

ENEOLITHIC MINE PRLJUŠA – MALI ŠTURAC ARCHAEOLOGICAL AND GEOPHYSICAL INVESTIGATIONS

UDK: 902.3:550.83(497.11)"2011" ; 903:622"636"(497.11)

DOI: 10.2298/STA1262095A

Preliminary communication

e-mail: d.antonovic@ai.sanu.ac.rs

Received: February 16, 2012

Accepted: June 21, 2012

Abstract. – The Eneolithic copper mine at Mali Šturac was discovered in 1980 and subsequently investigated to a smaller extent from 1981 to 1987. In 2010 the investigations at Prljuša were reactivated with the aim of defining how much and how long the mine had been exploited during prehistory. Pilot geophysical studies were followed by more extensive explorations in 2011. They focused on a zone related to Shafts 4 and 6, discovered in 1987. The geophysical explorations have comprised the methods of self-potential – SP, electrical scanning – ES and seismic profiling with one geophone – SGRP. The explorations covered a surface of 400 m² including five sections, each 50 m long, with 2 m intervals between them. These investigations identified underground channels in Shaft 4 and Shaft 6. Three meters below Shaft 4, a large underground gallery was found and in the continuation of the entrance of Shaft 6, a 10 m long horizontal channel was detected. Northwards from Shaft 4 and Shaft 6, at a distance of 6–8 m, at least six mining shafts were detected. However, they are not visible on the surface because their entrances are filled with loose material. The investigations carried out in 2011 proved that geophysical investigations are an efficient method for studying old mining works and, therefore, it has been decided to continue with this type of exploration.

Key words. – copper mine, geophysical investigations, Eneolithic, archaeometallurgy, Serbia.

The name Mali Šturac¹ has long been known in archaeology as an Eneolithic copper mine. The mine was discovered in 1980 during reconnaissance works on Mt. Rudnik in the preparation for a new project.² The first archaeological investigations were done in 1981 when potential entrances into two shafts (Shafts 1 and 2) were discovered. The explorations continued in 1987 when four additional shafts were found (Shafts 3, 4, 5 and 6) but further excavations of the already detected shafts have never been done. Shafts 5 and 6 have been extensively studied and their approaching platforms, with visible mining adits,

¹ The Eneolithic mine is located at the Prljuša site, which is situated at the top of Mali Šturac. However, the site appeared in literature with this second name and it is better known according to it.

² In 1980 the project entitled “Project of investigations of old mining and metallurgy on Mt. Rudnik” started. It finished in 1989 and it was completed in cooperation with the Archaeological Institute of Belgrade, the National Museum of Čačak, the Institute for Cultural Heritage Preservation of Kraljevo and the National Museum of Kraljevo. The coordinator of the project was Dr. Borislav Jovanović from the Archaeological Institute. The project aimed at investigating physical traces, indirect evidence and other cultural remnants related to old mining and metallurgy in the area of Mt. Rudnik, from Prehistory to the Medieval Age (Jovanović 1988, 11, footnote. 2).

* The article is the result of the projects: *Archaeology of Serbia: cultural identity, integration factors, technological processes and the role of the Central Balkans in the development of European prehistory* (no 177020) and *Cultural changes and population movements in the early prehistory of the Central Balkans* (no 177023) financed by the Ministry of Education, Science and Technological Development of the Republic of Serbia. The investigations at Prljuša have been done with the support of the Ministry of Culture, Media and Information Society of the Republic of Serbia and the Municipality of Gornji Milanovac.

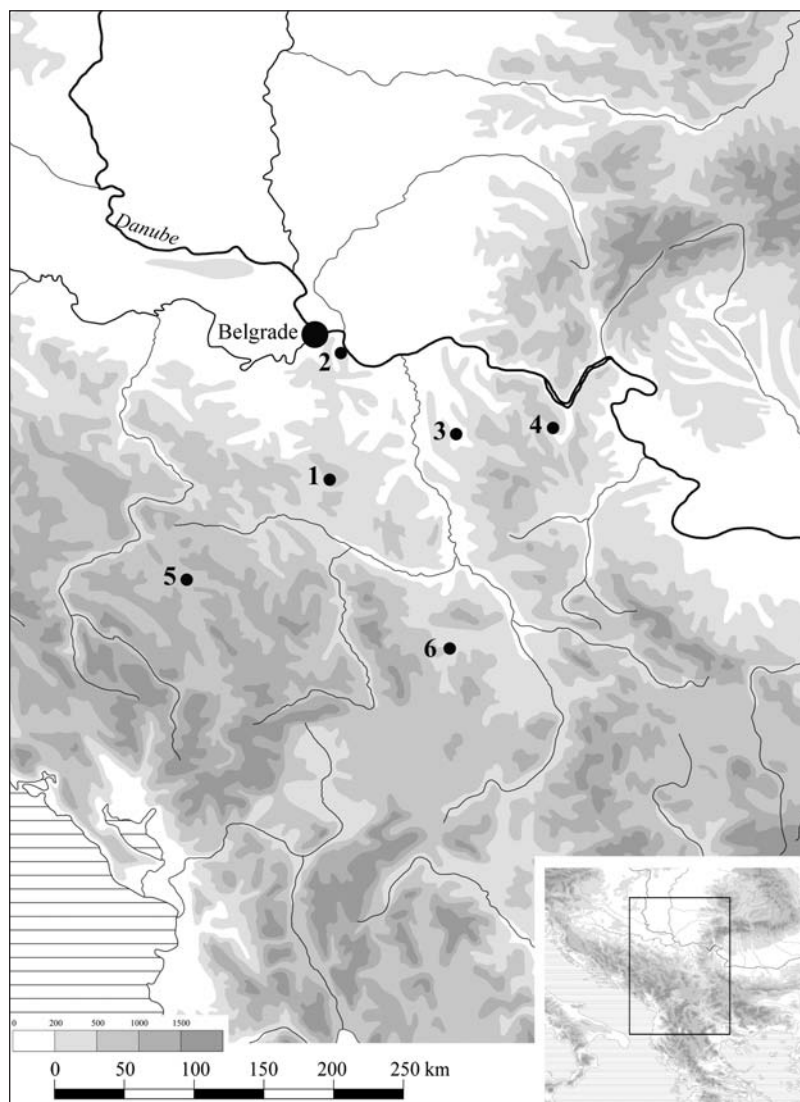


Fig. 1. The earliest copper ore mines and copper finds in Serbia: 1) Prljuša; 2) Vinča; 3) Belovode; 4) Rudna Glava; 5) Jarmovac; 6) Pločnik

