RESULTS OF STUDYING OF MATERIALS OF ARCHAEOLOGICAL RESEARCH

DOI: 10.14258/tpai(2021)33(3).-06
УДК 903.01«637»(470.55/.58)

THE CHAINE OPERATOIRE OF BRONZE AGE MINING: TOOLS FROM THE NOVOTEMIRSKY COPPER MINE (SOUTHERN TRANS-URALS)

Irina P. Alaeva[1], Ivan V. Molchanov[2], Alexander V. Fomichev[3], Maksim N. Ankushev[4], Polina S. Ankusheva[1,4]

[1]South Ural State Humanitarian Pedagogical University, Chelyabinsk, Russian Federation;
[2]Institute of History and Archaeology, Ural Branch of the Russian Academy of Sciences, Ekaterinburg, Russian Federation;
[3]Orsk Humanitarian-Technological Institute (branch) of Orenburg State University, Orsk, Russian Federation;
[4]South Urals Federal Research Center of Mineralogy and Geoecology, Ural Branch of the Russian Academy of Sciences, Miass, Russian Federation

ORCID: https://orcid.org/0000-0001-8322-5835, e-mail: alaevaira@mail.ru
ORCID: https://orcid.org/0000–0001–5668–6310, e-mail: kolis@mail.ru
ORCID: https://orcid.org/000-0001-7578-6683, e-mail: homabrut1987@gmail.com
ORCID: https://orcid.org/0000-0001-9628-5546, e-mail: ankushev_maksim@mail.ru
ORCID: https://orcid.org/0000-0002-1826-9919, e-mail: polenke@yandex.ru

Abstract: The paper is devoted to the problem of the development level and organization models of mining within the Eurasian metallurgical province of the Late Bronze Age in the 2nd millennium BC. The main research aim is to determine the chain of technological processes taking place at the Novotemirsky ancient mine in the Southern Trans-Urals. The sources of raw materials, traces of use, and functional identification of stone (n=58) and bone tools (n=1) were determined using traceological, petrographic, X-ray fluorescence, and X-ray diffraction analysis. All tools were divided into three groups depending on their use: mining (a casting mould for a pick), ore crushing (hammers, small hammers), supporting devices ("bases", counterweights for lifting ore).

The absence of mining and processing (grinding pestles, grinding stones) and metal-working (blacksmith hammers) tools at the Novotemirsky mine indicates a narrow range of technical operations associated only with direct mining of copper ore and ore-preparing (crushing large blocks). It is assumed that there is a partial specialization of mining, which consists in the formation of temporary miners' collectives, who are seasonally involved in these operations.

Keywords: stone tools, ancient mine, Late Bronze Age, Southern Trans-Urals, Alakul culture, traceological analysis, X-ray fluorescence analysis, X-ray diffraction analysis

Acknowledgements: The research was funded by RFBR and Chelyabinsk Region, project number 20-49-740002 r_a_Chelyabinsk "The Earliest Copper Mines in the Southern Trans-Urals". The functional analysis of the tools was carried out within the framework of theme No. AAAA-A16-116040110036-1 "Ancient and Medieval Cultures of the Urals: Regional Features in the Context of Global Processes" (analyst Ivan V. Molchanov). The authors are grateful to Leonid L. Gaiduchenko, Larisa Ya. Kabanova, Pavel V. Khvorov, for analytical work.

For citation: Alaeva I. P., Molchanov I. V., Fomichev A. V., Ankushev M. N., Ankusheva P. S. The Chaine Operatoire of Bronze Age Mining: Tools From the Novotemirsky Copper Mine (Southern Trans-Urals). *Theory and Practice of Archaeological Research.* 2021;33(3):89–115. *(In English)* DOI: 10.14258/tpai(2021)33(3).-06

ОПЕРАЦИОННАЯ ЦЕПЬ ГОРНОГО ДЕЛА В БРОНЗОВОМ ВЕКЕ: ОРУДИЯ НОВОТЕМИРСКОГО РУДНИКА (ЮЖНОЕ ЗАУРАЛЬЕ)

И. П. Алаева[1], И. В. Молчанов[2], А. В. Фомичев[3], М. Н. Анкушев[4], П. С. Анкушева[1, 4]

[1]Южно-Уральский государственный гуманитарно-педагогический университет, г. Челябинск, Российская Федерация;
[2]Институт истории и археологии УрО РАН, г. Екатеринбург, Российская Федерация;
[3]Орский гуманитарно-технологический институт (филиал) Оренбургского государственного университета, г. Орск, Российская Федерация;
[4]Южно-Уральский федеральный научный центр минералогии и геоэкологии УрО РАН, г. Миасс, Российская Федерация

ORCID: https://orcid.org/0000-0001-8322-5835, e-mail: alaevaira@mail.ru
ORCID: https://orcid.org/0000–0001–5668–6310, e-mail: kolis@mail.ru
ORCID: https://orcid.org/000-0001-7578-6683, e-mail: homabrut1987@gmail.com
ORCID: https://orcid.org/0000-0001-9628-5546, e-mail: ankushev_maksim@mail.ru
ORCID: https://orcid.org/0000-0002-1826-9919, e-mail: polenke@yandex.ru

Резюме: В статье обсуждается проблема оценки уровня развития и моделей организации горного дела в пределах Евразийской металлургической провинции позднего бронзового века. Основная цель работы — определение цепи технологических процессов, происходящих на древнем руднике Новотемирский в Южном Зауралье. Основным источником являются каменные (58 экз.) и костяные орудия (1 экз.) позднего бронзового века, обнаруженные в ходе раскопок на памятнике. Их функциональное назначение и следы использования, состав и источники сырья были определены при помощи трасологического, петрографического, рентгенофлуоресцентного и рентгенофазового анализов. В коллекции памятника выделено три группы орудий: горнопроходческие (литейная форма для отливки кайла), рудодробительные (молоты, молотки), вспомогательные приспособления (подставки, противовесы для подъема руды).

Отсутствие в материалах Новотемирского рудника орудий горно-обогатительного (песты, терочники) и металлообрабатывающего (кузнечные молотки) циклов указывает на узкий спектр технических операций, практиковавшихся на Новотемирском руднике, связанных только с непосредственной добычей медной руды и первичным обогащением (дроблением крупных форм). Предполагается существование частичной специализации горного дела, которая заключается в образовании временных коллективов рудокопов, сезонно задействованных на горных работах.

Ключевые слова: каменные орудия, поздний бронзовый век, Южное Зауралье, алакульская культура, трасологический анализ, рентгенофлуоресцентный анализ, рентгенофазовый анализ

Благодарности: Исследование выполнено при финансовой поддержке РФФИ и Челябинской области в рамках научного проекта № 20-49-740002 «Древнейшие медные рудники Южного Зауралья». Функциональный анализ орудий выполнен И. В. Молчановым в рамках темы №АААА-А16-116040110036-1 «Древние и средневековые культуры Урала: региональные особенности в контексте глобальных процессов». Авторы благодарят Л. Л. Гайдученко, Л. Я. Кабанову, П. В. Хворова за проведение аналитических работ.

Для цитирования: Алаева И. П., Молчанов И. В., Фомичев А. В., Анкушев М. Н., Анкушева П. С. Операционная цепь горного дела в бронзовом веке: орудия Новотемирского рудника (Южное Зауралье) // Теория и практика археологических исследований. 2021. Т. 33, № 3. С. 89–115. DOI: 10.14258/tpai(2021)33(3).-06

Introduction

The development of a large number of copper and tin deposits in the Late Bronze Age is associated with the functioning of the Eurasian metallurgical province [Chernykh, 2008: 46–47]. Nowadays, several centers of mining and metallurgical activity are known within its boundaries. In the western part of the province there are some complexes (copper mines and settlements) of the Srubnaya culture were investigated: the Kartamysh complex in Eastern Ukraine (Donetsk region) [Tatarinov, 1977: 193; Brovender, 2008: 184]; the Mikhailo-Ovsyanka complex on the Middle Volga (Samara region) [Matveeva, Kolev, Korolev, 2004: 78; Kolev, 2010]; Kargaly in the Cis-Urals (Orenburg region) [Chernykh, 2008]. The deposits of the eastern part of the province were developed by the Andronovo populations, in particular, Ural-Mugodzhary mining and metallurgical center [Tkachev, 2011; Yuminov et al., 2013], deposits of Central and Eastern Kazakhstan [Chernikov, 1960; Zhauymbaev, 1984; Margulan, 1973]. The Zarafshan tin deposits were used by the Srubnaya, Andronovo, and Tazabagyab metallurgists [Avanesova, 2012].

Determining the degree of specialization of Bronze Age mining is an actual task for paleometallurgists. Its solution is facilitated by the assessment of the spectrum of technological operations presented at the mining and metallurgical complexes. In general, the list of processes at the mines of the 2nd millennium BC in Northern Eurasia can be represented in the following sequence:

1. Overburden works and ore mining (mattocks, mining picks made of copper, stone, wedges made of bone.
2. Ore crushing (hammers, small hammers).
3. Enrichment and preparation of the ore for smelting (pestles, grinding stones).
4. Pre-roasting for sulphide ores in burn pits.
5. Ore smelting, ingots production (metallurgical furnace, slags, ingots).
6. Metalworking (blacksmith's hammers, metal polisher, casting moulds for a series of tools-sickles, knives, shafts).

The list of processes identified at a mine may indicate a mining model. The identification of a set of tools and items with functionality associated with the entire spectrum of processes indicates a far-reaching process of specialization. The achievement of ingots production and the manufacture of serial items for trade and exchange operations are indicated a sufficiently high level of specialization in mining.

The Kartamysh microdistrict mines demonstrate the presence of tools and evidence of all stages of metal production: mining, ore-preparing, and metallurgy [Brovender, 2008: 198; Brovender, Zagorodnyaya, 2009]. The Mikhailo-Ovsyanka materials reflect a similar situation [Gorashchuk, Kolev, 2004; Kolev, 2010]. Localization next to the ancient quarries of manufacturing and living buildings determines the type of Srubnaya miners' specialization. The Karagaly mines, in addition to the full range of the tool complex, also have evidence of the serial production of tools (fragments of foundry molds with multiple negatives of tools) for possible trade and exchange operations [Kargaly, 2004].

The Andronovo (Alakul, Kozhumberdy) mines of the Ural-Mugodzhar region, Kazakhstan, and Uzbekistan are less studied. The overwhelming numbers of toolsets come from collections from the modern surface of mines and are devoid of a stratigraphic context and accurate cultural and chronological attribution. Most of these tools were used in mining and ore crushing processes; evidence of the identification of other stages of metal production is limited [Zhauymbaev, 1984: 52; Tkachev, 2011: 50, 52; Avanesova, 2012: 27, 29].

