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Metal ornaments from the burial mound necropolis Chornyanka of the Bilozerka culture (11th–10th centuries BC)

Abstract. *The flat cemetery near the village of Chornyanka, Kakhovka district, Kherson region, is one of the largest row grave fields of the Late Bronze Age archaeological culture of Bilozerka in the northern Black Sea region. The cultural and chronological location of the Chornyanka burial ground was determined on the basis of an analysis of the main features of the funerary constructions, ceremonies and equipment. The established date of its functioning is the 11th–10th century BC. 24 graves were identified and investigated. Most contained grave goods: pottery, bone and bronze tools, jewellery of bronze, bone, agate, mother-of-pearl, chitin and glass. This paper presents the results of metallographic and X-ray spectral analysis of bronze jewellery from Chornyanka cemetery: pins, temple rings and earrings. It presents and describes the characteristic microstructures of the metal finds. In addition, the process of production of various metal objects was investigated. Several chemical and metallurgical groups stand out in the spectral analyses of metals from Chornianka: Cu-Sn; Cu-Sn-As; Cu-As(Sn) and possibly remelting. Correlation diagrams of the characteristic pairs of elements are also given. In all the analyses, arsenic is present in tenths of a per cent. There is also a stable presence of an impurity such as antimony, mostly in tenths of a per cent, with concentrations in two cases reaching whole per cent. This means that they were probably included in the original ores. Some scientists believe that this feature is characteristic of the metallurgy of the Greater Caucasus. The results are compared with similar analyses from another cemetery of the Bilozerka Culture – Shyroke. Despite the general similarity and tradition, it is possible to highlight some differences in metalworking in both Bilozerka cemeteries (Chornyanka and Shyroke). Jewellery was made not only by casting. It was also forged with the help of mandrels. In addition, some products were made by welding several metal strips. Most researchers pay attention to the influence of the cultures of the Northwest region on the Bilozerka culture. Metalworking is traditionally thought of as having a Volga-Urals orientation. In this article, we propose to take into account new data on the chemical composition of metal and technology, which testify to the contacts of the Bilozerka culture with the Caucasus.*

Keywords: *Late Bronze Age; Bilozerka culture; bronze jewellery; metallographic analysis; X-ray fluorescence analysis*

Introduction.

The Kherson archaeological expedition investigated the Bilozerka culture burial ground in 1979. It was located near the village of Chornyanka, Kakhovsky district, Kherson region, on the plateau above the left slope of the "Black Dolyna" tract. The burials were arranged in a northwest–southeast chain with a slight shift in the middle. A total of 24 burials were identified and examined (Kubyshev & Chernyakov, 1986, p. 140, fig. 1).

Nowadays, the scientific community knows the Bilozerka culture burial grounds, which are concentrated along the Dnipro and between the Bug and Prut rivers (Kubyshev & Chernyakov, 1986, p. 155, fig. 9). Among them, Shyroke is the flat cemetery with the largest number of burials, studied in 1975 and only recently published in detail (Leskov, Kravchenko, & Hoshko, 2019). Chornyanka is the second largest cemetery after Shyroke.

Artefacts of material culture, represented by ceramics, tools, clay moulds, weapons and jewellery of the Bilozerka culture, have been studied by many archaeologists. The vast majority of works were devoted to chronology, funerary rites, and the typology of ceramics and metalwork. The chemical composition of the metal of the Bilozerka culture was studied by E. M. Chernykh (1976, pp. 48–50). His main conclusion was that the eastern centres – the Urals or the Volga-Urals – played a leading role in the development of Bilozerka metalworking. Later, similar studies were conducted only by the author of this article (Horbenko & Hoshko, 2010, pp. 97–111; Hoshko, 2019a; Hoshko, 2019b). It is assumed that the metal came to the Right bank of the Dnipro (to the fortified settlement of Dykyi Sad, located in Mykolaiv, at the confluence of the Pivdennyi Buh and Ingul rivers) from the Carpathian mining and metallurgical centres. In contrast, on the left bank of the Dnipro (Shyroke flat cemetery cemetery), the metal is of Caucasian origin.

There is a small number of studies on the technology of manufacturing Bilozerka metal products using metallographic analysis. This includes only the author's work mentioned above.

The metal products of the Bilozerka culture on the left bank of the Lower Dnipro are not distinguished by their variety. They are mainly ornaments and a small number of tools. The technological and X-ray analysis of the materials of the Shyroke became the beginning of their study (Hoshko, 2019b). This article is a logical continuation of the research on the Bilozerka metal.

Methods.

Metal products from Chornyanka are presented in a small collection – only 23 items. Most of them are ornaments: pins, wire temple rings (earrings?), tube beads and spirals (Fig. 1–2). Unfortunately, the metal is damaged by corrosion. It is sometimes impossible to determine the shape or thickness of the product. A small awl is the only tool found in the burials.