Сл. 1. Најстарији рудници бакра и налази од бакра у Србији: 1) Прљуша; 2) Винча; 3) Беловоде; 4) Рудна Глава; 5) Јармовац; 6) Плочник

indicate that a few ore veins might have been exposed at this place. Poor archaeological material collected during the excavations comprised numerous mining hammers, broken mining tools originally made of deer horns as well as small fragments of Late Eneolithic or Early Bronze age ceramics.³ Two years later, in 1989, geodetic surveys were carried out on the part of the slope where shafts had been detected and these were the last investigations carried out in this area. However, during the last decades significant advancements were made in the study of the beginning of metallurgy in the territory of Serbia. The earliest occurrences of copper were dated to the period of the end of the early phase of the Vinča Culture (the transition from Vinča–Turdaš II to Gradac Phase), i.e. 5000 years BC.⁴ Intensive metallurgic activity was recorded at a few sites in Serbia (Belo-

vode, Pločnik and Vinča),⁵ and it raised the question as to where the copper ore, which was melted and produced the first metal in this area, came from (Fig. 1). Until now there was only one unequivocally documented mine from the period of the Vinča Culture – Rudna Glava in eastern Serbia, while the locality of Jarmovac near Priboj is considered to have been exploited during the late Vinča Culture, mainly based on the fact that, in the neighbourhood, a settlement of the same period exists.⁶ Taking

³ Јовановић 1988, 8; Богосављевић 1988, 21, 31.

⁴ Radivojević et al. 2010, 2778.

⁵ Antonović 2002; Radivojević 2007; Šljivar et al. 2006.

⁶ Јовановић 1982; Derikonjić et al. 2011.

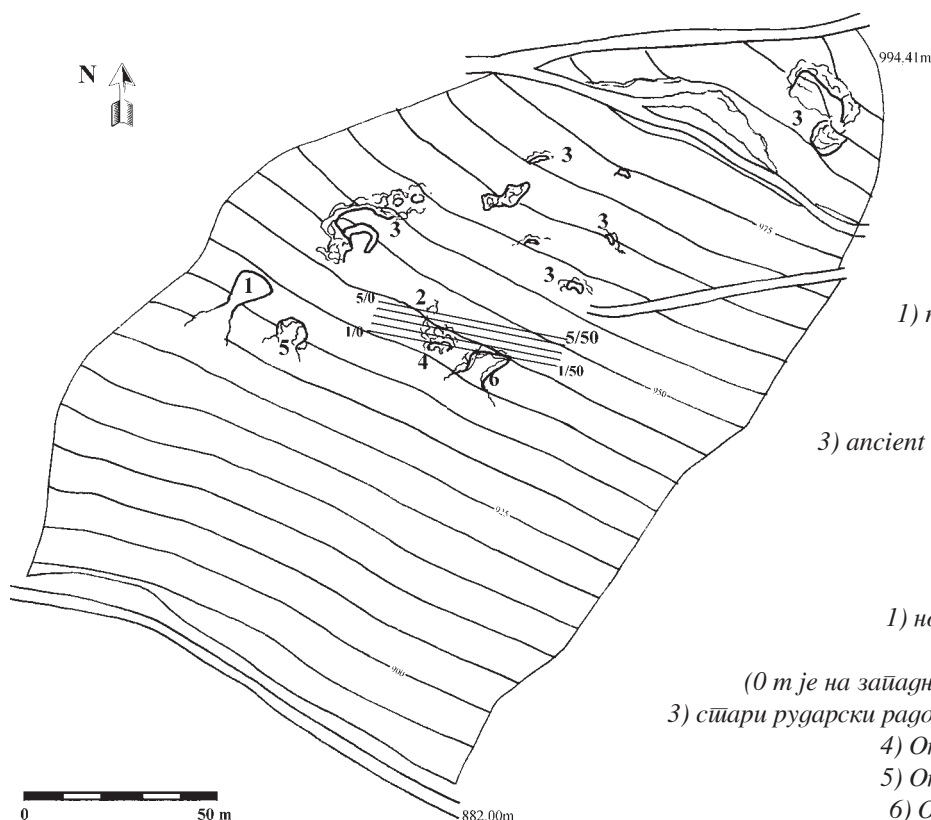


Fig. 2. The locality of Prljuša:
 1) modern shaft from 20th century;
 2) geophysical profiles 1–5
 (0 m is on the west end,
 50 m on the east end);
 3) ancient mining works detected in 2011;
 4) Shaft 4, discovered in 1987;
 5) Shaft 5 discovered in 1987;
 6) Shaft 6 discovered in 1987

Сл. 2. Локалитет Прљуша:
 1) ново рударско окно из 20. века;
 2) геофизички профили 1–5
 (0 m је на западном, 50 m на источном крају);
 3) стари рударски радови децектовани 2011. године;
 4) Окно 4 ошкривено 1987. године;
 5) Окно 5 ошкривено 1987. године;
 6) Окно 6 ошкривено 1987. године

into account the evidence of intensive metallurgic activity, there is no doubt that at that time, as well as later on, there were several active mines in the territory of Serbia and that one of them was Mali Šturac. Until now, however, there has been a lack of material evidence regarding the exploration at Prljuša during the Vinča culture. Due to this fact, and because of the size of the locality and the volume of ore reserves of Mali Šturac, there was a growing need for a more intensive investigation of this site. This was the major reason for renewing investigations at Prljuša in 2010.⁷ These studies, principally focused on geophysical methods, are hoped to define the extent at which the Prljuša site was exploited during prehistory.

ABOUT THE LOCALITY

The locality of Prljuša is situated on the south-western slopes of Mali Šturac. It is not a typical gossan deposit appearing as an almost ellipsoidal surface without vegetation⁸, elongated from the southwest to the northeast. The locality covers a surface of 2.5 ha. It is 234 m long (SW–NE) and 138 m wide (SE–NW), rang-

ing in altitude from 882 m to 994.41 m. The slope is very steep with an average dipping angle ranging from 28° to 31°, reaching as much as 37° in the lower part (Fig. 2). The investigations undertaken in 2011 revealed the presence of 13 complexes of older mining works in the area above the line connecting Shafts 4, 5 and 6 (discovered in 1987). The field relationships suggest that this number is likely to be exceeded in the future. Considering the shape of the mining works (irregular form of adits) and the huge number of mining

⁷ The project of the Archaeological Institute entitled “Prospection of Mali Šturac: an investigation of prehistoric mining” is performed in cooperation with the Museum of Rudnik–Takovo region in Gornji Milanovac. Additional co-operators in the project are Ana Cicović, archaeologist-custodian from the aforementioned museum and Momir Vukadinović, geophysicist from the Institute for the Development of Water Resources “Jaroslav Černi”, Belgrade. The coordinator of the project is Dr. Dragana Antonović from the Archaeological Institute of Belgrade.