In this regard, the Southern Trans-Urals region is represented by significant metal-producing assemblages of the Sintashta and Alakul Late Bronze Age cultures [Koryakova, Epimakhov, 2007; Grigoriev, 2015] remains studied not enough. The cultural layer dating to the second millennium BC is known here in three mines of the steppe zone of the modern Chelyabinsk region: Vorovskaya Yama, Novonikolaevsky, and Novotemirsky [Zaykov et al., 2005; Ankushev et al., 2018], but large-scale excavations were carried out only on the last one [Ankusheva et al., 2021a, b]. In the course of these activities, a representative collection of tools was found, the analysis of which makes it possible to raise the problem of defining a model of mining activity. The research aim is to determine the chain of technological processes taking place at the Novotemirsky mine. The tasks include determining the functionality of tools, use-wear of traces on them, composition and source of raw materials. The identification of technological operations contributes to the determination of the specialization level and possible social actions in the mining industry in the Bronze Age of the Southern Trans-Urals.

Materials and Methods

The Novotemirsky mine is located in the Chesma district of the Chelyabinsk region (Russia, South Urals) (Fig. 1). It was discovered as a geoarchaeological site in 2014. The deposit is confined to the Kulikovsky ultrabasic massif, the primary copper ores are chalcopyrite and bornite. Chrysocolla, malachite, azurite, less often delafossite, covellite, chalcocite, and native copper are represented in the supergene zone [Blinov et al., 2018]. The mine is a system of mine workings (shafts, hollows, and small pits) and adjacent waste rock dumps, the central object of which is a quarry measuring 20×30 m 2.5 m in deep. Archaeological excavations were carried out at the border of the quarry in 2017–2019, the investigated area was 400 m^2. Sectror A (240 m^2) covered the space above the shaft No.1 located on the southeastern side of the central quarry, while Sector B (160 m^2) was located in the area with the dumps of the south-western boundary of the quarry (Fig. 2). The site identifies three stages of the deposit development during the Bronze Age: the Sintashta period (the 21st — 20th centuries BC), Alakul period (the 17th — 16th centuries BC), and the period of the Final Bronze Age (the 15th — 13th centuries BC) [Ankusheva et al., 2021a].

The inventory of the mine includes 58 tools made of stone and one tool made of the long bone of cattle. The tools were found in different layers of the dumps, in the filling mine workings, which may indicate their use throughout the entire life of the mine in the Late Bronze Age. Some of these artifacts were precisely linked to the dated layers of the Alakul culture: the shutters of the casting mould for the pick, tool and devices from the shaft filling and the space next to it [Ankusheva et al., 2021a].

Fig. 1. Location of the Novotemirsky copper mine
Рис. 1. Местонахождение Новотемирского медного рудника

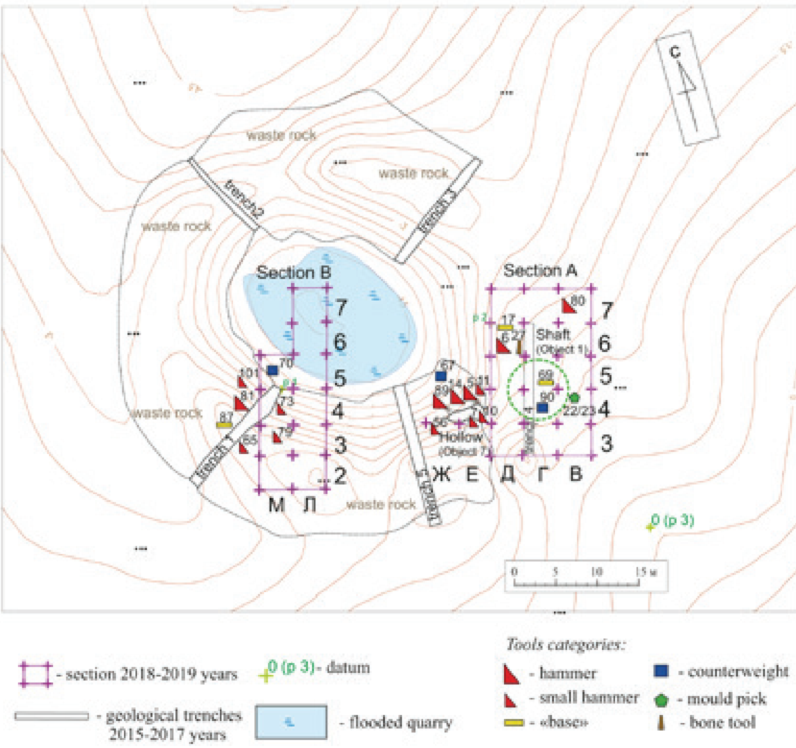

Fig. 2. The Novotemirsky copper mine. Plan. Excavation area 2018–2019
Рис. 2. Новотемирский медный рудник. План. Раскопы 2018–2019 гг.

The traseological analysis of stone tools was carried out in the archaeological laboratory of the South Ural State Humanitarian Pedagogical University using an MBS-2 optical microscope (oblique illumination, magnification up to 40 times, analyst Ivan V. Molchanov). Photographing of micro traces on the artifact's surface was carried out using an MC-2-Zoom TD-2 stereomicroscope with a TOUPCAM 10M video ocular. Petrographic analysis of 6 thin sections of tools (hammers, counterweights) was carried out on Olympus BX 51 microscope (SU FRC MG UB RAS, analysts Maksim N. Ankushev, Larisa Ya. Kabanova). X-ray fluorescence analysis of the mould surface was carried out on a portable device INNOV-X α 400, Soil mode, exposure time 30 s (SU FRC MG UB RAS, analyst Maksim N. Ankushev). X-ray diffraction analysis of the mould was carried out on a SHIMADZU XRD 6000 diffractometer, Cu anode, graphite monochromator; the content was calculated by the Rietveld method in the SIROQUANT V4 program (SU FRC MG UB RAS, analyst Pavel V. Khvorov).

Results

The sample from the excavations 2017–2019 amounted to 59 items. 22 of them are classified as tools; the remaining 37 items are represented by stone fragments and boulders without evidences of work or use. Morphological features made it possible to divide the tools into five categories:

1. **Percussion** tools (n=14)

1a. Hammers (n=6)

1b — Small hammers (n=8)

2. "Bases" (n=3)

3. Counterweights (n=3)

4. The casting mould of the pick (n=1)

5. Bone tool (n=1)

The characteristics of the tools are presented in table 1.

Tab. 1

Tools from the excavations of the Novotemirsky ancient mine (2017–2019)

Таблица 1

Орудия из раскопок древнего рудника Новотемирский (2017–2019)

№	Code of tool	Location / depth from conditional 0	Whole or fragment	Weight, kg	Size, cm	Material	Functionality	Labor operations
1	*5*	4E, hollow,—270	whole	3.6	22.5*15.5 *11.2	sandstone	sledgehammer	**percussion**
2	*6*	6Д,—195	whole	6	21*18.3 *14.5	sandstone	sledgehammer	**percussion**, crushing
3	*14*	4E, hollow,—346	fragment	2.1	20.5*13.2 *7.5	sandstone	sledgehammer	**Percussion,** crushing
4	*80*	7B,—178	whole	8.2	27.5*18 *14.5	sandstone	sledgehammer	**percussion**, crushing
5	*81*	Dumps of the trench 1	fragment	5	20*21.8*11	sandstone	sledgehammer	**percussion**, crushing?
6	*89*	4E	whole	3.5	27.4*11.5 *11	sandstone	sledgehammer	**percussion**?
7	*7*	4E, hollow,—270		1	13*11.2 *7.5	sandstone	hammer	**percussion**?

Окончание таблицы 1

№	Code of tool	Location / depth from conditional 0	Whole or fragment	Weight, kg	Size, cm	Material	Functionality	Labor operations
8	*10*	4E, hollow,—518	fragment	1	16.7*11.9*7.3	sandstone	hammer	**percussion**
9	*11*	4E	fragment	0.6	15*10*4	sandstone	hammer	**percussion**
10	*56*	4E	fragment	0.6	10*11*8.7	sandstone	hammer	**percussion**
11	*65*	Dumps of the trench 1	whole	0.5	13*8.1*5.5	sandstone	hammer	**percussion**?
12	*73*	Section B	whole	1.9	17.5*12.4 *10	sandstone	hammer	**percussion**, crushing
13	*79*	3M,—233	whole	0.5	14.3*7*4.4	sandstone	hammer	**percussion**
14	*101*	Dumps of the trench 1	whole	1.4	15.7*13.7*6.5	sandstone	hammer	**percussion**
15	*17*	6D,—196	fragment	1.9	15*13*8.5	sandstone	base	?
16	*69*	Shaft 1	whole	4.1	27.2*14.5 *10.2	sandstone	base	?
17	*87*	Dumps of the trench 1	fragment	6.7	23.5*21 *14.5	sandstone	base	grinding a soft materials, touching up metal artifacts
18	*67*	4E	whole	8.2	22.5*17 *15.5	rodingite	counterweight	lifting rock
19	*70*	5M	fragment	3.5	21.8*15.5 *11.2	rodingite	counterweight	lifting rock
20	*90*	Shaft 1	whole	16	40*18*21.5	serpentinite	counterweight	lifting rock
21	*22–23*	4B,—171	whole, two parts		22.9*11.3 *6 23.3*12*5.6	micaceous-epidote-chlorite metasomatite	the casting mould of the pick	mining
22	*27K*	6Д,—205	fragment	0.1	13*1.5–2	bone of cattle	tool	?

Stone tools (Fig. 3–7).

1. Percussion tools (n=13).

1a. *Hammers* (n=6) (*Fig. 3–4*). Large, massive tools, main function of them are percussion (codes 5, 6, 14, 80, 81, 89). Almost all of them were found in the waste rock: three tools come from filling heap of the boundary of quarry (object 7), two from heap planned around of the mine (object 1), one of them was found on surface of heap of the geological trenches.

The tools are represented by whole forms, only one by a fragment. The weight of the whole hammers is from 3.5 to 8.2 kg. Their measures are from 20 to 27.5 cm in length, from 11.5 to 21.8 cm in width, from 11.5 to 14 cm in thickness. The tools are subrectangular, elongated in form, wedge-shaped or trapezoidal with flattened edges in section. In most cases the working surface is located on the wedge-shaped end.

The wide grooves on the side edges are fixed on tools. It is a characteristic feature of this type of tool. In four cases, depressions for the groove were made in the center of the side edges (code 6, 80, 81, 89). In one case — in the upper part of the tool (code 5). The measures of the grooves are 4.5 to 8 cm in length, 4.5–6.5 cm in width, and 1–1.2 cm in depth. The design of the grooves is perfunctory. In some cases natural grooves are decorated with rough chips, debitage.

