom istraživanja od 2011. godine iskopavanjima je prikupljeno oko 400 batova, dok je na površini registrovano čak preko 600 ovih kamenih rudarskih alatki. Kameni batovi se pojavljuju u raznim oblicima i veličinama (Антоновић 2013; Bogosavljević 1995), teški od 100g do čak 20 kg. Pretpostavlja se da su manji batovi imali drvenu držalju i bili korišćeni kao ručni alat, dok su oni veći bili okačeni o drveni stativ i tako korišćeni za razbijanje tvrdih stena u kojima se ruda nalazila (Dimić 2017).

A field survey of the site, conducted in 2011 and 2012, yielded at least 13 groups of traces of ancient mining activities at the higher part of the site. Some of these shafts are impressively large, proving that Prljuša had, before the beginning of mining exploitation, been especially rich in ore that was visible on the surface in the shape of mighty lodes. After the ore was extracted, spacious galleries were created that subsequently caved in and buried the remains of prehistoric shafts (Fig. 13). The excavation of one of these shafts, situated on the highest point of the site, began in 2014, and was the first to yield a chronologically clearly defined Eneolithic pottery of the Bubanj-Hum culture (Fig. 14). This find, from the highest parts of the site, suggests that the exploitation of carbonate ore at Prljuša lasted until the end of the Eneolithic.

The excavations conducted in 2012 yielded around 400 hammers, with over 600 additional tools of this type that were recorded on the surface. Stone hammers appear in different forms and sizes (Антоновић 2013; Bogosavljević 1995), and weigh from 100 g up to even 20 kg. It is assumed that smaller hammers had a wooden handle and were used as hand tools, while larger ones were hanged on from wooden frames and were used for crushing the hard rocks that contained the ore (Dimić 2017).

Ždrelo

Rekognosciranje okoline Belovoda, vinčanskog naselja kod Petrovca na Mlavi u istočnoj Srbiji na kome su zabeleženi najraniji tragovi metalurgije u Evropi, dovelo je do otkrića starih rudarskih radova blizu sela Ždrelo (Šljivar et al. 2006: 254). Za ovo mesto karakteristična je crvena boja površinskih geoloških slojeva gde bogate žile malahita i azurita izlaze na površinu.

Ždrelo

A field survey of Belovode, a settlement of the Vinča culture near Petrovac na Mlavi in estern Serbia, where the earliest traces of metallurgy in Europe have been recorded, led to the discovery of ancient mining activities near the Ždrelo village (Šljivar et al. 2006: 254). This area is characterized by red surface geological layers where the rich lodes of malachite and azurite are visible on the surface.

Slika / Figure 14. Mali Šturac, keramički sud iz okna Objekat 1 / Mali Šturac, ceramic vessel from the shaft Object 1 (foto / photo: V. Dimić, dokumentacija AI, Beograd / documentation of the IA, Belgrade).

Izuzetno strma padina na kojoj je smešten ovaj lokalitet je ispresecana paralelnim vertikalnim jarugama koje se pružaju od rečice Reškovice u podnožju padine do samog vrha brda, ogranka planine Vukan (Sl. 15). Pretpostavlja se da je kopanjem jaruga na površini praćena mineralizacija malahita i azurita kako bi se otkrila mesta gde je ruda izbijala na površinu i odakle je počinjalo formiranje rudnog okna kojim se rudna žila pratila u dubinu.

Iskopavano je samo jedno okna 2006. godine, ali tom prilikom je otkriven samo ulaz u okno. Dokazi praistorijskog rudarenja nisu otkriveni, a pravilan oblik ulaza u okno ostavlja mogućnost da je okno nastalo u nekom kasnijem praistorijskom dobu (bronzano ili gvozdeno doba).

The exceptionally steep slope, where this site is situated, is crisscrossed with parallel vertical ditches that go from the Reškovica River at the foot, up to the very top of the hill – an offshoot of the Vukan Mountain (Fig. 15). It is assumed that the ditches were dug following the malachite and azurite mineralization, in order to reveal the places where the ore was visible on the surface, and where mining shafts were formed in order to follow the lodes vertically.

Only one shaft was excavated in 2006, and only the entrance was unearthed. No traces of prehistoric mining were discovered, and the regular shape of the shaft entrance suggests that the shaft was created at some later period of prehistory (Bronze or Iron Age).