⁸ The word Prljuša means burned soil. Gossan originated from the decay of sulphide mineralisation of iron minerals (pyrite) and the formation of limonitic products due to the influence of oxygen and electrochemical processes. Due to these processes, the soil is sterile and without plant cover.

hammers with grooves which were found on the surface along the slope, it can be supposed that these were Eneolithic and Bronze Age shafts.

The Mt. Rudnik area is characterised by a complex geological framework.⁹ It consists of sedimentary, igneous and contact-metamorphic rocks. The most abundant sedimentary rocks are Cretaceous flysches. The origin of igneous rocks is explained by volcanic activity in the Mt. Rudnik area during the Oligocene and Miocene. Dacite-andesites were formed in the Oligocene, while the majority of volcanic rocks are represented by quartzlatites which erupted in the Miocene as huge irregular masses and tiny dikes and sills, widespread in the “Rudnik” ore district. Contact-metamorphic rocks are represented by weakly metamorphosed, marl-clayey sediments, sandstones and conglomerates, as well as by products of higher grade metamorphic rocks, such as hornfels and skarn. Intrusions of dacite-andesites and quartzlatites were mainly controlled by NE–SW fault systems.

The “Rudnik” lead-zinc ore deposit is polymetallic in character and consists of a few tens of ore bodies. The geological framework of the deposit is composed of several rock complexes, different in genesis, age and composition. Four main groups can be distinguished: 1. Cretaceous sedimentary complex (sandstone, breccia, conglomerate, marl and limestone), 2. Tertiary igneous rocks (dacite-andesite, quartzlatite and rare granitoid rocks), 3. Contact-metamorphic complex (hornfels, epidosite, marble, garnetite, skarn, etc.); these are important because they host the mineralisation, and 4. Hydrothermal breccia complex; these rocks are significant because they originated simultaneously to the mineralisation.

GEOPHYSICAL INVESTIGATIONS

Field geophysical investigations at Prljuša were conducted in order to detect the spatial distribution of subsurface mining galleries which, presumably, exist in this area as well as to plan future excavations. It was, therefore, decided to first investigate the space above Shafts 6 and 4 (discovered in 1987) (Fig. 2). Pottery shards that were found at the access platform of Shaft 6 defined the shaft chronologically as belonging to the Late Eneolithic or Early Bronze age. The fact that the entrance to the mining channel was discovered is the reason to believe it is a real mining shaft. The entrance was discovered in 1987.

Geophysical explorations were done using the methods of self-potential – SP, electrical scanning – ES and seismic profiling with one geophone – SGRP.

The measurements were carried out along the terrain surface delineated by five, 50 m long, parallel sections at 2 m intervals. The measured points at the sections were located at every 2 m, and the sections were oriented approximately east-west, according to archaeological and geological facts.

Self-potential measurements were taken along the same sections. Vertical, two-dimensional (2D) terrain sections were defined by electrical scanning on the basis of specific electrical resistivity. These measurements, along with the measurements taken by seismic profiling were taken along sections 1, 4 and 5.

Self-potential method

The self-potential method (SP) is based on the investigation of natural electrical currents which spontaneously appear in material below the terrain surface. The most frequent occurrences of self-potential are connected with the movement (i.e. filtration) of ground water through rock masses. The most intensive appearances of self potential are those related to the presence of metallic ore deposits, where the self potential is generated as the consequence of electrochemical processes occurring in response to interactions between ore bodies and ground water.¹⁰

Due to the simplicity and efficacy in performing the SP method in the field, and because of the speed with which qualitative data can be obtained, this geophysical method was selected for detecting ore occurrences and the prehistoric mining works, chambers and shafts, from which the ore was extracted.

The efficacy of this method was practically examined at the Prljuša site in 2010. On that occasion, two, 51 m long, sections were allocated – one immediately below and another above Shafts 6 and 4 from 1987.¹¹

After having obtained satisfactory results by the SP method, it was decided to apply the same method of investigation to the majority of the area above the two shafts.

⁹ All information about the geological framework of the Mt. Rudnik area presented in the paper has been obtained by the courtesy of the Geological Service at “AD Rudnik i flotacija ‘Rudnik’” in Rudnik. The authors are very grateful to geologists of the Service for their very kind cooperation.

¹⁰ Vukadinović 2011, 79.

¹¹ Антоновић, Вукадиновић 2011.

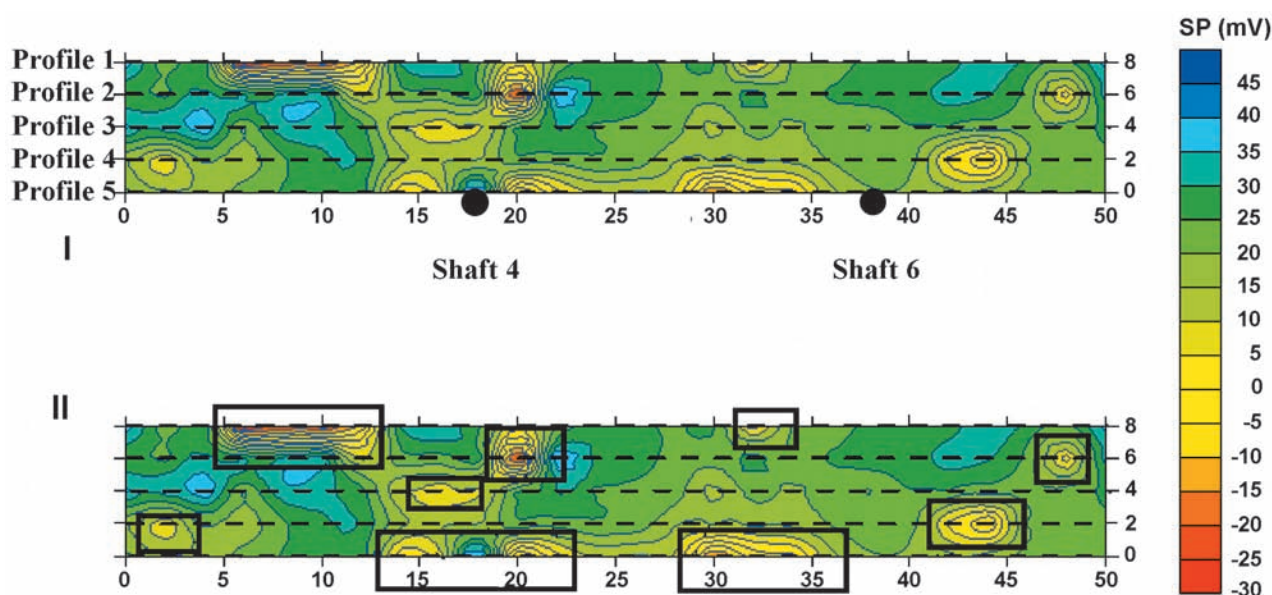


Fig. 3. Self-potential map: I) with position of adits in Shafts 4 and 6 discovered in 1987; II) with position of the zones of anomalies which represent ore deposit or prehistoric mining works