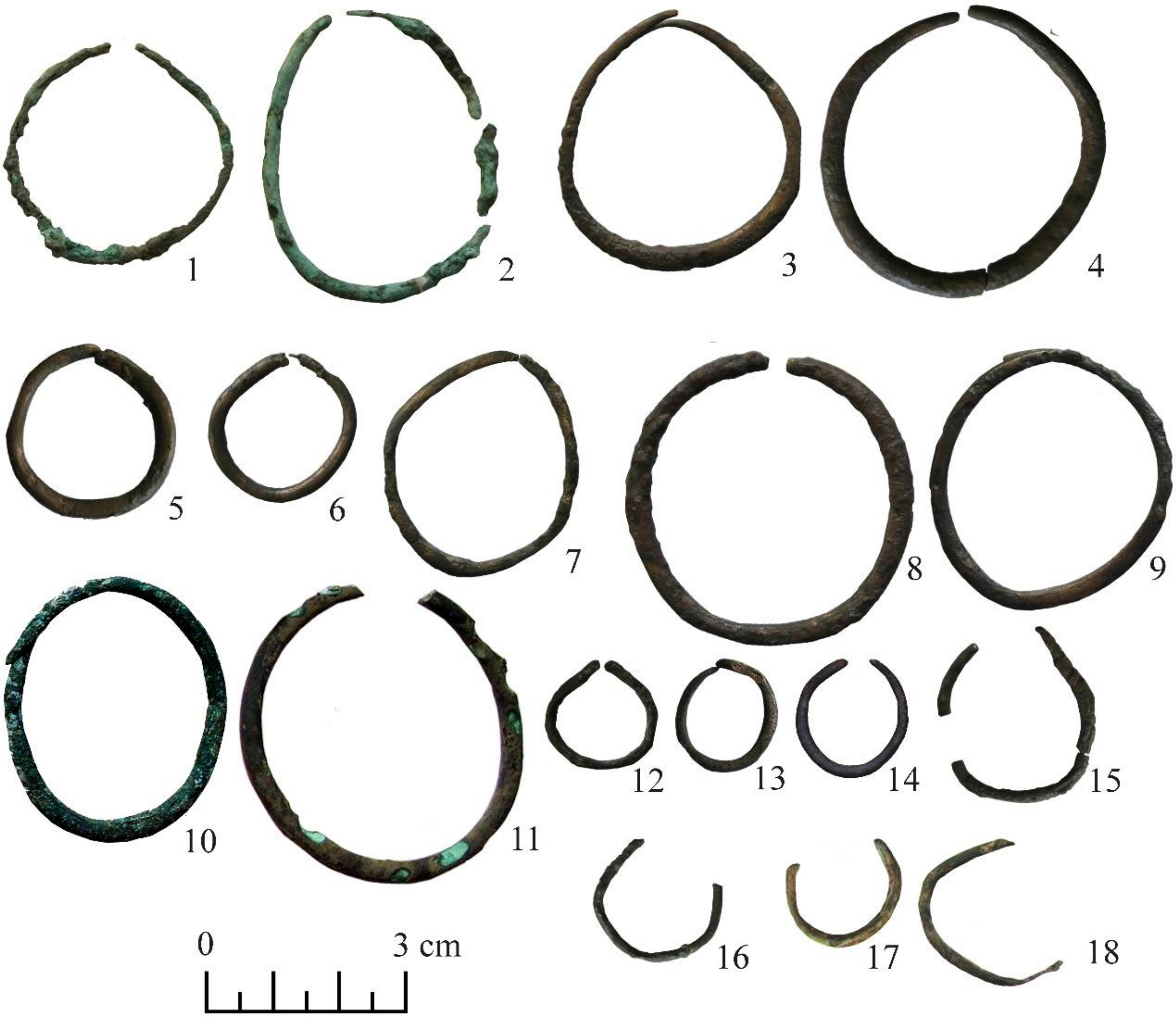

Figure 1. Metal products from Chornianka. The slant indicates metallographic/X-ray fluorescence analysis. 1–2 – grave 1; 3 – grave 2 (lab. No. 261/120); 4 – grave 2 (lab. No. –/1002); 5 – grave 13 (lab. No. 262/121); 6 – grave 13 (lab. No. 263/122); 7 – grave 16 (lab. No. 264/123); 8 – grave 19 (lab. No. 265/124); 9 – grave 19 (lab. No. 266/125); 10 – grave 20; 11 – grave 20 (lab. No. 267/126); 12 – grave 20 (lab. No. 268/127); 13 – grave 20 (lab. No. 269/128); 14 – grave 20 (lab. No. -/997); 15 – grave 20 (lab. No. –/1004); 16 – grave 20 (lab. No. -/1005); 17 – grave 24 (lab No. 70/129); 18 – grave 24 (lab. No. 271/130).

Temporal rings, regardless of their size, were placed on the skull or under the skull close to the auditory canal. There is no doubt that rings of small diameter are earrings. They have either one pointed end or both are blunt.

Table 1 shows the parameters of these ornaments: diameter, wire thickness and others. In general, they can be divided into three groups. The first group consists of five large rings with a diameter of 40–44 mm, made of wire 2–4 mm thick, round or rectangular in cross-section. Both ends of the wire are pointed (2 rings), or only one (2 rings), or both are blunt (1 ring).