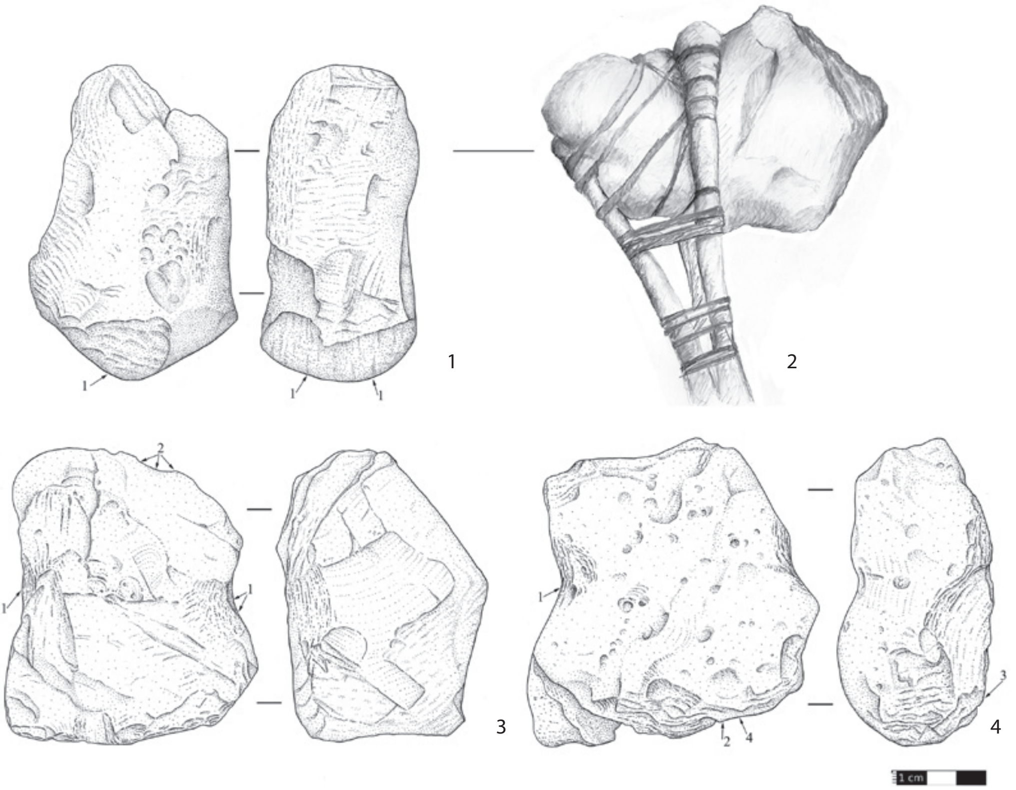

Fig. 3. Percussion tools. Hammers:
1. Hammer (code 369H/5): 1 — chipping. 2. Reconstruction of percussion tool (369H/5) by Sergey V. Kozhevnikov. 3. Hammer (code 369H/6): 1 — grinding, weakly observed linear traces, 2 — grinding, multidirectional linear traces. 4. Hammer (code 369H/81): 1 — grinding, close to polishing, multidirectional linear traces, 2 — grinding with thin linear marks, 3 — rolled edge of the hole, 4 — rolled edge of the hole

Рис. 3. Ударные орудия. Молоты:
1. Молот (шифр 369Н/5): 1 — скалывание. 2. Реконструкция ударного орудия (369Н/5), выполнена С. В. Кожевниковым. 3. Молот (шифр (369Н/6): 1 — пришлифовка, слабо выраженные линейные следы, 2 — пришлифовка, разнонаправленные линейные следы. 4. Молоток (шифр 369Н/81): 1 — пришлифовка, близкая к заполировке, разнонаправленные линейные следы, 2 — пришлифовка с тонкими линейными следами, 3 — завальцованый край ямки, 4 — скругленный край ямки

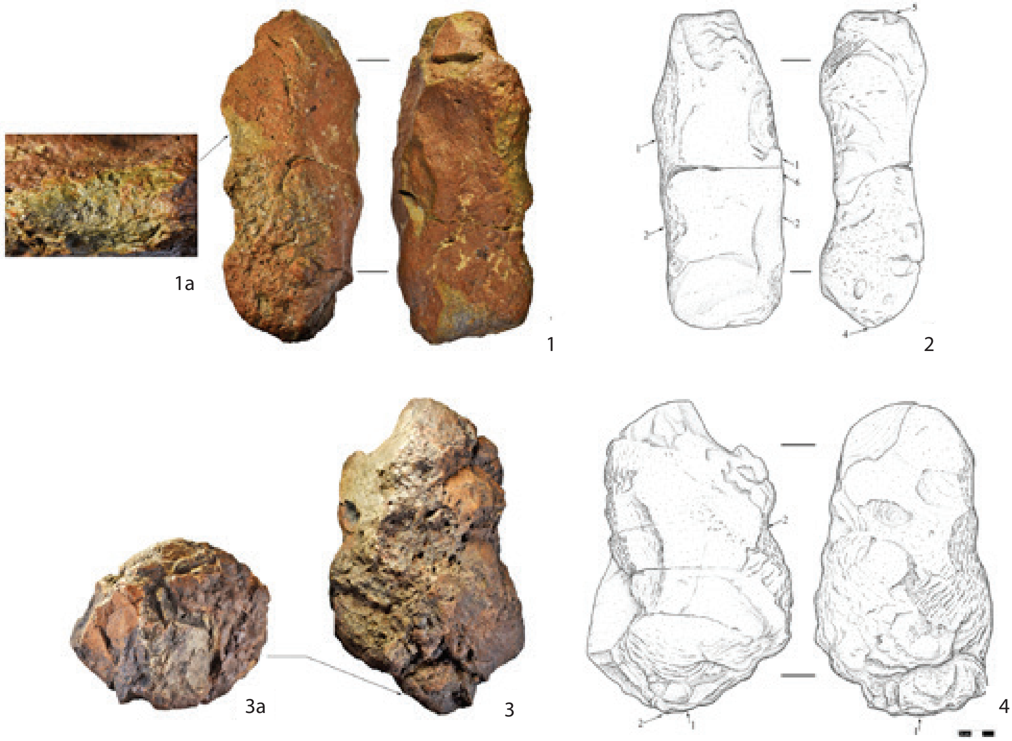

Fig. 4. Percussion tools. Hammer:
1 — Hammer (code 369H/89). Photo of tool. 1a — photo of groove surface with chipping traces, x40; 2 — Hammer (code 369H/89). Drawing of tool: 1, 2 — grooves, smoothness surface, 3 — smoothed edge, 4 — chipping, 5 — chipping, grinded area, 6 — copper fractions; 3, 3a — Hammer (code 369H/80). Photo of tool; 4 — Drawing of hammer (code 369H/80): 1 — rare, shortly linear traces, 2 — smoothness, deformation of rock grain
Рис. 4. Ударные орудия. Молоты:
1 — Молот (шифр369H/89). Фотография. 1а — фотография поверхности выемки со следами сколов, x40; 2 — Молот (шифр 369H/89). Рисунок: 1, 2 — выемки, сглаженность поверхности, 3 — сглаженная грань, 4 — скалывание, 5 — скалывание, пришлифованный участок, 6 — медные фракции; 3, 3а — Молот (шифр 369H/80). Фотографии; 4 — прорисовка молота (шифр 369H/80): 1 — редкие короткие линейные следы, 2 — сглаженность, деформация зерен породы

1b. *Small hammers* (n=8) *(Fig. 5)* elongated-sub-rectangular shape stones with a percussion function (codes: 10, 11, 56, 101, 65, 73, 79, 7). Five of them were found within the limits of the excavation: in waste rock and in the filling heap of the boundary of quarry (object 7). Two collected from the surface of waste rock, which formed during the laying of geological trenches. The weight of whole small hammers is from 0.5 to 1.5 kg. Their measures are from 13 to 17.5 cm in length, from 7 to 12.4 cm width, from 3.6 to 10 cm thickness.

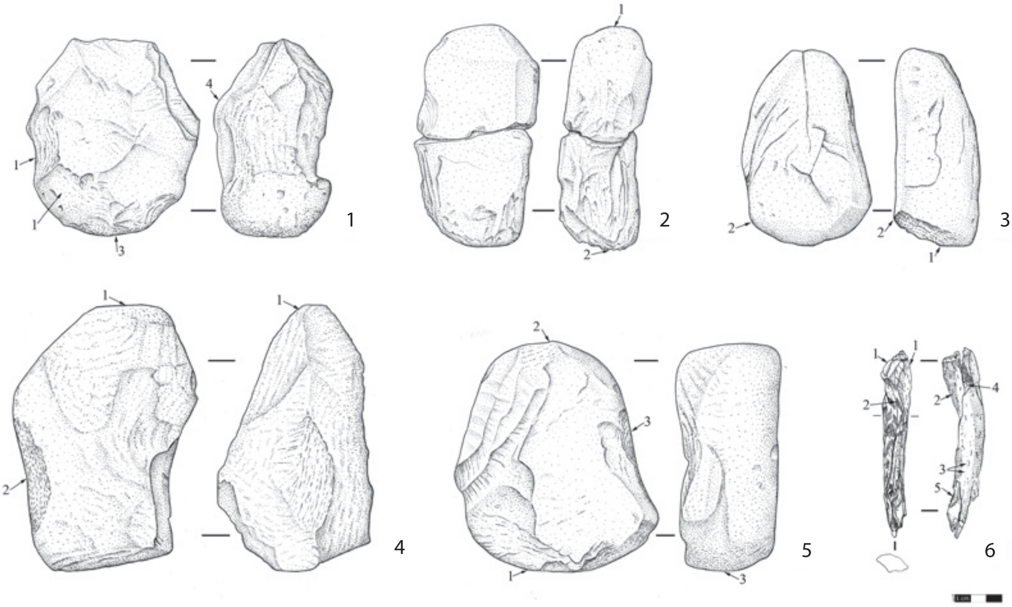

Fig. 5. Percussion tools. Small hammers, bone:
1 — Small hammer (code 369H/7): 1 — gloss of surface, 2 — chipping of the plaque, 3 — multidirectional linear traces, 4 — smoothed grains with linear traces; 2 — Small hammer (code 369H/79): 1 — grinded area with short linear marks, 2 — grinded area with short linear marks: 3 — Small hammer (code 369H/65): 1 — chipping wear area, 2 — ground area with linear marks; 4 — Small hammer (code 369H/73): 1 — clogging and short linear traces, 2 — grinded; 5 — Small hammer (code 369H / 101): 1 — flattening of the edge by chipping, 2 — clogging areas with deep, short linear traces, 3 — thin short traces; 6 — Bone tool (code 369H / 27K): 1 — working with a metal blade, 2 — cutting, 3 — groups of thin linear traces, 4 — thin linear traces, 5 — drop of metal (?)