Сл. 3. Карта сопственог појеницијала: I) са означеним улазима у Окно 4 и Окно 6 из 1987. године; II) са означеним аномалијским зонама које представљају оруђење односно појеницијалне старе рударске радове

The SP measurements were conducted at all 5 sections; the measured points were placed at 2 m intervals throughout a regular network of 50 x 8 m.¹² The obtained data were used for constructing a map of potential isolines in the interval range of -30 to 45 mV (Fig. 3).

In accordance with the physical laws and explanations of the origin of self-potential in ore-bearing areas, anomaly zones were delineated on the map. These anomalies are controlled by negative values which indicate the presence of mineralisation, e.g. the presence of copper ore bodies. The defined anomaly zones have a value of -10 to -30 mV (Fig. 3, from orange to red colour in the legend).

The zones of anomalies defined by positive self-potential values represent the zones of compact, intensively silicified rock masses in which there is no mineralisation. A strong silicification is also inferred by the presence of abundant quartz aggregates on the surface.

During the measuring of the self-potential at Prljuša it was observed that if, in the zone of mineralisation or ore deposit, a prehistoric pit was opened, there were pre-conditions for the subsequent filling of the shaft with atmospheric water. This gave rise to electrochemical processes which generated self-potential. Furthermore,

if the shaft was not opened, the mineralisation remained hermetically captured in compact and water-impermeable, highly silicified rocks. In such a scenario, atmospheric water cannot enter and self-potential cannot be generated. On the basis of this explanation, it could be concluded that the detection of self-potential anomalies at Prljuša is most probably related to the presence of prehistoric pits.

Electrical scanning measurements

Electrical scanning by direct current (Direct Current Resistivity Imaging) is a commonly used technique in archaeology. It is aimed at getting 2D (two-dimensional) terrain models in the form of a vertical section according to a specific electrical resistivity parameter.¹³ The scanning represents a method of investigating a certain area at several depth levels below the surface in order to detect subsurface structures (cultural remnants) and to determine their spatial

¹² In the field, self-potential was measured by millivoltmetre Voltcraft type M-3630B. The nonpolarised electrodes are of Canadian production (Scintrex Company).

¹³ Vukadinović 2011, 55.

position. Moreover, it is possible to use different types of electrodes, depending on the aims of the investigation and the desired outcome.

At the Prljuša site, the electrical scanning method was chosen with the goal of creating spatial 2D detections of ore occurrences and mineralisations, i.e. prehistoric mining works, such as mining chambers or adits from where the ore was extracted.

After having analysed the results obtained by the self-potential method, we concluded that the electrical scanning should be done along sections 1, 4 and 5 because it is along these sections that the most significant anomaly zones, indicating the presence of mineralisation extracted from prehistoric shafts, were identified.

Along the above mentioned sections, the electrical scanning measurements were conducted at intervals of 1 m. The protocol pole-pole was used¹⁴, and a penetration of around 10 m was achieved. The data obtained by the measurements were processed using inversion procedures and in this way 2D electrical models were produced (Fig. 4).

On these 2D electrical models, different geological units are detected in the range between 170 and 18 000 Ohmm. The lowest values of electrical resistivity correspond to copper ore (malachite), while high resistivity values indicate the presence of crystalline and silicified rocks with abundant aggregates of quartz crystals.

Based on the obtained 2D models it is observed that copper mineralisation (malachite) is distributed in the form of irregular steep, vertical channels. The copper mineralisation has an electrical resistivity from 170 to 300 Ohmm (Fig. 4, dark blue and blue colour in legend). These channels were created by the deposition of mineralisation during the post-magmatic hydrothermal phase. The circulating hydrothermal fluids leached copper and accompanying elements and precipitated them along the channels, forming characteristic north-northwest-south-southeast stretching ore veins.

In section 1 (Fig. 4), two large zones with anomalies were distinguished. The first zone is close to the terrain surface and stretches between the 12th and 19th metre of the section. It further reaches depths of around 10 m where it continues from the 18th to 34th metre along section 1. The aforementioned zone is most probably in functional connection with Shaft 4 which has a 2–3 m long, vertical entrance. The second anomaly zone is isolated in the right-hand side of the 2D electrical section, between the 38th and 48th metre along the section.

This zone is detected at depths of around 5 m and it is most probably in functional connection with Shaft 6. This shaft continues horizontally towards the east, i.e. towards the central part of the mineralisation zone.

Given that there are no known shafts for correlation with the results of the electrical scanning, we have only reported the position of three anomaly zones that have the lowest electrical resistivity in section 4 (Fig. 4). These anomaly zones could indicate that buried shafts, not visible from the terrain surface, also exist. The first zone was detected at depths of around 4 m and between the 4th and 15th metre along the section. The second zone was detected at similar depths from the 27th to 29th metre along the section. The third zone was found at depths of 4–5 m and from the 34th to 43rd metre along the section.

Neither of the section 5 prehistoric shafts, whose position can be used for correlation with the results of electrical scanning, are present (Fig. 4). In this section three anomaly zones with low electrical resistivity are detected, suggesting that some shafts may be present. The first anomaly zone is located from the 16th to 18th metre along the section and runs vertically more than 10 m in depth. The second anomaly zone is situated from the 25th to 27th metre, reaching depths of around 3 m. The third anomaly zone is almost vertical and stretches from the 37th to 42nd metre and is as deep as 10 m.

Seismic profiling

The SGRP method (Single Geophone Refraction Profiling) represents a procedure of seismic terrain mapping with one or two geophones. It relies on methodological approaches used for carrying out refraction or reflective seismic methods. The SGRP method enables the detection of the lateral influences of geological materials and distinguishing hollowed spaces as decompression zones beneath the terrain surface. In addition, it allows the detection of vertical and subvertical discontinuities between various geological materials characterised by differences in seismic wave velocities.¹⁵

The application of the SGRP method at Prljuša was aimed at distinguishing hard and silicified rock masses from disintegrated zones and subsurface cavities from which prehistoric miners had extracted the raw material, malachite.