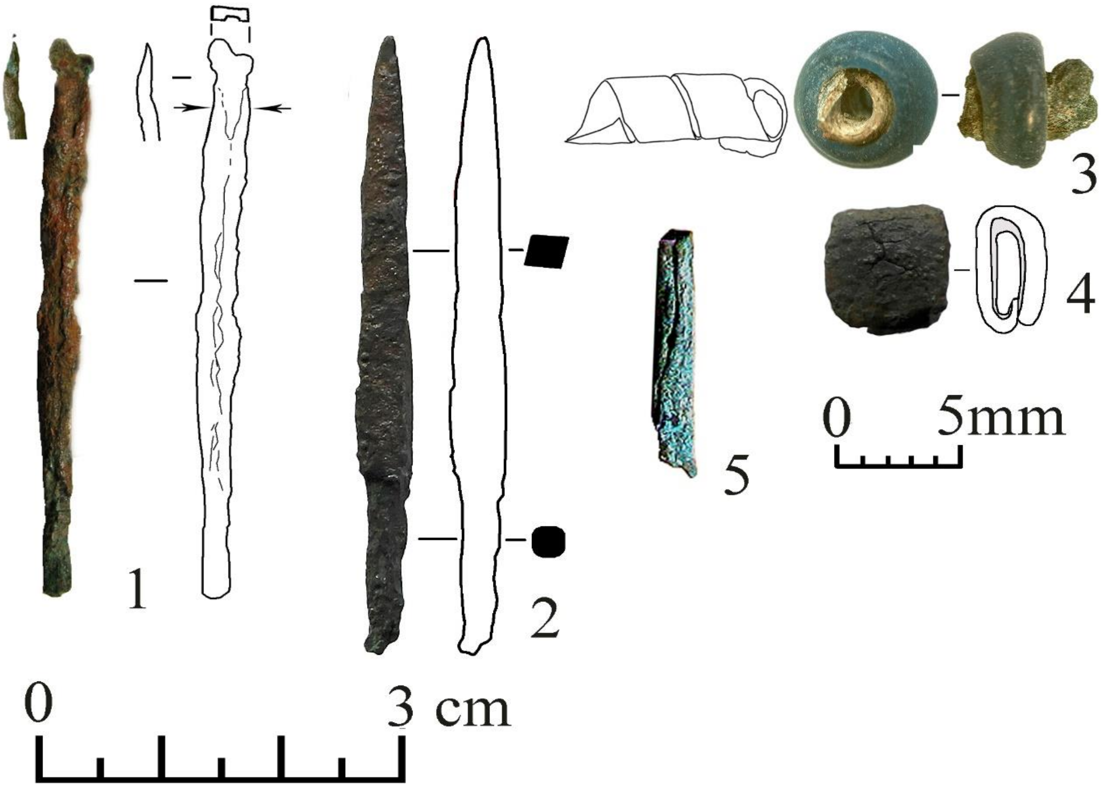

Figure 2. Metal products from Chornianka: 1 – pin, grave 5 (lab. No. 272/392); 2 – awl, grave 12 (lab. No. – /1003); 3 – spiral, grave 9; 4 – piercing, grave 9; 5 – piercing, grave 19.

Table 1. Parameters of temple rings and earrings from Chornyanka.

No. burial	X-ray fluorescence analysis	metallographic analysis	Diameter mm	Wire		Wire ends			
				Thickness mm	Cross-section	Pointed		Both blunted	Both narrowed
						one	both		
1	—	—	37×44	2	○		•		•
1	—	—	38.5	3	○		•		•
2	120	261	37×40	3.5×2	▨		•		•
2	1002	—	26	4	○			•	•
13	121	263	23	3×2	▨			•	•
13	122	262	27	3	○			•	•
16	123	264	30×40	~2	▨	•			•
19	124	265	42	3	○			•	
19	125	266	36×38	3.5×2	▨	•			•
20	—	—	32×38	3	○	•			
20	126	267	44	3.3	○	•			
20	127	268	16.8×16	2	○			•	
20	128	269	16	2	○	•			
20	997	—	*	2	○	*	*	*	*
20	1004	—	*	1.5	○	*	*	*	*
20	1005	—	~18	~2	○	•			
24	129	270	16	2	○	•?			*
24	130	271	*	2	○	*	*	*	*

Comments: ○ – round wire cross-section; ▨ – flattened wire cross-section; * – not restored.

Table 2. Results of X-ray fluorescence analysis of products from Chornyanka.

No. analysis	Grave	Product	Sn	Pb	Zn	Bi	Ag	Sb	As	Fe	Ni	Co	Au
120	2	ring	5.542	0.129	—	—	0.188	0.667	0.222	0.053	0.018	—	—
122	13	ring	1.159	0.128	—	—	0.246	0.761	0.328	—	0.031	—	0.135
124	19	ring	2.328	0.171	0.305	—	0.114	0.551	0.372	0.054	0.123	—	—
127	20	ring	8.242	0.2	—		0.106	0.239	0.307	traces	0.266	—	—
392	5	pin	1.482	0.2	—	—	0.5	1.033	0.479	traces	0.467	—	—
1004	20	ring	11.563	0.222	0.118	—	0.037	0.094	0.162	0.07	—	<0.029	—
1005	20	ring	8.806	0.585	0.309	—	0.142	0.54	0.366	0.121	0.072	<0.04	—
126	20/1	ring	1.32	0.014	—	0.006	0.066	0.155	1.081	—	0.025	—	0.073
997	20/1	ring	1.066	—	0.044	0.027	0.1	0.171	1.516	traces	0.179	—	—
123	16	ring	1.548	0.06	0.191	—	0.161	0.262	0.759	<0.013	0.313	—	0.088
125	19	ring	2.033	0.038	—	—	0.093	0.141	0.691	0.024	0.016	—	0.092
129	24	ring	2.781	0.033	—	0.009	0.128	0.309	0.898	<0.046	<0.051	0.071	0.044
128	20	ring	0.238	0.021	—	—	0.05	—	1.463	0.063	0.009	—	0.09
1003	12	awl	0.07	—	0.216	—	0.04	0.036	1.264	<0.046	<0.051	0.071	0.044
1002	2	ring	0.674	0.115	—	0.015	0.298	0.633	0.848	0.059	0.086	<0.048	—
121	13	ring	0.872	0.183	—	—	0.286	0.872	0.446	—	0.447	—	0.126
130	24	ring	0.41	0.158	2.113	—	0.644	1.366	0.268	0.022	0.108	—	—

The second consists of three rings of medium size – 30–38 mm in diameter – made from wire of the same thickness as the large rings (3–4 mm). In one case the wire is flattened in the center, the others have a round cross section. A pointed end of the wire in 2 rings; one has both blunted.