Рис. 5. Ударные орудия. Молотки, костяное орудие:
1 — Молоток (шифр 369Н/7): 1 — блеск поверхности, 2 — скалывание желвачной корки, 3 — разнонаправленные линейные следы, 4 — сглаженные зерна породы с линейными следами; 2 — Молоток (шифр 369Н/79): 1 — слабая пришлифовка с короткими линейными следами, 2 — пришлифованный участок с короткими линейными следами; 3 — Молоток (шифр 369Н/65): 1 — выкрошенный участок, скалывания, 2 — пришлифованный участок с линейными следами; 4 — Молоток (шифр 369Н/73): 1 — небольшая забитость и короткие линейные следы, 2 — пришлифовка; 5 — Молоток (шифр 369Н/101): 1 — уплощение края скалыванием, 2 — выкрошенные участки с глубокими, короткими линейными следами, 3 — тонкие короткие царапинки; 6 — костяное орудие (шифр 369Н/27К): 1 — подработка металлическим лезвием, 2 — резка, 3 — группы тонких линейных следов, 4 — тонкие линейные следы, 5 — воздействие капли металла (?)

The general outline of the tools has a sub-rectangular shape, but the parameters of the products are not standardized. The tools have subrectangular, square and wedge-shaped section. Some of the edges of the tools undefined, not specially flattened. Fragmented objects are transverse splits. They are represented by either the upper or lower part of the tool. Usually, the working surface is located on the lower end of item. The shape of the working surface is different — round, flattened, wedge.

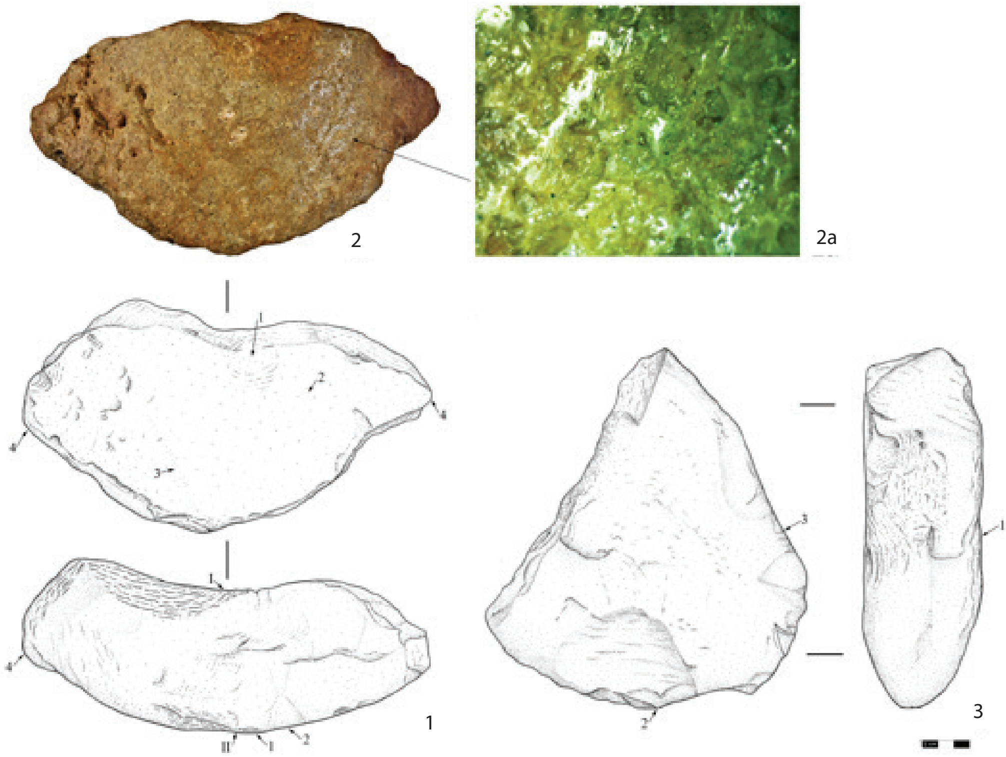

Fig. 6. "Bases":
1 — Drawing of "base" (code 369H/69): I — concave plane, II — convex plane;
1 — grinding around the chipped area, 2 — polished area with a group of thin linear traces,
3 — clogging areas with smoothed grains, 4 — rounded edge between the plane and the end;
2 — Photo of "base" (code 369H/69); 2a — Photo of gloss surface with linear traces x40;
3 — Drawing of "base" (code 369H/87): 1 — deep, multidirectional and crossing linear traces,
2 — flattening of the surface by chipping, 3 — chipping along the edge
Рис. 6. «Подставки»:
1 — Прорисовка «подставки» (шифр 369Н/69): I — вогнутая плоскость, II — выпуклая плоскость; 1 — пришлифовка вокруг сколотой площадки, 2 — заполированный участок с группой тонких линейных следов, 3 — выкрошенные участки со сглаженными зернами породы, 4 — скругленная грань между плоскостью и торцом; 2 — Фотография «подставки» (шифр 369Н/69); 2а — Фотография заполированной поверхности с линейными следами, x40; 3 — Прорисовка «подставки» (шифр 369Н/87): 1 — глубокие разнонаправленные и перекрещивающиеся линейные следы, 2 — уплощение поверхности скалыванием, 3 — скалывание по краю

The working surface of hammers and small hammers was located on one of the ends, or on one of the flatness side of the tool. Multidirectional, different sizes linear traces are marked on crumbled and a little clogged contact surfaces. The morphology and use-wear traces on whole objects are correlated with medium-size hammers. Large tools have a wedge-shaped edge in section, formed as a result of flattening of the planes adjacent to it, in addition to percussion zones. Wear was represented by rare, thin traces distinguished on grains on the flattened areas. The edge has no visible deformation. On the surface of several objects the areas with the copper fractions are preserved.

2. *"Bases"*[1] (n=3) *(Fig. 6)* are objects with a flattened surface for some material processing. Two of them are whole, one is fragmented. Localization of "bases" is associated with the functioning of Object 1 (mine). The tool with the code 17 was found in the waste rocks near the mine, with code 69 — in the filling of the mine, at the level –715, one meter from the bottom, with code 87 — from the waste. The tools are close to sub-triangular in plane, sub-rectangular in section. The working surface is flattened and located on wide surfaces of the stone. The weight of the whole product ranges from 4.1 to 6.7 kg. Measures: 23.5×21×14.5 cm (87), 27.2×14.5×10.2 cm (69).

Shiny plaque on the surface of "bases" is the problem for functional analysis and determine the material processed on them. The objects have one or two smoothed, grinded working surfaces, on which thin, multidirectional, different traces are recorded. Short, multidirectional traces are recorded on the slightly crashed grains of the contact zones. An interesting artifact seems to have a curved shape in the plane (code 69). Most of its convex surface is well grinded and polished; the "top" is flattened by chipping. Close to "top" is a smoothed area with a metallic sheen, slightly different from the shiny plaque of surface. On the flattened area, deformation of the rock grains is noted, on which short, multidirectional scratches are recorded. Groups of thin, parallel to each other, longitudinal and diagonal linear traces are visible on a smoothed surface with a metallic sheen. They are located to elongated axis of the stone. Probably, this item could be used to soft material processing; also it can be used as an abrasive for metal objects.

All stone hammer tools and "bases" are made of sandstone, as well as a series of boulders and fragments without traces of work. According to the petrographic analysis, the clastic material is represented by quartz, rare grains of feldspar, rutile, and muscovite and makes up 80% of the sample. Quartz grains are rounded and corroded with cement in some areas. Opal cement makes up 20% of the sample volume and is colored with iron oxides and hydroxides. The mineral composition and textural features of the rock (content of quartz grains in the opal cement), provides high hardness and strength of the tools. This makes it possible to successfully reuse a heavy piece of sandstone as a hand-held beating tool [Kozhevnikov, Ankushev, 2018]. Minimal processing to give the tool shape and unexpressed traces of work indicate a quick replacement of tools, their consumability. Numerous pieces of sandstone with no trace of work are likely a byproduct of the hammer-making process right at the mine.

The sandstone can be safely considered specially brought to the mine. The Novotemirsky deposit is confined to the Kulikovsky massif ultramafic rocks, composed of serpentinites with blocks of dolerites and gabbroids. Sandstones are developed at some distance, on the Sukhtelinskaya and Berezinskaya strata located to the north and east of the Novotemirsky

[1] For flat stones, which have surfaces with some kind of processing wear we are use the term "base".

deposit [Tevelev et al., 2018]. The field survey of the nearby area revealed a deluvial spread of rounded sandstone boulders of small and medium-size (from 5*5 to 20*25 cm), which were found at the site of modern arable land 1.5 km east of the mine.

3. *Counterweights* (n=3) *(Fig. 7)* — represented by massive stones with grooves (codes 67, 70, 90). Two whole and one fragmented tools of this category were found.

The first large tool has measurement 40×18×21.5 cm and weight of 16 kg (code 90). It was found at the bottom of the mine. The product was made of a large fragment of serpentinite, practically without modification. It is trapezoidal, triangular in section. One of the edges is concave, other are flattened. Two wide grooves are grinded on the side edges (8.2×3.6×1.2 cm; 7.8×4.9×2.1 cm). The grooves are chipped and with debitage modified, there are abrasion traces visible. The second whole stone (code 67) was found in a waste of mine (Object 7). It is presented in a more compact version and has cubic shape measure is 22.5×17×15.5 cm and weigh 8.2 kg. 4 grooves are sharpened on each side edge. A fragment of the third item was found in waste at the bottom of a quarry (code 70). A wide groove for the fastening was marked on one of the surfaces of it.

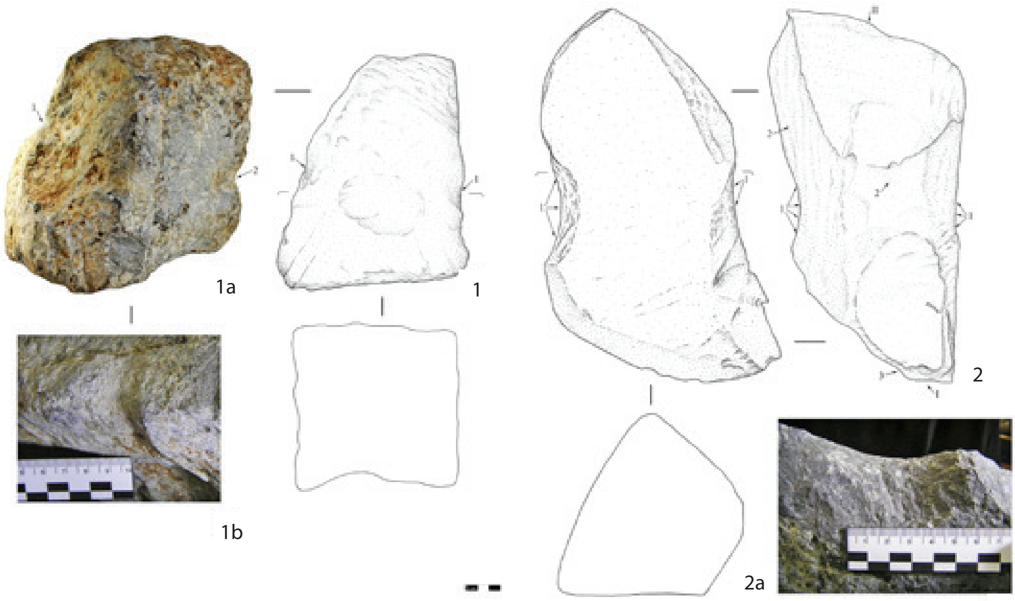

Fig. 7 Counterweights:
1 — Counterweight (code 369H/67), 1 — drawing, 1a — photo, 1b — photo of groove surface x40: 1 — grooves, smoothed surface; 2 — Counterweight (code 369H/90): I — trapezoidal section, II — triangular section; 1 — smoothed surface with linear traces from the strapping, 2 — chipped plane, 3 — chipping of the end surface; 2a — photo of groove surface x40
Рис. 7. Противовесы:
1 — Противовес (шифр 369Н/67), 1 — рисунок, 1а — фотография, 1б — фотография поверхности выемки, х40; 1 — выемка, сглаженная поверхность; 2 — Противовес (шифр 369Н/90): I — трапециевидное сечение, II — треугольное сечение; 1 — сглаженная поверхность с линейными следами от обвязки, 2 — сколотая плоскость, 3 — скалывание поверхности торца; 2а — фотография поверхности выемки, х40