## Ostali eneolitski rudnici na centralnom Balkanu

Kao i na istočnom Balkanu tako i na centralnom Balkanu ima puno mesta na kojima su nađeni neki, ali ne i dovoljno pouzdani dokazi praistorijskog rudarsva. Oko savremenog rudnika bakra Rebelj u severozapadnoj Srbiji postoje ostaci starih rado-

## Other Eneolithic copper mines in the central Balkans

Just like the eastern Balkans, the central Balkans also yielded numerous places where some, but not reliable-enough, evidence of prehistoric mining has been discovered. The area around the contemporary copper mine of Rebelj in northwestern Serbia yield-

va koji po obliku mogu biti eneolitski (Simić 1951: 172), uz koje je nađen i jedan kameni rudarskih bat sa žlebom.[2]

Sudeći na osnovu analiza izotopa olova, ruda iz Majdanpeka, savremenog rudnika bakra u istočnoj Srbiji, bila je korišćena za izradu bakarnog oruđa tokom eneolita i ranog bronzanog doba (Pernicka et al. 1993: 38; Radivojević 2007: 19). U Majdanpeku je na više mesta, još početkom 20. veka, nađeno nekolika desetina kamenih batova (Simić 1951: 252), tipičnih praistorijskih rudarskih alatki koje su se koristile do kraja bronzanog doba.

Na Avali, planini blizu Beograda i samo nekoliko kilometara udaljenoj od neolitskog naselja u Vinči, nalazi se mali rudnik bakra nepoznate hronološke pripadnosti. Po izgledu samog rudnika – pinga i deponija usitnjenog kamena pomešanog sa malahitom – može da se pretpostavi da je ekploatacija bakarane rude na ovom mestu rađena u praistoriji.

2 Usmeno saopštenje, Borislav Jovanović, Srpska akademija nauka i umetnosti.

ed traces of ancient mining activities that could, based on their shape, be ascribed to the Eneolithic (Simić 1951, 172), and which were accompanied by a stone hammer with a gauge.[2]

Based on the analyses of iron lead isotopes, the ores from Majdanpek, a contemporary copper mine in eastern Serbia, were used in copper tool production during the Eneolithic and the Early Bronze Age (Pernicka et al. 1993: 38; Radivojević 2007: 19). At the beginning of the 20th century, several locations at Majdanpek yielded several tens of stone hammers (Simić 1951: 252), typical prehistoric mining tools that were used until the end of the Bronze Age.

A small copper mine of unknown age is situated on Avala, a mountain close to Belgrade, and only several kilometers away from the Neolithic settlement at Vinča. The shape of the mine – a landfill of crushed rocks mixed with malachite – suggests that copper ore exploitation took place here during prehistory.

2 Personal communication, Borislav Jovanovć, Serbian Academy of Sciences and Arts.

Slika / Figure 15. Ždrelo, pogled na lokalitet / Ždrelo, a view of the site (foto / photo: D. Šljivar).

Rudišta u srednjoj Bosni, Mračaj i Maškara, sa tetraedritom kao glavnim orudnjenjem, eksploatišu se još od praistorije za šta postoje indirektni dokazi. U srednjem veku tu su bili vađeni zlato, srebro i živa što je potrajalo do danas. U Mračaju su nađeni fragmenti bronzanodobne i gvozdenodobne keramike kao i kameni rudarski batovi sa žlebom kao sigurna potvrda praistorijske eksploatacije rude (Simić 1951: 128). Moguće da je eksploatacija ovih rudišta započela već tokom eneolita, ali za to ne postoje pouzdani arheološki dokazi. Zanimljliv je zaključak vezan za prsten izrađen od kalajne bronze otkriven u sloju vinčanske kulture na Gomolavi za koji je, nakon analiza, pretpostavljeno da je bio izrađen od rude tetraedrita (Radivojević et al. 2013: 1032 Abb. 1B, 1035). Veza Gomolave i oko 250 km udaljenih rudišta u srednjoj Bosni nije dokazana dosadašnjim istraživanjima, ali nije nemoguće da su i ona korišćena za nabavljanje rude u primitivnoj metalurgiji. Ipak treba imati u vidu da su analize izotopa olova u najstarijim bakarnim artefaktima iz Austrije, Slovačke, Nemačke i Mađarske pokazale da je za njihovu izradu korišćena ruda iz Srbije i Bugarske (Niederschlag et al. 2003; Höppner et al. 2005; Schriener 2007; Siklósi et al. 2017). Pretpostavlja se da su, paralelno sa njima, u manjoj meri korišćeni za sada nepoznati izvori bakarne rude u Slovačkoj i Mađarskoj (Siklóski et al. 2015; Siklósi et al. 2017: 71), a analizama je potvrđeno da je u Austriji eksploatacija lokalne rude počela tek u ranom bronzanom dobu (Höppner et al. 2005). Isto može da se pretpostavi i za zapadni Balkan, da je ruda za najstarije bakarno oruđe donošena sa istoka poluostrva, a da su lokalna rudište počela da se eksploatišu tek kasnije, najranije od bronzanog doba, što pokazuju nalazi iz okoline Mračaja i Maškara u Bosni.