Small rings, probably earrings, with a diameter of 16 to 27 mm (7 specimens) are part of this group. The thickness of the wire varies from 1.5 to 4 mm, one of them is flattened in the middle. Four ends are blunt. Three ends are pointed.

Temple rings and earrings are mainly women's and children's jewelry. Men's clothing also shows similar decoration. However, it is much rarer. Temple rings and earrings were found in only one burial, No. 2 at Chornyanka[1]. In another ground necropolis of the Bilozerka culture, Shyroke, the same ornaments are more frequently found in the accompanying inventory of male burials. Temple rings and an earring were found in burials 30, 40 and 107 (Kravchenko, 2019, pp. 48, 57, 118). It should be noted that the skeleton of a man[2] from burial 107 was lying on his left side and had, in addition to two temple rings, a pin with a looped head (Kravchenko, 2019, p. 118, fig. 1.118, 2).

Results and discussion.

Spectro-analytical (17) and technological (12) studies of the products from Chornyanka have been carried out. Technological details of production were revealed in the process of visual surface examination of objects with the help of binocular microscope MBS-200. The metallographic analysis was carried out with a MIM-7 microscope, and a PMT-3M micro-hardness tester was used to measure micro-hardness. The surfaces of the products cleaned of oxides were subjected to metallographic and X-ray fluorescence analyses.

[1] As concluded by anthropologist S. I. Kruts (Kubyshev & Chernyakov, 1986, p. 145).
[2] Zinevych & Kruts, 1968, p. 61, tab. 9.

X-ray fluorescence analysis[3].

The determination of cobalt (Co) and bismuth (Bi) by this spectrometer makes it impossible to include these two elements in the analysis. As shown in Table 2, small concentrations of cobalt and bismuth in the metal are sometimes indicated in the analyses. The X-ray fluorescence results in the table are grouped by selected compositions.

Several chemical and metallurgical groups have been identified in the metal samples from Chornyanka: Cu-Sn; Cu-Sn-As; Cu-As(Sn) and possibly remelting.

The first Cu–Sn group contains 7 analyses – lab. No. 120, 122, 124, 127, 392, 1004, 1005. Their stannic content ranges from 1.159 to 11.563%. It is noteworthy that in all analyses arsenic is present in quite noticeable concentrations (from 0.162 to 0.479%). There is no doubt that a tin ligature was used here.

The second group, Cu-Sn-As, can be considered as a double tin-arsenic alloy. It includes five analyses – lab. No. 123, 125, 126, 129 and 997.

The content of tin in the metal composition is lower: from 1.066 to 2.781%, and the concentration of arsenic slightly increases in comparison with the previous group (from 0.759 to 1.516%).

Three analyses are included in the group of arsenic bronzes Cu-As(Sn): lab. No 128, 1003 and 1002. As in the previous group, the analyses of the third group contain a rather significant percentage of arsenic (As – 0.848–1.463%).

The appearance of such low percentages of tin in the analyses of this group can be explained either by its transition into metal from copper ore or by the use of remelted products.

A similar metal with a reduced tin content (from 0.1 to 0.8%), known from the Caucasus in the Late Bronze Age, is called "conditionally tin bronze" by S. M. Korenevskyi (Korenevskyi, 1981, p. 148).

It is probable that the metal of the two temporal rings (lab. No 121 and 130) also belongs to the bronzes mentioned above. Alternatively, it may be a re-melted alloy, given the low content of both tin and arsenic.

It is noteworthy that in all analyses arsenic is present in tenths of a percent, as well as the stable presence of antimony, mostly in tenths of a percent, with concentrations reaching whole percent in two cases (lab. No 130 and 392). These minerals were probably part of the original ores. According to S. M. Korenevskyi, this feature is typical for the metallurgy of the Greater Caucasus (Korenevskyi, 1981, p. 153).

The study of the Shyroke metal suggested that it was smelted from Caucasian ores (Hoshko, 2019b, pp. 165, 172). Based on the correlation graphs of metal element pairs

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[3] The analyzes were carried out at the Institute of Archeology of the National Academy of Sciences of Ukraine on the X-ray fluorescence spectrometer CEP-01 AAES.412131.001, modification "ElvaXLight" with an extended range towards light elements. Registration of fluorescent radiation from the studied sample was carried out using a semiconductor Si-Pin detector manufactured by Amptek (USA) with thermoelectric cooling. The following operating modes of the X-ray tube (MOXTEK, anode material Pd) were set: voltage 45 kV, anode current within 0–100 μA. Registration of normal spectra at an emitter voltage of 40–49 kV and light spectra at a voltage of 10–15 kV.
The modification of the spectrometer "ElvaX Light" is equipped with a helium injection system into the working chamber. The standard spectrum acquisition time is 100 s. The sensitivity threshold of the spectrometer for tin (Sn) and nickel (Ni) – 0.05%, zinc (Zn) – 0.1%, lead (Pb) – 0.02%, silver (Ag) – 0.01%, 0.05%, antimony (Sb) – 0.01%, bismuth (Bi) –- 0.008%, and cobalt (Co) – 0.08%.

from the Chornyanka and Shyroke cemeteries, we can claim a great similarity (Fig. 3). It is particularly noticeable in the graphs of Sb–Ag and Sb–Pb.