The grooves located on all or several elongated lateral edges in line are characteristic feature of this type of objects. It used for fixing with a belt or rope. Only one fragment of the counterweight has a depression in plane, which slightly overhang the edges (code 70). A same depression of one of the planes is marked on other massive counterweight. It is wide, transverse, slightly deepen curved strip, which connecting two opposite grooves to each other. It is formed by knapping of the white plaque (code 90). On the surface of the grooves, traces of abrasion are visible. It is poorly distinguishable, rare traces, which are transverse to the edges. On the border of the abrasion area and natural surface are observed smoothed grains with multidirectional scratches on it. These traces could be formed after contact of the stone with transverse strapping rope, probably made of plant material. Perhaps, this mount had a slight backlash, which sometimes allowed the stone to vertically move in a horizontal axis.

Local rocks were used for manufacture of counterweights: codes 67, 70 — rodingite, code 90 — serpentinite. These rocks do not have sufficient hardness and strength. It is not very suitable for performing basic labor operations (percussion, abrasive). The general signs of counterweights are absence of traces of work, the presence of special grooves and heavy weight.

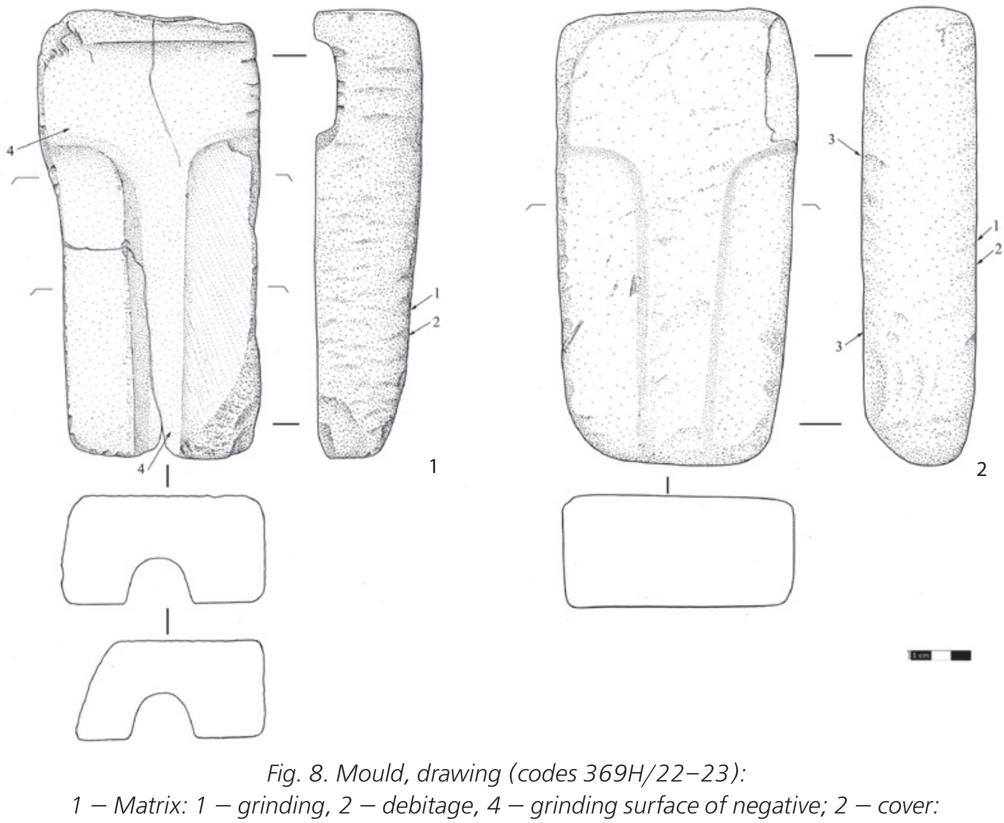

Fig. 8. Mould, drawing (codes 369H/22–23):
1 — Matrix: 1 — grinding, 2 — debitage, 4 — grinding surface of negative; 2 — cover:
1 — grinding, 2 — debitage, 3 — areas with a metallic gloss
Рис. 8. Рисунок литейной формы (шифр 369H/22–23):
1 — Матрица: 1 — шлифование, 2 — пикетаж, 4 — пришлифовка поверхности негатива;
2 — крышка: 1 — шлифование, 2 — пикетаж, 3 — участки с металлическим блеском

4. *A bivalve casting mould* (code 22–23) *(Fig. 8–9)* for casting a mining tool was found in 3 meters south-east of the mine in the waste rock field. The mould consists of two parts: a matrix and a cover. The matrix has a rectangular shape, measure is 22.9×11.3×6 cm and at the location of the negative of the fixing part of the tool are expands. A T-shaped negative of the pick is cut out on the matrix. It consisted of a spearhead (measure is 15.5×2–4×2 cm) and a plate for forming an open sleeve (measure 11.3×5x1–2 cm). Along the edges of the negative are distinguished traces of high-temperature exposure, which are presented by black calcined edging penetrating to a depth of 0.3–0.5 cm. The measure of the cover is 23.3×12×5.6 cm. Small fragment was chipped in ancient from one of the corners was found near mould. Close to the negative were visible wear traces, which were presented by black outline of blank of tool with reddish calcined filling. The width of outline is -0.5–1 cm.

Fig. 9 Mould, photo (codes 369H/22–23):
1 – Set of matrix and cover, 2 – view from the end of the mold,
3 – view from the opposite end, 4 – view from the side
Рис. 9. Фотография литейной формы (шифр 369H/22–23):
1 – набор литейной формы из крышки и матрицы; 2 – вид с одного торца;
3 – вид с противоположного торца; 4 – вид сбоку

Tab. 2

Evidence of copper and tin on the casting mould surface (code 22–23) from the Novotemirsky mine according to X-ray fluorescence analysis

Таблица 2

Следы меди и олова на поверхности литейной формы (код 22–23) с Новотемирского рудника по данным рентгенофлюоресцентного анализа

Part of the mould	Concentration, ppm	
	Cu	Sn
cover, an inner surface	5505	1165
cover, an outer surface	545	–
matrix, an inner surface	3624	387
matrix, an outer surface	1650	–

Note: dash — below the detection limit.

On the outer surfaces of both pieces wear grinding, presented by small- and medium-grained abrasives areas with characteristic for this operation traces was preserved. After that, all surfaces, except flat plane of matrix and the cover, were processed by debitage. This is evidenced by rather large, rounded, in places overlapping each other potholes, which cover almost all the outer surfaces of the mould. On the longitudinal edges of the cover, areas with metallic gloss are noted, a similar gloss is noted on the rounded end of the matrix. The surface of the matrix is well smoothed; traces of grinding with a small-grained abrasive are noted on it. The inner surface of the upper part of matrix is chipped, probably as a result of casting.

The results of X-ray fluorescence analysis of the casting mould surfaces indicate the bronze composition of the metal (copper + tin) from which the pick was cast; it is noteworthy that evidences of tin were recorded only on the inner (working) surface of the mould parts (Table 2).

According to X-ray diffraction analysis, the casting mould was made of mica-epidote-chlorite metasomatite (Table 3). This rock has not been found in the mine and the surrounding area, which makes it possible to attribute the casting mould to the brought artifacts.

Tab. 3

Mineral composition of the casting mould of a pick found at the Novotemirsky mine

Таблица 3

Минеральный состав литейной формы кирки, найденной на Новотемирском руднике

Code of analysis	Mineral composition (approx. weight %)					
	Chlorite	Epidote	Mica	Plagioclase	Talc	Amphibole
LF-1	38	27	26	9	trace	trace

5. *The bone tool* (Fig. 5.-*6*) is a fragmented item made from the diaphysis of the tibia of cattle (code 27K). It was found in the humus layer under the waste rock of the Alakul time. The tool is badly preserved, 13 cm in length, 1.5 to 2 cm in width. The safety of the tool fragment does not allow us to clearly defined function of it.

The same gloss as on stone objects is noted on the surface of this bone. The surface of the epiphysis is worked. Several areas are marked on it with wide lines, reminiscent of outlines. Directly (1) on the end, they are located at the edges opposite each other. On a small chip (4) adjacent to the end (epiphysis), a porous bone structure is noted. On its surface, thin, parallel to each other traces are fixed. They are located transversely to the elongated axis of the object. On the curved metaphysis (2), there are traces of cutting with a metal blade, probably by warmed bone. Traces formed small ledges placed in a cascade. Linear traces are not distinguished here. The outer edges of this section of the cut are straight. Closer to the broken end of the fragment (3), on the outer surface of the bone, two diagonal elongated axes of the object depressions are visible. One of them is deep, triangular in shape. Probably, it is result of direct percussion by metal object. Another observed as shallow, wide, curving trace. Inside of them parallel to each other traces are fixed, which repeating the outer contour of the depressions. Groups of thin, different-sized, transverse traces can be seen close to outside of them. A small, round brown drop is noted in a small depression on the inner surface of bone. Probably, it can be a drop of metal (5).

Thus, the distinguished evidence of wear allows classifying this fragment of bone as a tool. Tools made of animal bones are widely presented in the materials of the miners settlements: Kargaly [Kargaly, 2004], Michailo-Ovsyanka [Goraschuk, Kolev, 2004], Kartamysh ore occurrence [Brovender, Zagorodnyaya, 2009], but there are not enough data to relate this bone from Novotemirsky mine with a specific tool's type.

Discussion

According to results of the study of the tool complex of the Novotemirsky mine, we can noted that only two types of technical processes of the mining and metallurgical production are presented here: mining (casting mould for a bronze pick, counterweights) and crushing ore (hammers). There are no tools of the enrichment process (pestles, ore grinders) and metalworking (blacksmith hammers), as well as evidence of the serial production of tools in the artifact complex of the site, found during the excavations in 2017–2019.

Mining processes. This kind of work is represented by a bronze mining pick (pickaxe) cast in a bivalve casting mould. Finding a forged bushing pick mould with traces of use near the mine may indicate the production of these tools (picks) right at the mine.