Tokom eneolita eksploatisane su i druge rude. Šuplja stena na Avali kod Beograda je praistorijski rudnik rude žive cinabarita za koji su znali i stanovnici neolitskog naselja u Vinči. Grumenovi cinabarita su bili nalaženi u svim slojevima tog nalazišta (Васић 1932: 5). Postoji mišljenje da su stanovnici naselja u Vinči proizvodili živu, što je pre svega zaključeno na osnovu oblika peći (Durman 1988). Na osnovu nedavnih analiza cinabarita sa Avale, materijala i peći iz Vinče i Pločnika ustanovljeno je da u pećima na Vinči nema tragova prerade cinabarita. Ovaj mineral je u Vinči bio retko korišćen kao pigment i pažljivo je čuvan u posudama u sprašenom stanju (Mioč et al. 2004). Cinabarit je bio korišćen kao boja za figurine na Pločniku, ali nije poznato da li je korišćena ruda sa Avale (Gajić-

Ore fields in central Bosnia, Mračaj and Maškara, where tetrahedrite is the main ore, were exploited since prehistory, as suggested by indirect evidence. During the Middle Ages, these mines were used to extract gold, silver and mercury, as is the case to this day. Mračaj yielded fragments of Bronze and Iron Age pottery, as well as stone mining hammers with gauges, thereby confirming prehistoric ore exploitation (Simić 1951: 128). It is possible that the exploitation of these mining areas began during the Eneolithic, but there is no reliable archaeological data to support such a hypothesis. The analysis of a ring made of tin bronze, discovered in a layer of the Vinča culture at Gomolava, revealed that the find was probably made of tetrahedrite ore (Radivojević et al. 2013: 1032 Abb. 1B, 1035). The link between Gomolava and the ore fields in central Bosnia, which are about 250 km away, has not yet been confirmed, but it is possible that these sites were also used to obtain ore in primitive metallurgy. However, it should be noted that lead isotope analyses of the oldest copper artifacts from Austria, Slovakia, Germany and Hungary, show that the items were made of purified ore from Serbia and Bulgaria (Niederschlag et al. 2003; Höppner et al. 2005; Schriener 2007; Siklósi et al. 2017). It is assumed that, parallel with them, less known sources of copper ore in Slovakia and Hungary were used as well (Siklóski et al. 2015; Siklósi et al. 2017: 71), and analyses confirmed that ore exploitation in Austria began in the Early Bronze Age (Höppner et al. 2005). The same can be assumed for the western Balkans, meaning that ores used to produce the oldest copper tools were brought from the east of the peninsula, and that the exploitation of local mining zones began later, starting from the, at the earliest, Bronze Age, as attested to by finds from the area around Mračaj and Maškara in Bosnia.

Other ores were also exploited during the Eneolithic. Šuplja stena on the Avala Mountain near Belgrade is a prehistoric cinnabar mercury mine that was known to the inhabitants of the Neolithic settlement at Vinča. Lumps of cinnabar were discovered in all layers at the site (Васић 1932: 5). Based on the shape of kilns, some authors think that the inhabitants of Vinča produced mercury (Durman 1988). Based on recent analyses of cinnabar from Avala, and material and kilns from Vinča and Pločnik, it was established that the kilns at Vinča showed no traces of cinnabar processing. This mineral was rarely used at Vinča as a pigment, and was carefully stored in powder form in vessels (Mioč et al. 2004). At Pločnik, cinnabar was used as a dye for figurines, but it is not known whether the ore from Avala was

Kvašev et al. 2012: 1032). Arheološka iskopavanja ovog rudnika su bila sprovedena početkom tridesetih godina prošlog veka kada je otkriveno da je rudnik bio korišćen od strane nosilaca kasnoeneolitske kostolačke kulture (Milojčić 1943).

Na padinama planina Bukulja u centralnoj Srbiji i Cer u severozapadnoj Srbiji postoje aluvijalni nanosi kaseterita, i to su jedina lako dostupna ležišta rude kalaja u jugoistočnoj Evropi (Janković et al. 2003: 53). Zbog toga se pretpostavlja da su ona mogla biti eksploatisana tokom praistorije (Durman 1997), ali za to za sada ne postoje arheološki dokazi.

Novim istraživanjima starog rudarstva na Ceru do sada nisu otkrivena mesta eksploatacije kasiterita kao ni tragovi praistorijske prerade ove rude (Bankoff et al. 2011). Ipak, geohemijska analiza uzoraka kasiterita iz nekoliko potoka na Ceru i rekognosciranje cele oblasti otkrila su brojna kasnobronzana naselja na rečnim terasama upravo oko potoka sa visokom koncentracijom kasiterita pa se pretpostavlja njihova veza sa mogućom eksploatacijom kalajne rude (Huska et al. 2014). Na osnovu proučavanja izotopskog sastava kalaja u bronzanom oruđu sa Balkana utvrđeno je da je ruda sa Cera bila korišćena samo južno od Dunava, dok su oblasti severno od njega koristile rudu iz drugih rudnika, najverovatnije iz rudnika Erzgebirge u centralnoj Evropi na granica Nemačke i Češke (Powell et al. 2018: 149).