¹⁴ The device Geophysical Resistivity & Self Potential Meter RPM-12 IP was used for the measurements.

¹⁵ Vukadinović 2011, 43.

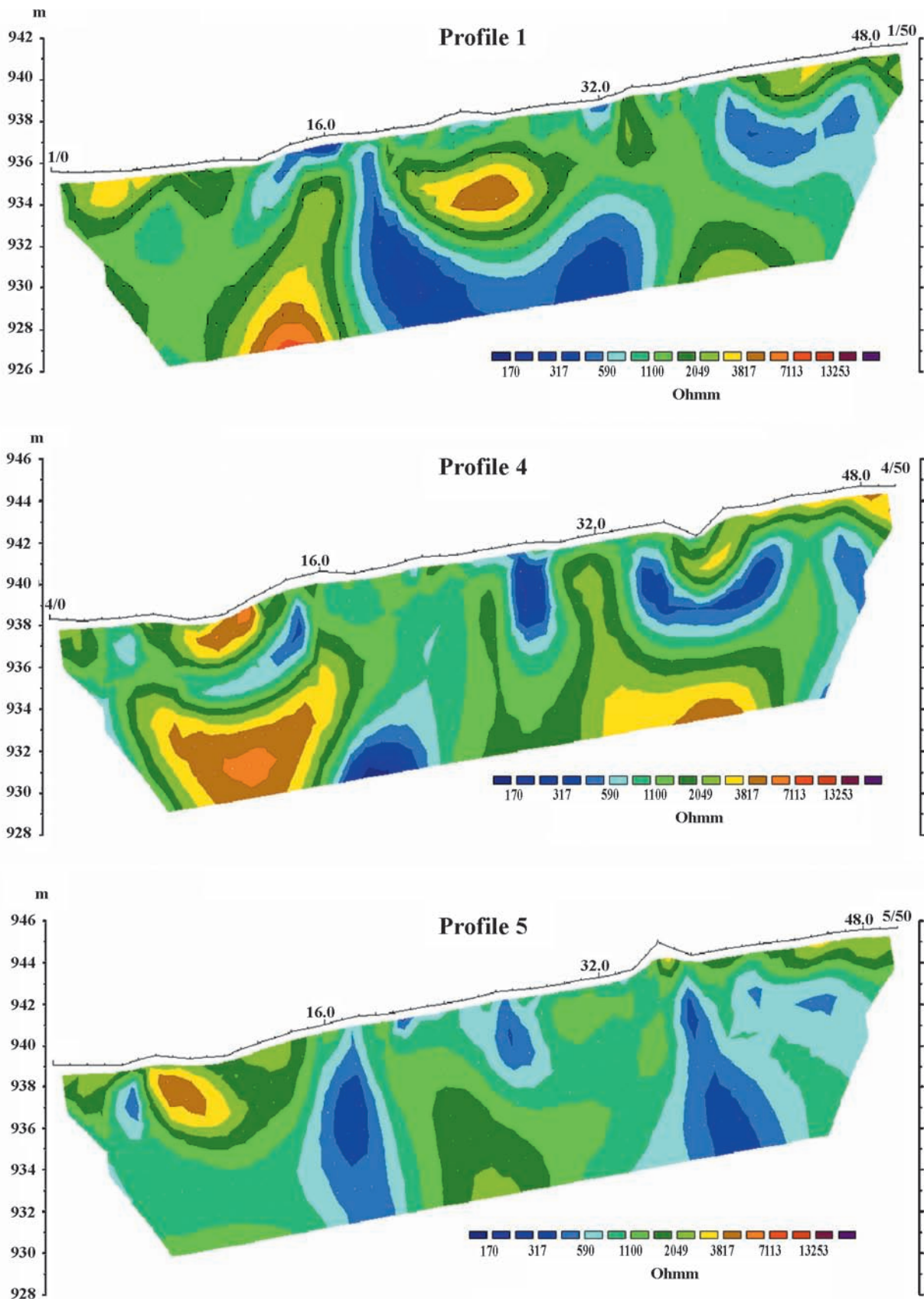


Fig. 4. 2D resistivity sections along the profiles 1, 4 and 5

Сл. 4. Геоелектрични пресеци по профилима 1, 4 и 5

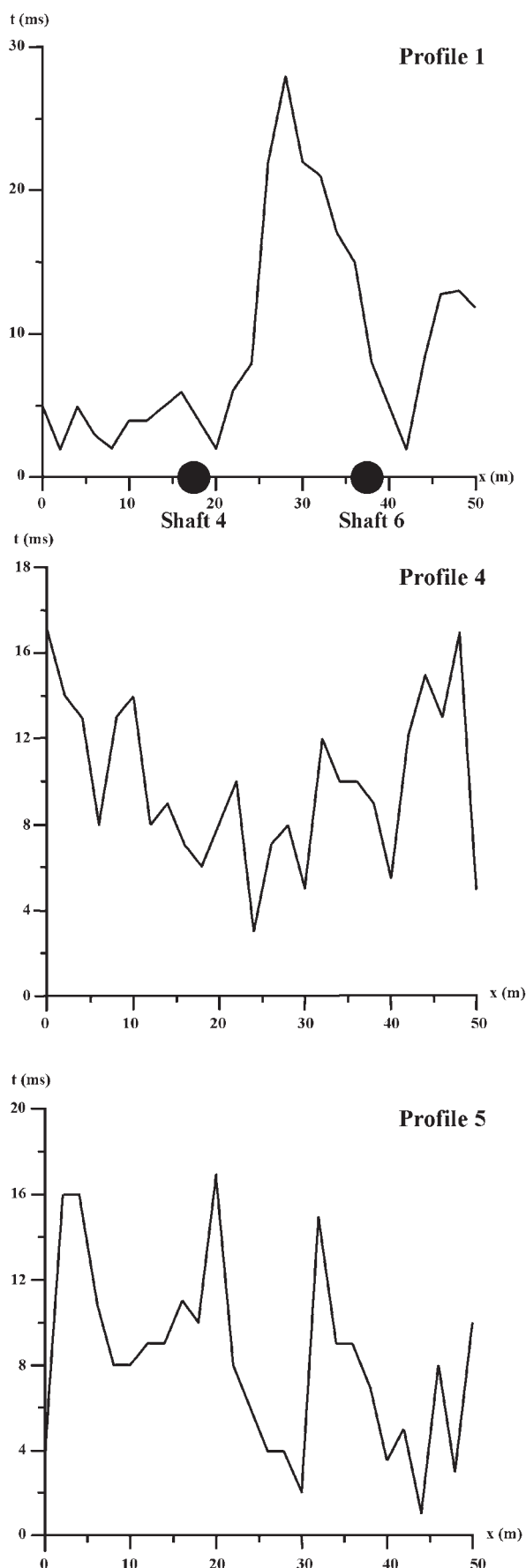


Fig. 5. Diagrams of seismic profiling along the profiles 1, 4 and 5. Position of adits in Shafts 4 and 6 discovered in 1987 is marked on the profile 1