There are few analogies of of this kind of tools from the surface collection of the Middle and Southern Trans-Urals sites [Avanesova, 2012], the Volga region [Tikhonov, 1960: 13], in old collections at Kargaly [Kargaly, 2004: 77; Kargaly, 2007: 101, Fig. 7.-2]. Nona Avanesova defines a similar category of tools as wedge-shaped socket chisels. The author notes that they could have been used for mining operations [Avanesova, 1991: 35].

Analogies of the pick from the Sintashta and Petrovka fortified settlements of the Southern Trans-Urals have a more reliable stratigraphic context. A tin-arsenic bronze tool (15 cm long) was found in the cultural layers of the Ustye I [Drevnee Ustye, 2013: 444, Fig. 15, 18.-1] and Kamenny Ambar settlements [Molchanov, Molchanova, in print].

At the same time, casting moulds for same tools in a fairly large series are presented in the materials of the Gorny I settlement at the Kargaly deposit [Kargaly, 2004: 134]. It is necessary to note the morphological difference between the Novotemirsky negative of the pick and the chlorite metasomatite form itself and sandstone forms from the Gorny I. The negative of the

Novotemirsky pick is strictly T-shaped, whereas the Gorny I pick negatives is wedge-shaped. Perhaps this difference is due to cultural and chronological specifics. The Novotemirsky casting mould is confined to the Alakul layers (the 17th — 16th centuries BC), whereas Gorny moulds are mostly associated with the B-3 subphase, with the end of the Bronze Age (the 15th — 13th centuries BC) [Kargaly, 2004: 134].

Auxiliaries for mining operations include heavy (16 kg and 8.2 kg) counterweights with grooves for tying. Analogies of similar items are also known in Kargaly [Kargaly, 2004: 179, Fig. 6.-17].

According to ethnographic evidence, the lifting of ore from vertical shaft could be carried out simply: in baskets, on ropes or slings [Agricola, 1962: 212]. However, the finding of counterweights suggests the presence of a more complex lifting mechanism. The rectangular shape of the Novotemirsky shaft 1 [Ankusheva et al., 2021a: 32–33, Fig. 2, 3] makes it possible and convenient to erect scaffolding inside it and a support site in the adjacent territory.

The manufacture of mining tools at the mine, as well as the possible use of complex lifting mechanisms in vertical workings, indicates a pronounced specialization of mining processes in the Bronze Age of the Southern Trans-Urals.

Ore crushing. These processes include the main set of the tool complex (sledgehammers and hammers). Numerous fragments of sandstone indicate that there were many such tools and, possibly, they were used throughout the Late Bronze Age. Typologically Novotemirsky hammer tools are distinguished by several characteristic features: wide grooves on the side edges of the tools, heavyweight, strong hard rock, and percussion marks on the working surface.

Reconstruction of the stone tools attached to the handle is a significant problem since the grooves suggest a handle method of attachment. An additional groove on the upper platform, difference on Kargaly hammers [Kargaly, 2004: 162, Fig. 6, 5.-1] is on the Novotemirsky tools. Nevertheless, special flattening chips on the upper platform were made on sledgehammers, probably for a better fit of the handle. According to ethnographic parallels, hammer handles are made of twigs, wood, ropes, and leather belts [Craddock et al., 2003: 57, Fig. 4.-6]. A possible reconstruction of a hafted stone mining hammer from the Novotemirsky mine is shown in the figure (Fig. 3.-*2*).

Ore crushing hammers are known at all Eurasian metallurgical province mines: at the Kartamysh ore occurrence [Brovender, 2008: 196, Fig. 8; Brovender, Zagorodnyaya, 2009: 254], at the Mikhailo-Ovsyanka mine [Gorashchuk, Kolev, 2004: 95, Fig. 1–4], at the Kargaly complex [Kargaly, 2004: 158–161], at the Ural-Mugodzhary [Tkachev, 2011: 50, Fig. 4, 6], Central and East Kazakhstan [Margulan, 2001; Chernikov, 1960], and Zarafshan mining and metallurgical centers [Avanesova, 2012: 27, Fig. 13, 16]. At the same time, this tools category is represented unevenly on household sites. These tools are spread on settlements located near mines. In particular, hammers were found in the settlements of the Ural-Mugodzhary mining and metallurgical center [Fomichev, 2015] and Central Kazakhstan: Zhezkazgan, Atasu I, Taldysai [Kuznetsova, Teplovodskaya, 1994: 57, Fig. 21, 23]. But such heavy ore-crushing tools are absent on the Sintashta and Alakul settlements in the Southern Trans-Urals. On the fortified settlement of Ustye I hammers are not founded [Drevnee Ustye, 2013: 288–289]; they have also not been found in the Alakul unfortified settlements [Zdanovich and Korobkova, 1988; Alaeva, 2015: Tab. 27].

The organization of mining at different stages of the Late Bronze Age in the Southern Trans-Urals could have a significant difference: the Sintashta fortified settlements with bright evidence of metal production (furnaces, slags, ingots, mining tools) in every house demonstrate the employment of their entire population in these processes. Mining tools and massive ore crushing hammers are absent in the unfortified settlements of the Alakul culture. At the same time, these categories of tools are represented at the mine which suggests a different model of labor organization — the presence of a specialized group of miners who perform work only at the mine.

We assume the existence of various models for organizing mining and metallurgical production at mines in Northern Eurasia in the Bronze Age:

— export, all-season, specialized model;
— pastoral, seasonal, non-specialized model;
— seasonal, partly specialized model.

Evgeny N. Chernykh defines the form of organization of Kargaly mining production as an "export model" that combines all production cycles: from mining, crushing and enrichment, ore smelting to the production of ingots and casting serial tools for trade and exchange operations. The export model assumes the existence of a specialized group of miners and metallurgists employed only in this production [Kargaly, 2007: 120].

Following to the materials of the Ural-Mugodzhary mining and metallurgical center Vitaly V. Tkachev reconstructs the pastoral model of metal production, which combines distant-pasture cattle breeding and ore mining during the warm season. Non-specialized groups of pastoralists are seasonally involved in mining as well [Tkachev, 2020]. A similar model associated with summer work at the mine and combination with a seasonal livestock system was proposed for the Mikhailo-Ovsyanka mine in the Volga region [Shishlina et al., 2020: 22].

It is still difficult for us to agree with the non-specialized model of mining in the Srubnaya and Alakul culture. This model is contradicted both by the difficulty of combining mining with cattle grazing and by evidence of specialization: the absence of mining tools in settlements and the availability of such tools only in mines, the existence of mining settlements near copper deposits (Mikhailo-Ovsyanka mine, Ural-Mugodzhary mines). In addition, to date, the exploration degree of the mines (fragmented data, insignificant excavation areas) do not allow to unambiguously interpreting the results of the herd composition analysis based on the bones of livestock at the mines.

The main stumbling block in attribution of a specialized or non-specialized model is the herd composition from mines. At the Kargalinsky mine, the herd composition is non-standard for settlements (up to 80% of cattle with a small proportion of small cattle and horses) [Kargaly, 2004: 187, 222]. At the Mikhaylo-Ovsyanka and Ural-Mugodzhar mines, the composition of the herd is identical to that of the settlement. However, the similarity of the parameters of the herd composition at mines and at household monuments can only indicate the use of the food base of settlements [Ankusheva et al., 2021b], and not the practice of developing mines by pastoralists combining these types of activities.

Most likely, we can talk about partial specialization, which consists of the formation of temporary collectives of miners who are seasonally involved in mining operations.

Boris Tikhonov argues in favor of working in mines during the cool season (spring, autumn and even winter). At this time, the population is freed from the economic affairs of the summer season. As evidence, the author points to the finds of winter clothes (fur coats, fur mittens) in old workings Gumeshevskie mines [Tikhonov, 1960: 14]. The slaughter season of the cattle on the Novotemirsky mine does not contradict the possible exploitation of deposits in the cold time of year, although the investigated sample of teeth (n=2) is too small to draw firm conclusions [Ankusheva et al., 2021b]. The presence of deepened buildings and thick deposits of the cultural layer at another Alakul mine (Vorovskaya Yama) also testifies in favor of mining in the cold season [Zaykov et al., 2005; the results of the author's field research in 2021].

The model of seasonal work in the cool (spring, autumn) and even cold (winter) seasons with partially specialized groups of metallurgical miners is in good agreement with the settled model of cattle breeding reconstructed for the population of the Bronze Age of the Southern Trans-Urals stall keeping livestock in the cold season [Rassadnikov, 2017].

Thus, the seasonal model of partially specialized mining could function at the Novotemirsky mine, as indicated by the set of tools, reconstruction of production stages, as well as the absence of buildings and a small number of artifacts and other evidence of human activity in the cultural layer of the site.

Conclusion

The complex of artifact's analysis from the Novotemirsky mine excavations made it possible to distinguish three groups of tools, depending on their functionality: mining (casting mould of a bronze pick), ore crushing (sledgehammers and hammers), auxiliary devices ("bases", counterweights for lifting ore).

The absence of enrichment (pestles, grinding stones) and metal-working (blacksmith hammers) tools in the Novotemirsky mine indicates a narrow range of technical operations, associated only with the direct extraction of copper ore and primary enrichment (crushing of large blocks).

The incomplete chain of operations at the Novotemirsky mine may be related to the peculiarities of this deposit. The laboriousness of mining due to the need to crush solid ore-hosting rocks, the poverty of copper deposits made it unprofitable to organize a specialized village of miners at this deposit.

REFERENCES

Agrikola G. O gornom dele i metallurgii v dvenadcati knigah [On Mining and Metallurgy in Twelve Books]. Moscow : Izdatel'stvo Akademii nauk SSSR, 1962. 598 p. *(In Russ.)*

Avanesova N. A. Kul'tura pastusheskih plemen epohi bronzy Aziatskoj chasti SSSR (po metallicheskim izdeliyam) [The Culture of the Bronze Age Pastoral Tribes of the Asian Part of the USSR (for metal products)]. Tashkent : Fan, 1991. 200 p. *(In Russ.)*

Avanesova N. A. Drevniye gornyaki Zarafshana [The Ancient Miners of Zarafshan]. Arheologiya Uzbekistana [Archaeology of Uzbekistan]. 2012. №1. Pp. 3–35. *(In Russ.)*

Alaeva I. P. Kul'turnaya specifika pamyatnikov pozdnego bronzovogo veka stepnoj zony Yuzhnogo Zaural'ya [Cultural Specificity of the Late Bronze Age Sites of the Southern Trans-Urals Steppe Zone]: Dis. … Cand. Hist. Sciences. Moscow, 2015. 539 p. *(In Russ.)*

Ankushev M. N., Yuminov A. M., Zajkov V. V., Noskevich V. V. Mednye rudniki bronzovogo veka v Yuzhnom Zaural'e [Copper Mines of the Bronze Age in the South Trans-Urals]. Izvestiya Irkutskogo gosudarstvennogo universiteta. Ser.: Geoarheologiya. Etnologiya. Antropologiya [Bulletin of the Irkutsk State University. Series Geoarchaeology. Ethnology. Anthropology]. 2018. Vol. 23. Pp. 87–110. DOI: 10.26516/2227-2380.2018.23.87. *(In Russ.)*

Ankusheva P. S., Alaeva I. P., Ankushev M. N., Fomichev A. V., Zazovskaya E. P., Blinov I. A. From Ore to Metal: Exploitation of the Novotemirsky Mine, Southern Trans-Urals, in the Second Millennium BC // Archaeology, Ethnology & Anthropology of Eurasia. 2021a. Vol. 49. № 1. Pp. 30–38. DOI: 10.17746/1563-0110.2021.49.1.030-038.