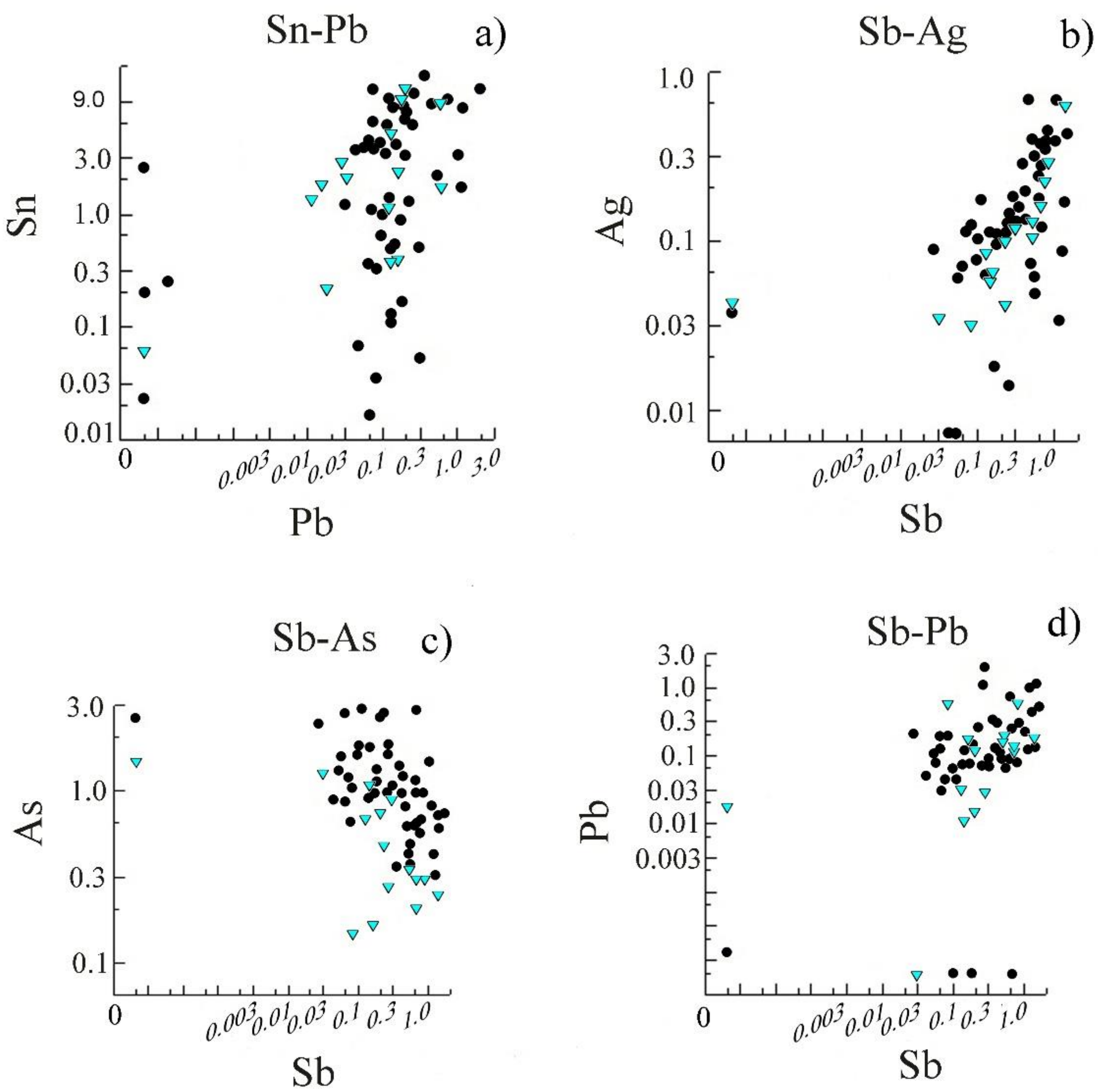

Figure 3. Correlation plots of copper impurities from Chornyanka and Shyroke cemeteries: a) Sn–Pb; b) Sb–Ag; c) Sb–As; d) Sb–Pb. Symbols and notation: △ – Chornyanka; ● – Shyroke.

So there is reason to believe that the masters of the Bilozerka culture imported metal from the Greater Caucasus. However, we can only talk about the population living in the lower reaches of the Dnipro.

E. A. Kravchenko also does not exclude a possible connection with the Caucasus (Kravchenko, 2019, p. 160). She draws attention to the similarity of the burial rites of the Bilozerka and Koban cultures and to the conclusions of anthropologists on the morphological similarity with some series of skulls from the Caucasus – from the Samtavro cemetery (second variant) (Zinevych & Kruts, 1968, p. 89).

Technological study.

A total of 12 items were subjected to metallographic examination: 11 temple rings and one pin (Fig. 4, Fig. 5).