Сл. 5. Дијаграми сеизмичкој профилсања по профилима 1, 4 и 5. Улази у Окна 4 и 6 из 1987. године су означени на профилу 1

The SGRP method was conducted using a measurement network composed of an excitation point, Tx and two reception points, Rx1 and Rx2.¹⁶ It required acquiring the variation of seismic waves coming between the two reception points in order to easily recognise the influences of lateral lithological changes or the presence of underground empty spaces, i.e. pre-historic mining shafts.

The above described seismic profiling was performed along sections 1, 4 and 5 in order to enable easier correlation with the results obtained by the self-potential and electrical scanning procedures.

In section 1 (Fig. 5) two anomaly zones with considerably longer arrival times of seismic waves were observed. The first zone (from the 18th to 34th metre along the section) with a maximum of almost 30 ms (milliseconds) overlaps with the anomaly in electrical resistivity, which was observed by the scanning method. The second anomaly zone is characterised by shorter arrival times, below 15 ms, and corresponds to the anomaly in the resistivity parameter, which was observed from the 38th to 48th metre along section 1.

The SGRP measurements in section 4 (Fig. 5) detected several anomaly zones characterised by longer arrival times of seismic waves. They are essentially located at the beginning and the end of the section. The first anomaly established by this method is located from the beginning to the 15th metre along section 4. The second, smaller anomaly of longer arrival times of seismic waves is detected around the 20th metre along the section. It is most probably connected to the electrical resistivity anomaly zone found occurring at depths of around 8 m. The third and fourth anomaly indications are situated between the 30th and 35th metre and between the 45th and 50th metre along the section, respectively. The identification of anomaly zones obtained by the SGRP method on this section was difficult due to fre-

¹⁶ To measure the arrival time of seismic waves an Iskrascope LCD type ODU0401 device was used. SN-3 geophones with a frequency range of 10–14 Hz were used as geophones.

quent lithological changes and vertical and/or steeply dipping structures.

The same SGRP measurements were performed along section 5 (Fig. 5). The estimated arrival times of seismic waves revealed the presence of two anomaly zones situated from the 15th to 20th metre and from the 30th to 40th metre along the section. These two anomaly zones spatially overlap with the locations of the anomalies detected by electrical scanning.

CONCLUSION

The field measurements performed using the geophysical methods of self-potential, electrical scanning and seismic profiling at the Prljuša site provided some useful data and conclusions.

The self-potential method conducted along five sections, each 50 m long, revealed the existence of malachite mineralisation zones inferred from distinctive negative values (Fig. 3). The acquired results suggest that the observed anomalies are most probably the result of the presence of subsurface prehistoric shafts. These shafts were subsequently filled with atmospheric water creating the necessary electrochemical conditions for the formation of self-potential.

Electrical scanning performed on sections 1, 4 and 5 gave clearer definitions of the anomaly zones obtained by the self-potential method. The results of these two methods enabled the correlation and connection with the opened prehistoric Shafts 4 and 6. This gave rise to the detection of old mining operations in the whole zone covered by geophysical investigations (Fig. 6). Thus, the reconstruction of mining operations in the zone of Shaft 6 was achieved. In section 1, from the 38th metre to the end of the section and at depths of around 5 m, a mineralisation zone (malachite) was detected. The altitude of this almost horizontal zone is 936 m and is directed towards the east. The beginning of the mineralisation zone at the 38th metre overlaps with the entrance of Shaft 6, which was discovered in 1987 at the eastern end of the entrance platform. Hence, it could be expected that the mining channel continues from the entrance horizontally to the east for the next ten metres, and then abruptly goes vertically down. Its termination point is still not known because that part of the shaft was not covered by geophysical investigations.

In section 1, from the 18th to 19th metre, there is inferred mineralisation which has an almost vertical position and is in direct connection with Shaft 4 (dis-

covered during archaeological excavations in 1987). The entrance of Shaft 4 is covered with loose material and is not visible today. According to the geophysical data, we expect that the shaft stretches vertically down for around 3 m from the surface and then continues further, forming a huge, almost horizontal, underground gallery. In fact, it is possible that it is a larger gallery or a crossroad of two vertical mining corridors which are situated deeper than 10 m from the surface. In this case, geophysical investigations reaching more than 10 m would resolve a large anomaly detected in section 1 where it connects with Shaft 4 (discovered in 1987).

If we combine the results obtained from section 1 with those acquired during the archaeological investigations in 1987, and apply them to the image provided by our geophysical studies in sections 4 and 5, we may conclude that there were at least six mining shafts whose entrances were situated 6 m and 8 m northwards from shafts 4 and 6, respectively. Some of these works penetrated 4 m in depth (2D electrical section 4: 4th–15th metre, 27th–29th metre, 34th–43rd metre, 2D electrical section 5: 25th–27th metre, Fig. 4) while others had depths greater than 10 m (2D electrical section 5: 16th–18th metre, 37th–42nd metre; Fig. 4).

The SGRP seismic profiling confirmed, albeit not so precisely, the most probable presence of mining shafts at the locations where anomaly zones were distinguished according to the parameters of self-potential and specific electrical resistivity.

Numerous pieces of evidence of mining operation works testify to intensive mining activity at the Prljuša site. The size of the entrances into some underground galleries led previous researchers to suppose that these shafts originated from periods younger than prehistory, possibly even from the Medieval Age. However, the fact that at Prljuša malachite was found – the carbonate copper ore which had not been exploited since the Iron Age. i.e. since the mastering of iron melting technology, along with the large number of stone mining hammers located on the surface from the top to the bottom of the locality, especially in the zone below the shafts, additionally suggest that Prljuša was a large prehistoric mine. The exploitation in the upper parts was carried out during the late Eneolithic and early Bronze Age, and this is confirmed by typical finds from Shaft 6. We presume that in the lower parts of the slope, now covered by thick layers of loose material, the exploitation could have been even earlier.