Ankusheva P. S., Kiseleva D. V., Bachura O. P., Alaeva I. P., Ankushev M. N., Okuneva T. G. Trud i pitanie gornyakov bronzovogo veka Yuzhnogo Zaural'ya (po dannym izotopnogo sostava stronciya v osteologicheskih ostatkah rudnika Novotemirskij [Labor and Food of Bronze Age Miners in the Southern Trans-Urals (based on the strontium isotopic composition in the Novotemirsky mine osteological remains]. Stratum Plus. 2021b. № 2. Pp. 69–83. *(In Russ.)*

Blinov I. A., Ankushev M. N., Rassomahin M. A., Medvedeva P. S. Mineraly medi, nikelja i mysh'jaka v rudah Novotemirskogo projavlenija zheleza (Juzhnyj Ural) [Minerals of Copper, Nickel and Arsenic in the Ores of the Novotemir Iron Occurrence (South Urals)] // Mineralogija [Mineralogy]. 2018. Vol. 4, № 3. Pp. 36–45. *(In Russ.)*

Brovender Yu. M. Itogi raskopok tehnogennogo uchastka na Kartamyshskom rudoproyavlenii [Results of Excavations of a Technogenic Site at the Kartamysh Ore Occurrence]. Drevnosti [Antiquities]. 2006–2008. Har'kov : NTMT. 2008. Pp. 184–203. *(In Russ.)*

Brovender Yu. M., Zagorodnyaya O. N. Orudiya metalloproizvodstva poseleniya Chervone Ozero-3 Kartamyshskogo kompleksa gorno-metallurgicheskyh pamyatnykov epohy bronzy [Tools of Metal Production of the Settlement Chervone Ozero-3 of the Kartamysh complex of mining and metallurgical Bronze Age Sites]. Materialy ta doslidzhennya z arheologii Skhidnoi Ukrainy [Materials and Researches on Archeology of Eastern Ukraine]. Lugansk : Naw. akad. nauk Ukrayiny, Skhidnoukr. nac. un-t im. Volodymyra Dalya, In-t arheologii. 2009. Pp. 251–262.

Chernikov S. S. Vostochnyj Kazakhstan v epohu bronzy [East Kazakhstan in the Bronze Age]. Materialy i issledovaniya po arheologii [Materials and Research on Archaeology]. №88. Moscow; Leningrad : Izdatel'stvo Akademii nauk SSSR, 1960. 270 p. *(In Russ.)*

Chernykh E. N. Formation of the Eurasian "Steppe Belt" of Stockbreeding Cultures: Viewed through the Prism of Archaeometallurgy and Radiocarbon Dating // Archaeology, Ethnology & Anthropology of Eurasia. 2008. 3(35). Pp. 36–53 DOI: 10.1016/j.aeae.2008.11.003

Craddock B. R., Cartwright C. R., Craddock P. T., Wray W. B. Hafted Stone Mining Hammer from Chuquicamata, Chile // Mining and Metal Production. Through the Ages. Edited by Paul Craddock and Janet Lang. London : The British Museum Press, 2003. Pp. 52–68.

Drevnee Ust'e: ukreplennoe poselenie bronzovogo veka v Yuzhnom Zaural'e. Red. N. B. Vinogradov; A. V. Epimahov [Ancient Ustye: Fortified Settlement of the Bronze Age in the Southern Trans-Urals. Eds. N. B. Vinogradov; A. V. Epimakhov]. Chelyabinsk : ABRIS, 2013. 482 p. (*In Russ.*)

Fomichev A. V. Orudiya gornogo dela i metallurgii poseleniy pozdnego bronzovogo veka na severe Ural'sko-Mugodzharskogo gorno-metallurgicheskogo centra [Mining and Metallurgy Tools of the Late Bronze Age Settlements in the North of the Ural-Mugodzhary Mining and Metallurgical Center]. Vestnik Chelyabinskogo gosudarstvennogo universiteta [Bulletin of the Chelyabinsk State University]. 2015. № 24. History. Issue 66. Pp. 9–16. *(In Russ.)*

Gorashchuk I. V., Kolev Yu. I. Kamennye i kostyanye orudiya s rudnika bronzovogo veka Mihajlo-Ovsyanka v Samarskoj oblasti [Stone and Bone Tools from the Bronze Age Mine Mikhailo-Ovsyanka in the Samara Region]. Voprosy arheologii Urala i Povolzh'ya [The Questions of Archaeology of the Urals and the Volga Region]. Vol. 2. Samara : Izd-vo "Samarskij universitet", 2004. Pp. 89–104. *(In Russ.)*

Grigoriev S. Metallurgical Production in Northern Eurasia in the Bronze Age. Oxford : Archaeopress Publishing Ltd., 2015. 831 p.

Kargaly. T. III: Selishche Gornyj: Arheologicheskie materialy: Tehnologiya gorno-metallurgicheskogo proizvodstva: Arheobiologicheskie issledovaniya. Sost. i nauch. red. Ye.N. Chernyh [Kargaly. Vol. III: Gorny Settlement: Archaeological Materials: Technology of Mining and Metallurgical Production: Archaeobiological Research. Compiled and scientific by ed. E.N. Chernykh]. Moscow : Yazyki slavyanskoj kul'tury, 2004. 320 p. *(In Russ.)*

Kargaly. T. V: Fenomen i paradoksy razvitiya: Kargaly v sisteme metallurgicheskikh provintsiy: Potayennaya (sakral'naya) zhizn' arkhaiyeskikh gornyakov i metallurgov. Sost. i nauch. red. Ye.N. Chernyh [Kargaly. Vol. V: Phenomenon and Paradoxes of Development: Kargaly in the System of Metallurgical Provinces: Hidden (Sacred) Life of Archaic Miners and Metallurgists. Compiled and scientific by ed. E.N. Chernykh]. M. : Yazyki slavyanskoj kul'tury, 2007. 200 p. (*In Russ.*)

Kolev J. I. Das Bergbau- und Verhüttungszentrumder Bronzezeit in Michael-Ovsânka an dermittleren Wolfgang // Der Anschnitt 62. 2010. 1–12. Pp. 2–19.

Koryakova L. N. Epimakhov A. V. The Urals and Western Siberia in the Bronze and Iron Ages. Cambridge : Cambridge University Press, 2007. 383 p. DOI: 10.1017/CBO9780511618451

Kozhevnikov S. V., Ankushev M. N. Kamennye orudiya iz otvala drevnego rudnika Novotemirskij (Yuzhnoe Zaural'e) [Stone Tools from the Dump of the Ancient Novotemirsky mine (South Trans-Urals)]. Geoarheologiya i arkeologicheskaya mineralogiya [Geoarchaeology and Archaeological Mineralogy]. Miass : Institute of Mineralogy, Ural Branch of the Russian Academy of Sciences. 2018. Pp. 80–82. *(In Russ.)*

Kuznecova E. F., Teplovodskaya T. M. Drevnyaya metallurgiya i goncharstvo Central'nogo Kazahstana [Ancient Metallurgy and Pottery of Central Kazakhstan]. Almaty : Gylym, 1994. 207 p. *(In Russ.)*

Margulan A. H. Dzhezkazgan — drevnij metallurgicheskij centr (Gorodishche Milykuduk) [Dzhezkazgan — an Ancient Metallurgical Center (Milikuduk fortified settlement)]. Arheologicheskie issledovaniya v Kazahstane [Archaeological Research in Kazakhstan]. Alma-Ata : Nauka, 1973. Pp. 3–42. (*In Russ.*)

Margulan A. H. Sochineniya: v 14 t. T. 2. Saryarka. Gornoe delo i metallurgiya v epohu bronzy. Dzhezkazgan — drevnij i srednevekovyj metallurgicheskij centr (gorodishche Milykuduk) [Essays: In 14 Volumes. V. 2. Saryarka. Mining and Metallurgy in the Bronze Age.

Dzhezkazgan is an Ancient and Medieval Metallurgical Center (settlement of Milykuduk)]. Almaty : Dajk-Press, 2001. 144 p. *(In Russ.)*

Matveeva G. I., Kolev Yu. I., Korolev A. I. Gorno-metallurgicheskij kompleks bronzovogo veka u s. Mihaylo-Ovsyanka na yuge Samarskoj oblasti [Mining and Metallurgical Complex of the Bronze Age near the Village Mikhailo-Ovsyanka in the South of the Samara region]. Voprosy arheologii Urala i Povolzh'ya [The Questions of Archaeology of the Urals and the Volga Region]. Vol. 2. Samara : Izd-vo "Samarskij universitet", 2004. Pp. 69–88. *(In Russ.)*

Molchanov V. Ivan. and Molchanova V. Vlada. Catalogue of Inventory from the Kamennyi Ambar Settlement (excavation unit 6) // in R. Krause and L.Koryakova (ed.). Culture, Environment and Economy of the Bronze Age in the Karagaily-Ayat microregion (South Urals, Russia) (в печати).

Rassadnikov A. Y. Rezul'taty arheozoologicheskih issledovanij na poseleniyah Bol'shaya Berezovaya-2, Malaya Berezovaya-4 i Aleksandro-Nevskoe-II v Yuzhnom Zaural'e [Results of Archaeozoological Studies at the Settlements Bolshaya Berezovaya-2, Malaya Berezovaya-4 and Aleksandro-Nevskoye-II in the South Trans-Urals]. Vestnik arheologii, antropologii i etnografii [Bulletin of Archaeology, Anthropology and Ethnography]. 2017. 3(38). Pp. 176–185. *(In Russ.)*. DOI: 10.20874/2071-0437-2017-38-3-176-185.

Shishlina N., Roslyakova N., Kolev Y., Bachura O., Kuznetsova O., Kiseleva D., Retivov V., Tereschenko E. Animals, Metal and Isotopes: Mikhailo-Ovsyanka I, the Late Bronze Age Mining Site of the Steppe Volga Region. Archaeological Research in Asia. 2020. 24. 100229. DOI: 10.1016/j.ara.2020.100229.