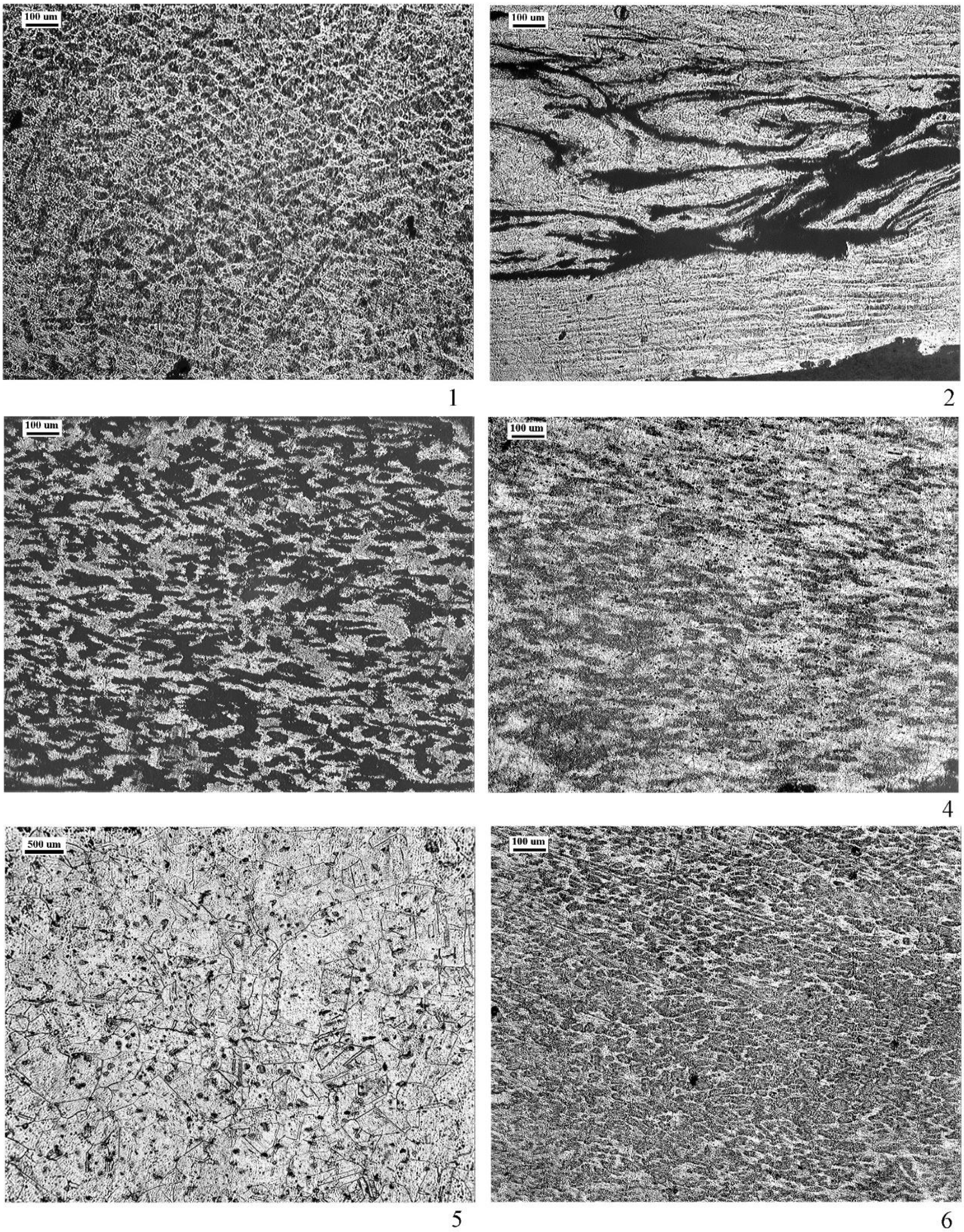

Figure 4. Microstructures: 1 – lab. No. 261; 2 – lab. No. 262; 3 – lab. No. 263; 4 – lab. No. 264; 5 – lab. No. 265; 6 – lab. No. 266.

There is not enough information on the effect of forging at different temperatures on copper with arsenic content up to 1%, despite an interesting and necessary work by Ravich and Ryndina (Ravich & Ryndina, 1999, pp. 77–98). Arsenic bronze castings have a dendritic structure. It was found that dendritic liquation in copper-arsenic alloys is more stable than in tin bronzes. It is preserved after high degrees of compression and after annealing. Therefore, it can only be stated that the temperature regime of the forging billets was in the range of the onset of recrystallisation (350°C) and in the range of the final recrystallisation (400–700°C).