Svakako je najzanimljiviji nalaz lima iz neolitskog naselja u Pločniku izrađenog od kalajne bronze sa čak 11,7 % kalaja i visokim sadržajem olova, nikla i gvožđa u svom sastavu (Radivojević et al. 2013: 1035). Nalaz potiče iz sloja datovanog u 4650 p.n.e. Metalografska analiza ukazuje na namernu proizvodnju i poznavanje karakteristika ovakvog novostvorenog metala. Analiza sastava ga povezuje sa topljenjem kompleksne bakarno-kalajne rude (halkopirit sa stanitom i tertraedritom), pa se isključuje mogućnost da je bronza nastala korišćenjem kasiterita (Radivojević et. al. 2013: 1037), a time i moguća rana eksploatacija ove rude iz aluvijalnih nanosa na Ceru i Bukulji.

Zlato se pojavilo vrlo brzo posle bakra, sredinom petog milenijuma pre nove ere. Nalazi zlatnih artefakata na nekropoli u Varni u istočnoj Bugarskoj su za sada najstariji predmeti od ovog metala u ljudskoj istoriji (Ангелов 1959; Иванов 1978; Dimitrov & Stoychev 2018). Dugo se postavljalo pitanje odakle potiče ruda od koje su ti predmeti bili napravljeni. Tek je u novije vreme, početkom 21. veka, utvrđe-

used (Gajić-Kvašev et al. 2012: 1032). Archaeological excavations of this mine that were conducted at the beginning of the 1930s revealed that this mine was used by the people of the Late Eneolithic Kostolac culture (Milojčić 1943).

The slopes of the mountains Bukulja, in central Serbia, and Cer in northwestern Serbia, include alluvial deposits of cassiterite, and are the only such, easily-available, sources of tin in southeastern Europe (Janković et al. 2003: 53). That is why it was assumed they could have been used during prehistory (Durman 1997), even though there is no archaeological evidence.

Recent explorations of ancient mining at Cer have, so far, yielded no places where cassiterite was exploited, nor any traces of prehistoric processing of that ore (Bankoff et al. 2011). However, the geochemical analysis of cassiterite from several streams on Cer, and a field survey of the entire area, revealed numerous Late Bronze Age settlements on the riverbanks, precisely around the streams that had a large concentration of cassiterite, so it was assumed that they were linked to the exploitation of tin ore (Huska et al. 2014). The study of the isotope composition of tin found in bronze tools from the Balkans established that the ore from Cer was used only south of the Danube, while ores from other mines, most likely from Erzgebirge in central Europe, on the border of Germany and the Czech Republic, were used north of the Danube (Powell et al. 2018: 149).

The most interesting find is certainly the metal plate from the Neolithic settlement at Pločnik that was made from tin bronze that contained 11.7% of tin and a large percentage of lead, nickel and iron (Radivojević et al. 2013: 1035). The find was discovered in a layer dated to 4650 BC. A metallographic analysis points to an intentional production and knowledge of the characteristics of this newly-created metal. The composition analysis connects it to the melting of a complex copper-tin ore (chalcopyrite with stannite and tetrahedrite), thereby excluding the possibility that the bronze was created by purifying cassiterite (Radivojević et. al. 2013: 1037), and suggesting that an early exploitation of this ore from the alluvial deposits at Cer and Bukulja was possible.

Gold appeared soon after copper, at the middle of the fifth millennium BC. The gold finds from the Varna necropolis in eastern Bulgaria are, so far, the earliest objects made of this metal in human history (Ангелов 1959; Иванов 1978; Dimitrov & Stoychev 2018). For a long time the origin of the ore used for

no da ruda potiče iz nekoliko različitih ležišta i svi se nalaze na teritoriji Bugarske – u oblasti planine Strandža kod Burgasa, te u gornjem toku reke Strume i nekih od njenih pritoka (Dimitrov & Stoychev 2018: 46). Reč je o zlatu iz aluvijalnih nanosa iz kojih se ruda dobijala ispiranjem. Bogata aluvijalna ležišta zlata postoje i u istočnoj Srbiji, ali za sada nemamo nikakvih indicija o njihovoj eksploataciji tokom praistorije, a posebno eneolita, već samo pretpostavku da su rudari tog doba verovatno prepoznali njihovo bogatsvo.