Due to all these facts, we argue that geophysical investigations should be continued along the whole

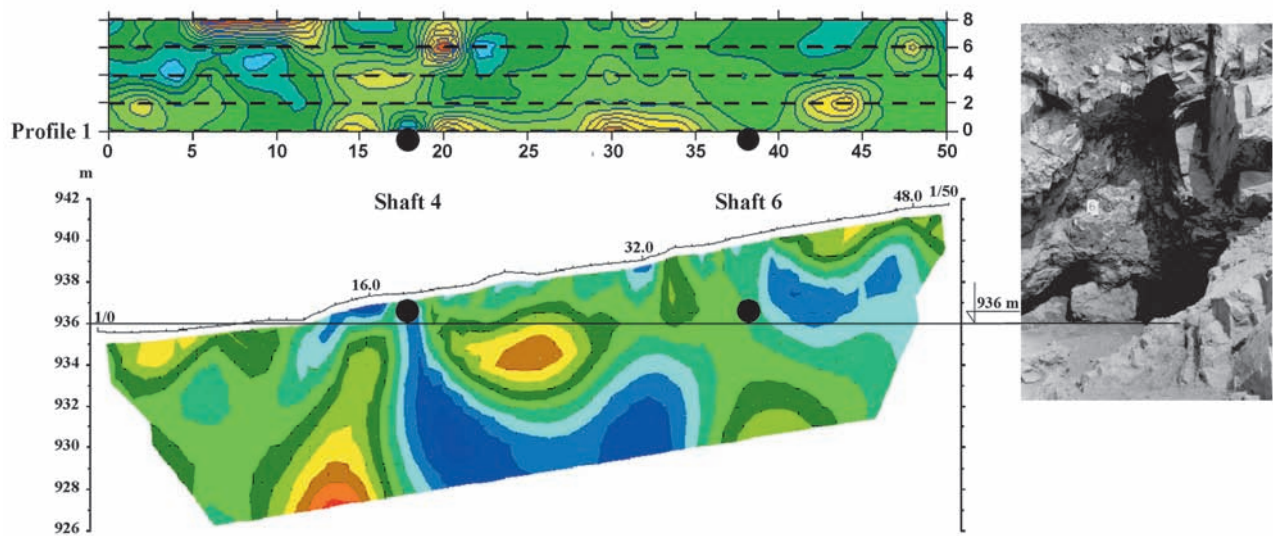


Fig. 6. Correlation of self-potential measurements and 2D electrical scanning along the profile 1 with the prehistoric Shafts 4 and 6 discovered in 1987; on the right is a photo of the entrance to the mining channel of the Shaft 6 when it was discovered

Сл. 6. Корелација резултата мерења сопствене појеницијала и електричне скенирања по профилу 1, са означеним у Окнима 4 и 6 из 1987. године; десно је слика улаза у Окно 6 из времена када је оtkривен

slope. In the upper part, above the mining works discovered during the 1980's, geophysical investigations should be conducted in the zone where the majority of potential shafts were detected in 2011. Such investigations should also be carried out in the lower parts of the slope as there is a reasonable possibility that old mining works and archaeological objects are hidden below the thick layers of loose material. According to the acquired results and taking into consideration the foreseen activities, it is concluded that the application of

self-potential (SP) and electrical scanning (ES) methods in using 2D and 3D variants would be most appropriate and most economic. The self-potential measurements should cover almost the entire locality and only at places revealing negative anomaly values, would the presence of prehistory mining works be proved by electrical scanning.

Translated by Kristina Šarić
and Vladica Cvetković

BIBLIOGRAPHY:

Antonović 2002 – D. Antonović, Copper processing in Vinča: new contribution to the thesis about metallurgical character of Vinča culture, *Старинар* LI (2002), 27–45.

Антоновић, Вукадиновић 2011 – Д. Антоновић, М. Вукадиновић, Прљуша – Мали Штурац: нова истраживања праисторијског рудника на Руднику, *Наша прошлост* 12, 35–45.

Богосављевић 1988 – В. Богосављевић, Покретни материјал са праисторијског рудника на Малом Штурцу, *Зборник радова Народне музеја XVIII* (1988), Чачак, 13–35.

Derikonjić et al. 2011 – S. Derikonjić, M. Radivojević, E. Pernicka and Th. Rehren, The Vinča culture mining complex in Jarmovac, southwest Serbia, in A. Hauptmann, D. Modarressi-Tehrani & M. Prange eds., *International Conference Archaeometallurgy in Europe III, 29 June – 1st July 2011, Bochum, Metalla Sonderheft* 4, Bochum, 39.

Jovanović 1982 – B. Jovanović, *Rudna Glava: najstarije rudarstvo bakra na centralnom Balkanu*, Bor, Beograd.

Јовановић 1988 – Б. Јовановић, Прљуша – Мали Штурац: праисторијски рудник бакра и горског кристала на Руднику, *Зборник радова Народне музеја XVIII*, Чачак, 5 – 12.

Radivojević 2007 – M. Radivojević, *Evidence for early copper smelting in Belovode, a Vinča culture site in Eastern Serbia*, Unpublished MSc Thesis, London UCL Institute of Archaeology, 2007.

Radivojević et al. 2010 – M. Radivojević, T. Rehren, E. Pernicka, D. Šljivar, M. Brauns, D. Borić, On the origins of extractive metallurgy: new evidence from Europe, *Journal of Archaeological Science* 37 (2010), 2775–2787.

Šljivar et al. 2006 – D. Šljivar, J. Kuzmanović-Cvetković, D. Jacanović, Belovode – Pločnik, new contributions regarding the copper metallurgy in the Vinča culture, in: *Homage to Milutin Garašanin* (N. Tasić, C. Grozdanov, eds.), Serbian Academy for Science and Arts, Belgrade, 251 – 266.

Vukadinović 2011 – M. Vukadinović, *Primena geofizike u arheologiji*, Kraljevo.

Резиме:

ДРАГАНА АНТОНОВИЋ, Археолошки институт, Београд
МОМИР ВУКАДИНОВИЋ, Институт за водопривреду „Јарослав Черни“, Београд

ЕНЕОЛИТСКИ РУДНИК ПРЉУША – МАЛИ ШТУРАЦ АРХЕОЛОШКА И ГЕОФИЗИЧКА ИСТРАЖИВАЊА

Кључне речи. – рудник бакра, геофизичка истраживања, енеолит, археометалургија, Србија.