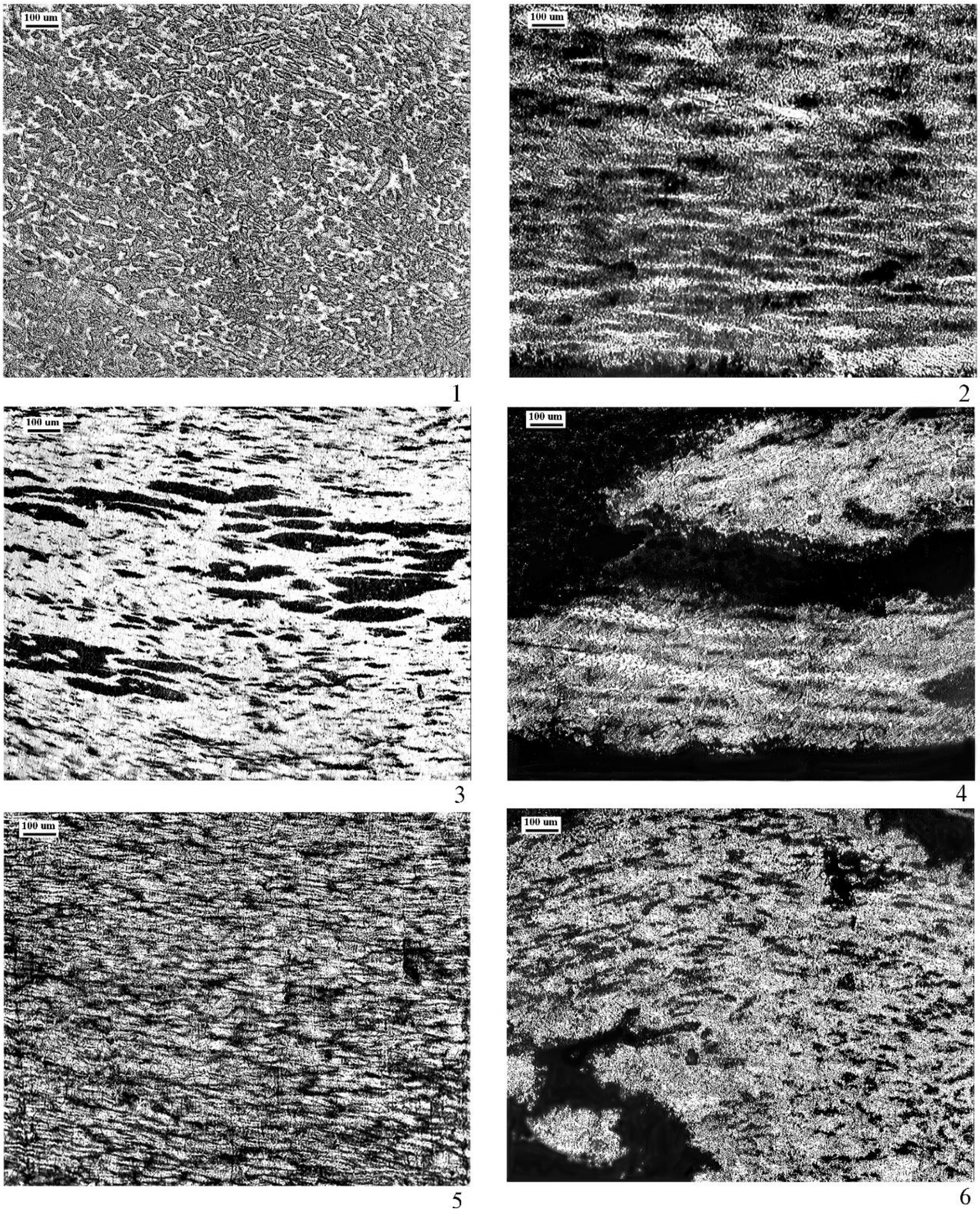

Figure 5. Microstructures: 1 – lab. No. 267; 2 – lab. No. 268; 3 – lab. No. 269; 4 – lab. No. 270; 5 – lab. No. 271; 6 – lab. No. 272.

The technological scheme for the production of wire products was as follows. The wire was made from a cast billet forged on a special anvil with a chute. It is impossible to determine whether the forging was carried out in cold metal with annealing or in a hot state. However, given the residual more or less deformed microstructure of the castings, the billets were mainly heated to an incandescent temperature of 500°C. The workpiece was then cut into the required lengths, sometimes with one or both ends sharpened. Sometimes both ends were left blunt. Finally, the rings themselves were formed. Sometimes the bent ring was additionally flattened on the sides (lab. No. 261/120, 263/121, 264/123, 266/125).

I feel it is necessary to remind you that the metallographic analyses were carried out on whole objects and the location of the grinding was in the central part of the ring. Therefore, the information about the forging temperature and the degree of crimping applies only to the central part of the rings. Accordingly, the deformation was undoubtedly more intense at the pointed ends.

Two pieces of jewellery are interesting from a technological point of view: an earring from grave 13 (lab. No. 262/121) with round wire cross-section and blunt converging ends and a large temporal ring from grave 19 (lab. No. 265/124) made of round wire with converging blunt ends (Fig. 1.5, Fig. 1.8).

Microstructural analysis revealed the presence of a blacksmith's seam on both. There is a branching weld on the earring and a barely noticeable weld on the temporal ring (Fig. 4.2, Fig. 4.5). The microstructure of the earring is a deformation texture with small recrystallised grains with twins on a background of smooth elongated dendrites by forging. The grain size is 0.025 mm. Microhardness 98.6 kg/mm^2. Despite the fact that a fairly high degree of deformation has been applied, welding has been unsuccessful, although the seam is not visible from the outside.

However, the welding of the temporal ring was successful – the seam is almost invisible. The strain was higher because the cast structure is more deformed and the percentage of recrystallised structure is higher than in previous analyses. The grain size with twins is 0.035 mm. Microhardness 134.6 kg/mm^2.

The next few temporal rings from burials 2, 19, 20 (lab. No. 261/120; 266/125; 267/126) are less forged (Fig. 4.1, Fig. 4.6, Fig. 5.1). Two of them are flattened in the middle and the third has a round cross section (Table 1). The cast microstructure is slightly disturbed by forging, with a low degree of compression – about 20%. Microhardness 127.6 kg/mm^2 (261/120); 112.7 kg/mm^2 (266/125); 132.2 kg/mm^2 (267/126). No recrystallised grains were observed. It is likely that the microstructures acquired this appearance as a result of a single heating to 400–500ºC, which may be due to their bending into a ring.

As for the other five earrings (lab. No. 263/122; 268/127; 269/128; 270/129; 271/130) and the temple ring (lab. No. 264/123), the technology of their manufacture differs little from that of the previous three, except for a greater degree of deformation by 20–40%. This is reflected in the microstructures with smaller polyhedral grains against a background of dendrites deformed by forging (Fig. 4.3; Fig. 5.2–5). Microhardness 108 kg/mm^2 (lab. No. 263/122); 133.6 kg/mm^2 (lab. No. 264/123);

146 kg/mm^2 (lab. No. 268/128); 108.4 kg/mm^2 (lab. No. 269/128); 108.4 kg/mm^2 (lab. No. 270/129); 110 kg/mm^2 (lab. No. 271/130).