## Poreklo rude u primitivnoj metalurgiji

Radi razrešenja pitanja porekla rude od koje se dobijao bakar za izradu eneolitskog i bronzanodobnog oruđa sa teritorije Balkana, urađene su brojne analize metala i uzoraka rude (Черньх 1978: 14; Gale et al. 2003; Pernicka et al. 1993; Pernicka et al. 1997). Sa nalazišta u Srbiji ispitan je uzorak od 90 eneolitskih i bronzanodobnih bakarnih predmeta, uzorci malahita iz dva kasnovinčanska naselja, ruda iz Rudne Glave i više rudišta u istočnoj, centralnoj i južnoj Srbiji (Majdanpek, Blagojev kamen, Lipa, Aljin Do, Crnajka, Biljevina, Trnjane, Bor, Velika Brestovica, Rudnik, Lajkovača, Čadinje, Šatorica (Pernicka et al. 1993: 25–29; Radivojević 2007: 98 f). U Bugarskoj je urađen znatno veći broj analiza. U okviru bugarsko-sovjetskog projekta sedamdesetih godina prošlog veka izvršene su hemijske analize elemenata u tragovima na uzorku od 1244 eneolitskih i bronzanodobnih predmeta od bakra i bronze sa 250 različitih nalazišta (Черньх 1978: 14), koje ukazuju na korišćenje rude iz različitih ležišta. Analize izotopa olova urađene su na c. 400 predmeta i uzoraka rude sa brojnih rudišta u Bugarskoj (Pernicka et al. 1997: 83 Abb. 14, 91 Tab. 1; Gale et al. 2003: 157–168).

Na osnovu svih pomenutih analiza primećeno je da je u ranoj metalurgiji na Balkanu korišćen veći broj ležišta, ponekad vrlo udaljenih od oblasti iz koje potiču metalni predmeti. Na lokalitetima oko Ai Bunara konstatovana je ruda iz najmanje četiri rudnika iz bliže okoline, pa se pretpostavlja da je tokom srednjeg halkolita, pored Ai Bunara, postojalo još nekoliko rudnika u toj rudnoj oblasti (Gale et al. 2003: 161). Ista praksa je primećena i na Belovodama gde je korišćena ruda iz Ždrela u blizini Belovoda, Majdanpeka i nepoznatog rudnika iz oblasti oko Rudne Glave, Crnajke, Biljevine i Velike Brestovice, ali ne i ruda iz same Rudne Glave (Radivojević 2007: 98-116; Radivojević et al. 2010: 2781,

their production was unknown. It was, only recently, at the beginning of the 21st century, established that the ore originates from several different areas of Bulgaria – the region of the Strandzha Mountain near Burgas, and the upper part of the Struma River and some of its tributaries (Dimitrov & Stoychev 2018: 46). The gold was obtained by flushing alluvial deposits. The rich alluvial gold deposits also exist in eastern Serbia, but there are still no indications that they were being exploited during prehistory, but only assumptions about the miners from the past knowing about their richness.

## The origin of ore in primitive metallurgy

Numerous analyses of metals and ore samples were made in order to answer the question of the origin of ores used to obtain copper for the production of Eneolithic and Bronze Age tools in the Balkans, (Черньх 1978: 14; Gale et al. 2003; Pernicka et al. 1993; Pernicka et al. 1997). A total of 90 Eneolithic and Bronze Age tools from Serbia were analyzed, as were malachite samples from two settlements of the late Vinča culture and ores from Rudna Glava and several mines from eastern, central and south Serbia (Majdanpek, Blagojev kamen, Lipa, Aljin Do, Crnajka, Biljevina, Trnjane, Bor, Velika Brestovica, Rudnik, Lajkovača, Čadinje, Šatorica; Pernicka et al. 1993: 25-29; Radivojević 2007: 98 f). A far greater number of analyses were conducted in Bulgaria. The Bulgarian-Soviet project from the 1970s included chemical analyses of trace elements on a sample of 1244 Eneolithic and Bronze Age copper and bronze finds from 250 different sites (Черньх 1978: 14), and the results suggest the use of ore from different mining zones. The analyses of lead isotopes were conducted on c. 400 finds and ore samples from numerous deposits in Bulgaria (Pernicka et al. 1997: 83 Abb. 14, 91 Tab. 1; Gale et al. 2003: 157-168).

All of the listed analyses have shown that a larger number of ore deposits were used in the early metallurgy of the Balkans, which were sometimes very far from the regions where the finds were discovered. The sites around Ai Bunar yielded ores from at least four mines in the vicinity, so it was assumed that, during the middle Eneolithic, several other mines existed in this mining area apart from Ai Bunar (Gale et al. 2003: 161). The same practice was recorded at Belovode that yielded ore from Ždrelo in the vicinity of Belovode, Majdanpek and an unknown mine from the area around Rudna Glava, Crnajka, Biljevina and Velika Brestovica, but not ores from Rudna Glava itself (Radivojević 2007: 98-116; Radivojević et al. 2010:

2784 Fig. 10). Kao mnogo verovatniji izvor rude u tom periodu ističe se Majdanpek, čija je ruda korišćena i na teritoriji zapadne Bugarske. Pretpostavlja se da je na mestu današnjeg rudnika postojao ranoeneolitski rudnik većih razmera koji ili nije otkriven do sada ili je uništen kasnijim rudarskim radovima (Pernicka et al. 1993; Pernicka et al. 1997: 146), što je mnogo verovatnije.