Име Малог Штурца одавно је познато у археологији као назив енеолитског рудника бакра. До његовог открића дошло је још давне 1980. године током рекогносцирања планине Рудник у оквиру једног новог пројекта. Археолошка истраживања вршена су од 1981. до 1989. године. Тада су откривене улазне платформе у шест праисторијских рударских окана. Даље ископавање детектованих окана никада није извршено. Малобројан археолошки материјал прикупљен током ископавања састојао се од већег броја рударских бадова, уломака рударских алатки од јеленског рога и малих фрагмената керамике из касног енеолита или раног бронзаног доба. Како је у међувремену, током протеклих деценија, учињен знатан помак у проучавању почетка металургије на тлу Србије, питање порекла руде бакра од које се топио

први метал на овом тлу постало је врло актуелно. До сада је на овим просторима поуздано документован само један рудник из времена винчанске културе – Рудна Глава у источној Србији. Нема сумње да је у то време, али и касније, с обзиром на интензивну металуршку активност, било више активних рудника на територији Србије и да је Мали Штурац био један од њих.

Локалитет Прљуша налази се на југозападној падини Малог Штурца. Реч је о не баш типичном „гвозденом шеширу“ – површини без вегетације, скоро елипсоидно издуженој правцем југозапад–североисток. Локалитет има површину око 2,5 ha и простира се од 882 m у подножју до 994,41 m надморске висине при врху падине. Реч је о веома стројој падини са нагибом од 28° до 37°. Током истраживања 2011.

године на делу падине изнад линије коју чине окна 4, 5 и 6, откривена 1987. године, констатовано је 13 комплекса старих рударских радова. Према изгледу рударских радова (улази неправилног облика) и великом броју камених батова са жлебом, на које се налази на површини до самог врха падине, претпостављамо да је реч о енеолитским и бронзано-добним окнима.

Геофизичка истраживања спроведена 2011. године у зони, величине 400 m², изнад Окна 4 и Окна 6 дала су неке корисне податке и закључке.

Методом сопственог потенцијала, дуж пет профила појединачне дужине од по 50 m, детектована су места односно зоне орудњења малахита на основу изразито негативних вредности (сл. 3). Према добијеним резултатима може се закључити да се аномалије највероватније стварају искључиво у зони праисторијских окана која су током времена запуњена и у које је ушла атмосферска вода, која је створила неопходан услов за електрохемијско генерисање сопственог потенцијала.

Геоелектрично скенирање изведено на профилима 1, 4 и 5 јасније је дефинисало аномалијске зоне добијене методом сопственог потенцијала (сл. 4). На основу добијених резултата помоћу ове две методе сачињена је међусобна корелација и веза са откривеним праисторијским окнима 4 и 6 (сл. 6), а према томе и детектовање старих рударских радова у целој зони обухваћеној геофизичким истраживањима. Тако је извршена реконструкција рударских радова у зони Окна 6. На профилу 1, по стационажи од 38. метра до краја профила, са дубином залегања од око 5 m, детектована зона орудњења (малахит) простире се ка истоку, налази се приближно на коти 936 m и има скоро хоризонтални положај. Почетак зоне орудњења на 38. метру поклапа се са улазом у Окно 6, који је 1987. године откривен на источном крају улазне платформе. Зато се може очекивати да се од улаза рударски канал хоризонтално наставља ка истоку наредних десет метара, а да се затим нагло вертикално спушта у дубину. Крај му за сада није детектован, пошто тај део ходника није обухваћен геофизичким снимањем.

На профилу 1, на стационажи од 18. до 19. метра детектовано је присуство орудњења које има скоро вертикални просторни положај и у непосредној је вези са Окном 4 откривеним археолошким ископавањем 1987. године. Улаз у Окно 4 засут је сипаром и данас се више не види. Према резултатима геофизичког испитивања очекујемо да се окно вертикално спушта око три метра од површине тла, а да затим прелази у скоро хоризонталну пространу подземну галерију. Заправо, могуће је да је реч или о већој галерији или о укрштању два вертикална ходника која се спуштају дубље од 10 m испод површине тла. Геофизичко испитивање са дубинским захватом већим од 10 m дало би у овом случају разрешење ве-

лике аномалије констатоване на профилу 1 у делу који се повезује са Окном 4 из 1987. године.

Ако се резултати који су добијени за профил 1 и њихова корелација са резултатима археолошких испитивања из 1987. године примене на слику добијену геофизичким снимањем за профиле 4 и 5, онда се може рећи да је постојало бар шест рударских окана чији су се улази налазили на удаљености од 6 m и 8 m северно од окана 4 и 6. Неки од ових радова ишли су до дубине од 4 m (2D геоелектрични пресек профила 4: 4–15. метра, 27–29. метра, 34–43. метра; 2D геоелектрични пресек профила 5: 25–27. метра; сл. 4), а неки су имали дубину већу од 10 m (2D геоелектрични пресек профила 5: 16–18. метра, 37–42. метра; сл. 4).

Применом сеизмичког профилисања методом SGRP потврђено је, мада не потпуно прецизно, највероватније постојање рударских окана на местима где се појављују аномалијске зоне по параметрима сопственог потенцијала и специфичне електричне отпорности.

О интензивној рударској активности на Прљуши сведоче бројни видљиви стари рударски радови. Величина улаза у подземне галерије код неких од њих навела је некадашње истраживаче на претпоставку да се ради о окнима из периода млађих од праисторије, могуће чак из средњег века. Међутим, чињеница да је на Прљуши вађен малахит, карбонатна руда, као и велики број камених рударских батова који се налазе свуда по површини локалитета, а посебно око окана, говори у прилог томе да је цела Прљуша била један велики праисторијски рудник. У горњим деловима експлоатација је вршена током касног енеолита и раног бронзаног доба, што је потврђено карактеристичним налазима из Окна 6. Претпостављамо да је у доњим деловима падине, сада прекривеним дебелим слојем сипара, и пре овог времена могла бити вршена експлоатација руде.

Зато би свакако требало да се наставе геофизичка испитивања на целој падини. У горњем делу, изнад рударских радова откривених током осамдесетих година двадесетог века, испитивање геофизичким методама требало би извести у зони већине потенцијалних окана која су детектована 2011. године. У доњем делу падине би такође требало извршити испитивања ове врсте, пошто постоји могућност да се испод дебелих наслага сипара крију стари рударски радови и археолошки објекти. Према добијеним резултатима досадашњих геофизичких истраживања на локалитету Прљуша закључено је да би у склопу будућих радова примена метода сопственог потенцијала (SP) и електричног скенирања (ЕК) у варијантама 2D и 3D била најсврхисходнија и најјекономичнија. Мерењем помоћу методе сопственог потенцијала прекрио би се већи простор локалитета, а само на местима са негативним аномалијским вредностима би се електричним скенирањем потврдило присуство рударских радова из праисторије.