All that remains of the pin is a fragment of the rod with the remains of the head (lab. No. 272/392). The pin was made by free forging from a rectangular billet (the outer seam formed during forging is visible along its entire length) forged to a circular cross section (Fig. 2.1). The head was made from the riveted end of a rod rolled into a loop. Forging was carried out at low temperatures with annealing. The microstructure is residual dendritic against a background of small recrystallised grains with twins (Fig. 5.6).

Comparing the technologies of jewellery production at Chornianka and Shyroke cemeteries, we see that in both cases metalworking schemes were used to make temple rings and earrings, which involved casting blanks and then forming them on a fluted anvil with a shaped lining. This explains the uniform thickness and round cross-section of the wire on many products.

Forging at both sites took place mainly at low temperatures of 400–500°C, sometimes rising to 600–700°C at Shyroke. It is possible that the blacksmiths were aware of the high volatility of arsenic vapours, which is why they preferred to heat the metal to low temperatures.

The degree of metal crimping in Chornyanka was low, mostly 20–40%. At the same time, in Shyroke, craftsmen more often chose a higher degree of crimping – 60–80%, less often – 20–40%, and sometimes 100%.

Blacksmith welding can be traced in both collections. There are two cases in Chornianka and one in Shyroke. Most of the temporal pendants from Shyroke are noticeably flattened on both sides. There are only four in Chornianka. Two pins with looped heads from both sites were made by free forging. The rods still have surface seams on them, which were formed when the billets were forged from square sections.

There is no point in comparing the results of technological analysis from the settlement of the Bilozerka culture Dykyi Sad. That collection is more diverse, and the jewellery is represented by a different category – bracelets and hairpins (Horbenko & Hoshko, fig. 1). This explains the variety of technological schemes of metalworking. In general, it is associated with the forging of cast billets at temperatures not exceeding 600ºC.

Conclusions.

The nearest to Chornianka in terms of location is the Shyroke necropolis. Therefore, it is best to compare the technology of making metal jewellery from these two sights. There are both similarities and differences between the two collections: 1) the same schemes of metalworking of wire decorations were used; 2) forging at both sights took place mainly at low temperatures of 400–500°C; 3) the degree of crimping of the Chornianka metal was low, mostly 20–40%. At the same time, in the Shyroke collection, craftsmen more often chose a higher degree of crimping of the workpieces – 60–80%, less often – 20–40%, and sometimes 100%; 4) in both collections, forging welding can be traced. The previously expressed opinion about the possible Caucasian origin of the metal in the Shyroke necropolis is now confirmed by the analysis of metal from Chornianka.

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Conflicts of interest.
The author declare no conflict of interest.

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Металеві прикраси з курганного некрополя білозерської культури Чорнянка (11–10 ст. до н. е.)

Анотація. *Рівнинний могильник біля села Чорнянка Каховського району Херсонської області є одним з найбільших ґрунтових могильників Білозерської археологічної культури доби пізньої бронзи у Північному Причорномор'ї. Культурно-хронологічне місце могильника Чорнянка було визначено на основі аналізу основних особливостей поховальних конструкцій, обряду та інвентарю. Встановлена дата його функціонування – 11–10 ст. до н. е. Виявлено та досліджено 24 поховання. Більшість з них містили поховальний інвентар: кераміку, кістяні та бронзові знаряддя праці, прикраси з бронзи, кістки, агату, перламутру, хітину та скла. У статті представлено результати металографічного та рентгеноспектрального аналізу бронзових прикрас з могильника Чорнянка: шпильок, скроневих кілець та сережок. Представлено та описано характерні мікроструктури металевих знахідок. Крім того, досліджено процес виробництва різних металевих предметів. У спектральному аналізі металів з Чорнянки виділено кілька хіміко-металургійних груп: Cu-Sn; Cu-Sn-As; Cu-As(Sn) і, можливо, переплав. Також наведено кореляційні діаграми характерних пар елементів. У всіх аналізах арсен присутній у десятих частках відсотка. Також стабільно присутня така домішка, як сурма, переважно в десятих частках відсотка, причому в двох випадках її концентрація сягає цілих відсотків. Це означає, що вони, ймовірно, входили до складу вихідних руд. Деякі вчені вважають, що ця особливість характерна для металургії Великого Кавказу. Результати порівнюються з аналогічними аналізами з іншого могильника Білозерської культури – Широке. Незважаючи на загальну схожість і традиції, виділяються деякі відмінності в металообробці на обох білозерських могильниках (Чорнянка та Широке). Прикраси виготовлялися не тільки методом лиття. Його також кували за допомогою оправки. Крім того, деякі вироби виготовлялися шляхом зварювання кількох металевих смуг. Більшість дослідників звертають увагу на вплив культур Північно-Західного регіону на Білозерську культуру. Про металообробку існує традиційна уява її волго-уральської орієнтації. У даній статті пропонується взяти до уваги нові дані вивчення хімічного складу металу і технології, які свідчать також і про контакти білозерської культури з Кавказом.*

Ключові слова*: доба пізньої бронзи; Білозерська культура; бронзові прикраси; металографічний аналіз; рентгенофлуоресцентний аналіз*

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