Iako nije bila praksa da se ruda sa istočnog Balkana koristi za proizvodnju metala na centralnom Balkanu i obrnuto, veza ove dve oblasti u korišćenju rude iz istih ležišta dokazana je na materijalu iz Pločnika i nekropole u Varni. Naime, osam predmeta iz Pločnika i 16 iz nekropole uVarni su bili izrađeni od metala dobijenog iz iste rude, iskopane u za sada neidentifikovanom rudniku čije je izotopsko polje vrlo blisko onom sa poljem Ai Bunara (Gale et al. 2003: 165, Fig. 10.13). Takođe je sasvim moguće da je ruda iz ležišta Varli Briag bila upotrebljena za izradu jedne alatke iz Pločnika, ali i za izradu kasnoeneolitskih alatki iz Srbije (krstasta sekira iz Stojačka, HDM 1401 i dleto iz Jelašnice, HDM 1421; Gale et al. 2003: 165, Fig. 10.14, Fig. 10.16).

Ruda od koje je bio dobijen metal od koga su bili izrađeni bakarni predmeti iz Varne dolazila je iz bugarskih ležišta, pa čak i iz turskog dela Trakije, ali ne i iz Ai Bunara, Majdanpeka, Rudnika i Rudne Glave. Bakar iz Varne je bio izrađen od rude iz Varli Briag, Diebeli Rit, Sokolec, Plakalnica, Vozdol, Vinica-Lakatnik, Meden Rid, Osikota, kao i od rude iz nekog rudnika sa izotopskim poljem bliskim Ai Bunaru, (Gale et al. 2003: 166, Abb. 10.15).

Bakarni predmeti iz Dolnoslova, njih 52 koji su bili podvrgnuti analizi izotopa olova nisu bili izrađeni od rude iz Rudne Glave, Bora, Majdanpeka, Lesova i Sedmočislenici, ali su neki od njih bili izrađeni od rude iz rudnika Varli Briag, Ai Bunar i iz oblasti Rudnika u centralnoj Srbiji (Gale et al. 2003: 166). Isto tako 11 objekata iz Pločnika pokazuju slaganje sa nalazima iz Dolnoslova, pa se pretpostavlja da su i oni bili izrađeni od rude iz pomenuta tri rudna ležišta (Gale et al. 2003: 167). Jedna grupa predmeta pokazuje slaganje sa rudama iz grčkog dela Trakije (Kirki ležište u grčkom delu Rodopskog masiva, 25 km severno od Aleksandrupolisa i rudne zone Panađurski (Gale et al. 2003: 167–168, Fig. 10.19).

Ispitivanje bakarnih predmeta iz nekropola Durankulak i Varna I pokazala su da je veliki procenat predmeta bio izrađen od metala dobijenog od rude iz rosenskog rudnog polja (Dimitrov 2007; Leshtakov 2010: 175).

2781, 2784 Fig. 10). A more likely source of ores from that period is Majdanpek, which also provided ore that was used in western Bulgaria. It is assumed that there was a larger Early Eneolithic mine at the location of today's mine, but that it was either not discovered, or was destroyed by subsequent mining activities (Pernicka et al. 1993; Pernicka et al. 1997: 146), which seems more likely.

Although it was not common to use ores from the eastern Balkans in the production of the central Balkans, and vice versa, the links between these two regions, in the sense of using ores from the same mines, is attested to by the material from Pločnik and the Varna necropolis. Namely, eight finds from Pločnik and 16 from the Varna necropolis were made of metal obtained from the same ore that came from an, so far, unidentified mine that had an isotopic field very similar to that of Ai Bunar (Gale et al. 2003: 165, Fig. 10.13). It is also possible that the ore from Varli Briag was used for the production of one tool from Pločnik, but also in the production of Late Eneolithic tools from Serbia (the axe-adze from Stojačak, HDm 1401 and the chisel from Jelašnica, HDm 1421; Gale et al. 2003: 165, Fig. 10.14, Fig. 10.16).

The ore used to obtain metal from which the Varna copper finds were made originated from Bulgarian ore fields, even those in the Turkish part of Thrace, but not from Ai Bunar, Majdanpek, Rudnik and Rudna Glava. The copper from Varna was made of ore from Varli Briag, Diebeli Rit, Sokolec, Placalnitsa, Vozdol, Vienietsa-Lakatnik, meden Rid, and Osikota, as well as of ore from a mine that had an isotopic field similar to that of Ai Bunar, (Gale et al. 2003: 166, Abb. 10.15).

The lead isotope analyses conducted on 52 copper find from Dolnoslov revealed that they were not made of ores from Rudna Glava, Bor, Majdanpek, Lesovo and Sedmochislenitsi, and that some of them were made of ore from the mines of Varli Briag, Ai Bunar and those in the Rudnik region in central Serbia (Gale et al. 2003: 166). Also, 11 finds from Pločnik are similar to the finds from Dolnoslov, so it is assumed that they too were made from ores from the three aforementioned mines (Gale et al. 2003: 167). One group of finds displays similarities to ores from the Greek part of Thrace, (the Kirki ore field in the Greek part of the Rhodope zone, 25 km north of Alexandroupoli and the Panagyurishte ore field (Gale et al. 2003: 167–168, Fig. 10.19).

The analyses of finds from the Durankulak and Varna I necropolises revealed that a large percentage of

Nisu svi rudnici i rudna ležišta podjednako korišćeni tokom eneolita i bronzanog doba. Intenzivna eksploatacija Rudne Glave tokom kasnog neolita i ranog eneolita (5400–4650 p.n.e; Borić 2009: 205), jasno vidljiva na samom lokalitetu, nije dokazana analizama metala sa Balkana,[3] za razliku od Majdanpeka gde nije otkriven rudnik, ali zato postoje dokazi da je ruda odatle bila korišćena u dužem vremenskom periodu. Tokom eneolita Ai Bunar i Medni Rid su snabdevali istočnu Bugarsku, a Majdanpek zapadnu Bugarsku i Srbiju. Ruda iz Mednog Rida nije prodrla dublje u kopno Bugarske, ali se pretpostavlja da je proširena na Kukuteni i Tripolje kulture na severu. Dok je Ai Bunar bio više korišćen tokom ranog i srednjeg eneolita, Majdanpek je postao intezivno eksploatisan rudnik tek tokom finalnog eneolita (Pernicka et al. 1997: 145).

## Zaključak

Dosadašnja istraživanja starog rudarstva bakra na Balkanu pokazuju da je ono bilo dobro razvijena aktivnost već od kraja neolita. Dva dobro istražena ranoeneolitska rudnika, Rudna Glava i Ai Bunar, zatim dokazi o korišćenju rude iz većeg broja različitih ležišta i brojni masivni bakarni predmeti otkriveni na centralnom i istočnom Balkanu jasni su dokaz razvijenog rudarstva i metalurgije bakra čiji se počeci stavljaju u sam početak V milenijuma pre nove ere (5000 p.n.e.).

Način eksploatacije rude u najstarijim rudnicima bakra je dobro poznat zahvaljujući istraživanjima na Rudnoj Glavi i Ai Bunaru, ali još nije poznato kako su funkcionisale zajednice prvih rudara. Do sada nije otkriveno nijedno rudarsko naselje u blizini nekog od istraživanih najstarijih rudnika bakra. Izuzetak predstavlja Jarmovac gde je vinčansko naselje bilo smešteno u neposrednoj blizini rudnika, samo 300 m od rudne zone, ali njegova veza sa rudnikom za sada nije poznata, pre svega zato što su iskopavanja tog nalazišta na samom početku. U okolini Ai Bunara otkriveno je više ranoeneolitskih naselja na kojima je nalažena ruda iz Ai Bunara. Nalazi keramike na ovom rudniku,

3 Prirodna radioaktivna kontaminacija rude sa Rudne Glave smatra se jednim od glavnih uzroka negativnih rezultata po pitanju njenog prisustva u bakarnim artefaktima iz Srbije (Jovanović 1993).

finds was made of metals obtained from ores from the Rhodope zone (Dimitrov 2007; Leshtakov 2010: 175).

Not all mines and ore deposits were equally used during the Eneolithic and the Bronze Age. The intensive exploitation of Rudna Glava during the Late Neolithic and Early Eneolithic (5400-4650 BP; Borić 2009: 205), which is clearly visible only at the very site, was not proved by the analyses of metal from the Balkans,[3] unlike at Majdanpek where no mines were discovered, but there is evidence of using locally available ore over a longer period. During the Eneolithic, Ai Bunar and Medni Rid provided ores for eastern Bulgaria, and Majdanpek for western Bulgaria and Serbia. The ore from Medni Rid was not used deeper in Bulgarian territory, but is assumed to have spread to the Cucuteni and Tripolye cultures in the north. While Ai Bunar was more commonly used during the Early and Middle Eneolithic, Majdanpek was more intensively exploited only during the Final Eneolithic (Pernicka et al. 1997: 145).

## Conclusion

The research of ancient copper mining in the Balkans conducted thus far shows that this was a well-developed activity already at the end of the Neolithic. Two well-researched Early Eneolithic mines, Rudna Glava and Ai Bunar, as well as evidence of using ore from different areas and the numerous copper artefacts discovered in the central and eastern Balkans, clearly show that copper mining and metallurgy were well-developed and that such activities started at the very beginning of the 5th millennium BC (5000 BC).

The modes of ore exploitation in the earliest copper mines are well-known due to the excavations conducted at Rudna Glava and Ai Bunar, but how the first mining communities functioned is still to be determined. So far no mining settlements have been discovered in the proximity of the excavated copper mines. The only exception is Jarmovac, where a settlement of the Vinča culture was registered only 300 m from the mining zone. However, seeing as the excavations of the settlement have only just begun, there are no clear links between it and the mine. The area around Ai Bunar yielded several Early Eneolithic settlements that contained ore from Ai

3 The natural radioactive contamination of ore from Rudna Glava is considered to be one of themain causes of negative results when it comes to its presence in the copper artifacts from Serbia (Jovanović 1993).

kao i na Rudnoj Glavi ukazuju na duži boravak ljudi na njima. Može se pretpostaviti da su na samim rudnicima postojali sezonski kampovi u kojima su bili smešteni rudari, ali do sada nigde nisu otkriveni bilo kakvi ostaci stambenih objekata ili tragovi stanovanja kao što su peći i ognjišta.

Dosadašnje analize metalnih predmeta i uzoraka rude iz ležišta nagovestile su da je cirkulacija iskopane rude i metala bila znatno razgranatija nego što se ranije pretpostavljalo. Ruda bakra je na Balkanu eksploatisana na znatno više mesta nego što je danas poznato na osnovu istraživanja starog rudarstva. Iako je ruda cirkulisala na većem prostoru od istočnog Balkana do centralne Evrope, za proizvodnju metala nije korišćena ruda iz susednih vanbalkanskih teritorija kao što su Kipar, Anadolija, Bliski i Srednji istoka, kako se ranije pretpostavljalo (Gale et al. 2003: 168).

Najstariju metalurgiju u Evropi, nastalu na Balkanu, pratilo je razvijeno rudarstvo bakra otkriveno na više mesta u Srbiji i Bugarskoj. Najverovatnije da dobavljanje i širenje rude nije išlo iz jednog usamljenog centra i da je već početkom ranog eneolita na Balkanu postojalo više centara u kojima se vršila eksploatacija rude. Već krajem eneolita na ovoj teritoriji sasvim sigurno postoji veći broj rudnika koji su snabdevali rudom brojne metalurške radionice i intenzivnu proizvodnju metalnih predmeta koju neki autori nazivaju "metalnim bumom" kasnog eneolita (Pernicka et al. 1997: 146). To dokazuje i rudnik na Malom Šturcu na kome su potvrđena okna iz kasnog eneolita. Na celom rudištu otkriven je impozantni broj kamenih batova (do sada c. 1000 alatki) koji ukazuju na veoma živu rudarsku aktivnost na tom mestu.

Kroz istraživanja rudnika Ai Bunar i Rudna Glava, ali u novije vreme i Jarmovac i Mali Šturac, upoznat je način eksploatacije rude u eneolitu. Ipak mnogo je više otvorenih pitanja koja se odnose na sve aktivnosti koje dolaze posle vađenja rude iz ležišta - distribucija rude do metalurških centara i njena prerada. Odgovor na sva ova pitanja zahteva još mnoga nova istraživanja ranog rudarstva i metalurgije Balkana zbog čega je ova tema jedna od nainteresantijih u izučavanju praistorije Balkana.

Bunar. The finds of pottery from this mine, just like at Rudna Glava, suggest that it was occupied for a longer period of time. It can be assumed that there were seasonal camps around the mines, which were occupied by miners, but, so far, there have been no recorded traces of residential structures or habitation, such as kilns or hearths.

The analyses of metal finds and samples of ore from mining zones that have been conducted thus far show that the circulation of the exploited ores and metals was significantly more widespread than was previously thought. In the Balkans, copper ore was exploited at a significantly larger number of places than is assumed based on research of ancient mining. Although the ore circulated on the larger territory from the eastern Balkans to central Europe, ores from neighboring regions outside the Balkans, such as Cyprus, Anatolia, and the Middle East, were not, as previously assumed, used in metal production (Gale et al. 2003: 168).

The earliest metallurgy in Europe, which developed in the Balkans, was accompanied by well-developed copper mining, as was shown at several locations in Serbia and Bulgaria. It seems most likely that the procurement and circulation of ores did not originate from a single centre, and that there were several centers of ore exploitation in the Balkans already at the beginning of the Early Eneolithic. By the end of the Eneolithic, there was definitely an even larger number of mines on this territory that provided ore to numerous metallurgical workshops for the intensive production of metal objects that some authors call the "metallurgical boom" of the Late Eneolithic (Pernicka et al. 1997: 146). This is attested to by the mine at Mali Šturac, which yielded shafts from the Late Eneolithic. The entire mining area yielded an impressive number of stone hammers (c. 1000 tools so far) that point to very dynamic mining activities at that location.

The excavations of the Ai Bunar and Rudna Glava mines, as well as the more recent ones conducted at Jarmovac and Mali Šturac, revealed the modes of Eneolithic ore exploitation. However, there are still more unanswered questions regarding all activities that follow ore extraction from the deposit – the distribution of ore to metallurgical centers and its processing. The answers to all of these questions require more new researches into early mining and metallurgy of the Balkans, making this topic one of the most interesting in the study of Balkan prehistory.

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