Tatarinov S. I. O gorno-metallurgicheskom centre epohi bronzy v Donbasse [About the Mining and Metallurgical Center of the Bronze Age in Donbass]. Sovetskaya arheologiya [Soviet Archaeology]. 1977. № 4. Pp. 192–207. *(In Russ.)*

Tevelev Al. V., Kosheleva I. A., Burshtejn E. F., Tevelev Ark. V., Kuznecov I. E., Popov V. S. Gosudarstvennaya geologicheskaya karta Rossijskoj Federacii. Masshtab 1 : 200 000. Izdanie vtoroe. Seriya Yuzhno-Ural'skaya. List N-41-XIX (Varna). Ob'yasnitel'naya zapiska [State Geological Map of the Russian Federation. Scale 1: 200 000. Second edition. South Ural series. Sheet N-41-XIX (Varna). Explanatory letter]. Moskow : Moscow Branch of FSBI VSEGEI, 2018. 236 p. *(In Russ.)*

Tihonov B. G. Metallicheskie izdeliya epohi bronzy na Severnom Urale i Priural'ye [Metal Products of the Bronze Age in the Northern Urals and the Cis-Urals]. Materialy i issledovaniya po arheologii [Materials and Research on Archaeology]. №90. Moscow; Leningrad : Izdatel'stvo Akademii nauk SSSR, 1960. 208 p. *(In Russ.)*

Tkachev V. V. Ural'sko-Mugodzharskij gorno-metallurgicheskij centr epohi pozdnej bronzy [Ural-Mugodzhary Mining and Metallurgical Center of the Late Bronze Age]. Rossijskaya arheologiya [Russian Archaeology]. 2011. № 2. Pp. 43–55. *(In Russ.)*

Tkachev V. V. Vozmozhnosti landshaftnoj arheologii v izuchenii lokal'noj mobil'nosti stepnyh skotovodcheskih kul'tur epohi paleometalla [Possibilities of Landscape Archaeology in the Study of Local Mobility of Steppe Cattle-Breeding Cultures of the Paleometal Era]. Ural'skij istoricheskij vestnik [Ural Historical Bulletin]. 2020. 4(69). Pp. 32–41. *(In Russ.)*

Zaykov V. V., Yuminov A. M., Dunaev A. Yu., Zdanovich G. B., Grigoriev S. A. Geologo-mineralogicheskie issledovaniya drevnih mednyh rudnikov na Yuzhnom Urale [Geological and Mineralogical Studies of Ancient Copper Mines in the Southern Urals]. Arheologiya, etnografiya i antropologiya Yevrazii [Archaeology, Ethnology & Anthropology of Eurasia]. 2005. 4 (24). Pp. 101–115. *(In Russ.)*

Zdanovich S. Ya., Korobkova G. F. Novye dannye o hozyajstvennoj deyatel'nosti naseleniya epohi bronzy (po dannym trasologicheskogo izucheniya orudij s poseleniya Petrovka II) [New Data on the Economic Activity of the Population of the Bronze Age (according to the tracological study of tools from the settlement of Petrovka II]. Problemy arheologii Uralo-Kazahstanskih stepej [Problems of Archaeology of the Ural-Kazakhstani steppes]. Chelyabinsk : Chelyabinskij gosudarstvennyj universitet, 1988. Pp. 60–80. *(In Russ.)*

Zhauymbayev S. U. Drevnie mednye rudniki Central'nogo Kazahstana [Ancient Copper Mines of Central Kazakhstan]. Bronzovyy vek Uralo-Irtyshskogo mezhdurech'ya [Bronze Age of the Ural-Irtysh Interfluve]. Chelyabinsk : Izdatel'stvo BGU, 1984. Pp. 113–121. *(In Russ.)*

Yuminov A. M., Zaykov V. V., Korobkov V. F., Tkachev V. V. Bronze Age copper mining in the Mugodzhary // Archaeology, Ethnology & Anthropology of Eurasia. 2013. 3/41. Pp. 87–96. DOI: 10.1016/j.aeae.2012.08.004

БИБЛИОГРАФИЧЕСКИЙ СПИСОК

Аванесова Н. А. Культура пастушеских племен эпохи бронзы Азиатской части СССР (по металлическим изделиям). Ташкент : ФАН, 1991. 200 с.

Аванесова Н. А. Древние горняки Зарафшана // Археология Узбекистана. 2012. № 1. С. 3–35.

Агрикола Г. О горном деле и металлургии в двенадцати книгах. М. : Изд-во АН СССР, 1962. 598 с.

Алаева И. П. Культурная специфика памятников позднего бронзового века степной зоны Южного Зауралья: дис. … канд. ист. наук. М., 2015. 539 с.

Анкушев М. Н., Юминов А. М., Зайков В. В., Носкевич В. В. Медные рудники бронзового века в Южном Зауралье // Известия Иркутского государственного университета. Сер.: Геоархеология. Этнология. Антропология. 2018. Т. 23. С. 87–110. DOI: 10.26516/2227-2380.2018.23.87.

Ankusheva P. S., Alaeva I. P., Ankushev M. N., Fomichev A. V., Zazovskaya E. P., Blinov I. A. From Ore to Metal: Exploitation of the Novotemirsky Mine, Southern Trans-Urals, in the Second Millennium BC // Archaeology, Ethnology & Anthropology of Eurasia. 2021a. Vol. 49. № 1. Pp. 30–38. DOI: 10.17746/1563-0110.2021.49.1.030-038.

Анкушева П. С., Киселева Д. В., Бачура О. П., Алаева И. П., Анкушев М. Н., Окунева Т. Г. Труд и питание горняков бронзового века Южного Зауралья (по данным изотопного состава стронция в остеологических остатках рудника Новотемирский) // Stratum plus. Археология и культурная антропология. 2021б. № 2. С. 69–83.

Блинов И. А., Анкушев М. Н., Рассомахин М. А., Медведева П. С. Минералы меди, никеля и мышьяка в рудах Новотемирского проявления железа (Южный Урал) // Минералогия. 2018. Т. 4, № 3. С. 36–45.

Бровендер Ю. М. Итоги раскопок техногенного участка на Картамышском рудопроявлении // Древности. 2006–2008. Харьков : НТМТ, 2008. С. 184–203.

Бровендер Ю. М., Загородняя О. Н. Орудия металлопроизводства поселения Червонэ Озеро-3 Картамышского комплекса горно-металлургических памятников эпохи бронзы // Матеріали та дослідження з археології Східної України. Луганск : Нац. акад. наук України, Східноукр. нац. ун-т ім. Володимира Даля, Ін-т археології. 2009. С. 251–262.

Горащук И. В., Колев Ю. И. Каменные и костяные орудия с рудника бронзового века Михайло-Овсянка в Самарской области // Вопросы археологии Урала и Поволжья. Самара : Изд-во «Самарский университет», 2004. Вып. 2. С. 89–104.

Древнее Устье: укрепленное поселение бронзового века в Южном Зауралье / ред. Н. Б. Виноградов, А. В. Епимахов. Челябинск : АБРИС, 2013. 482 с.

Жауымбаев С. У. Древние медные рудники Центрального Казахстана // Бронзовый век Урало-Иртышского междуречья. Челябинск : Издательство БГУ, 1984. С. 113–121.

Зайков В. В., Юминов А. М., Дунаев А. Ю., Зданович Г. Б., Григорьев С. А. Геолого-минералогические исследования древних медных рудников на Южном Урале // Археология, этнография и антропология Евразии. 2005. № 4 (24). С. 101–114.

Зданович С. Я., Коробкова Г. Ф. Новые данные о хозяйственной деятельности населения эпохи бронзы (по данным трасологического изучения орудий с поселения Петровка II // Проблемы археологии Урало-Казахстанских степей. Челябинск : Челябинский государственный университет, 1988. С. 60–80.

Каргалы. Т. III: Селище Горный: Технология горно-металлургического производства: Археобиологические исследования / сост. и науч. ред. Е. Н. Черных. М. : Языки славянской культуры, 2004. 320 с.

Каргалы. Т. V: Феномен и парадоксы развития: Каргалы в системе металлургических провинций: Потаенная (сакральная) жизнь архаических горняков и металлургов / сост. и науч. ред. Е. Н. Черных. М. : Языки славянской культуры, 2007. 200 с.

Кожевников С. В., Анкушев М. Н. Каменные орудия из отвала древнего рудника Новотемирский (Южное Зауралье) // Геоархеология и археологическая минералогия. Миасс : ИМин УрО РАН, 2018. С. 80–82.

Кузнецова Э. Ф., Тепловодская Т. М. Древняя металлургия и гончарство Центрального Казахстана. Алматы : Гылым, 1994. 207 с.

Маргулан А. Х. Джезказган — древний металлургический центр (городище Милыкудук) // Археологические исследования в Казахстане. Алма-Ата : Наука, 1973. С. 3–42.

Маргулан А. Х. Сочинения: в 14 т. Т. 2. Сарыарка. Горное дело и металлургия в эпоху бронзы. Джезазган — древний и средневековый металлургический центр (городище Милыкудук). Алматы : Дайк-Пресс. 2001. 144 с.

Матвеева Г. И., Колев Ю. И., Королев А. И. Горно-металлургический комплекс бронзового века у с. Михайло-Овсянка на юге Самарской области // Вопросы археологии Урала и Поволжья: сборник научных трудов. Самара : Издательство «Самарский университет», 2004. Вып. 2. С. 69–88.

Рассадников А. Ю. Результаты археозоологических исследований на поселениях Большая Березовая-2, Малая Березовая-4 и Александро-Невское-II в Южном Зауралье // Вестник археологии, антропологии и этнографии. 2017. № 3 (38). С. 176–185. DOI: 10.20874/2071-0437-2017-38-3-176-185

Татаринов С. И. О горно-металлургическом центре эпохи бронзы в Донбассе // Советская археология. 1977. №4. С. 192–207.

Тевелев Ал. В., Кошелева И. А., Бурштейн Е. Ф., Тевелев Арк. В., Кузнецов И. Е., Попов В. С. Государственная геологическая карта Российской Федерации. Масштаб 1:200 000. Издание второе. Серия Южно-Уральская. Лист N-41-XIX (Варна). Объяснительная записка. М.: Московский филиал ФГБУ ВСЕГЕИ, 2018. 236 с.

Тихонов Б. Г. Металлические изделия эпохи бронзы на Северном Урале и Приуралье. МИА № 90. М.; Л. : Изд-во АН СССР, 1960. 208 с.

Ткачев В. В. Уральско-Мугоджарский горно-металлургический центр эпохи поздней бронзы // Российская Археология. 2011. № 2. С. 43–55.

Ткачев В. В. Возможности ландшафтной археологии в изучении локальной мобильности степных скотоводческих культур эпохи палеометалла // Уральский исторический вестник. 2020. № 4 (69). С. 32–41. DOI: 10.30759/1728-9718-2020-4(69)-32-41

Черников С. С. Восточный Казахстан в эпоху бронзы. МИА № 88. М.; Л. : Изд-во АН СССР, 1960. 270 с.

Фомичев А. В. Орудия горного дела и металлургии поселений позднего бронзового века на севере Уральско-Мугоджарского горно-металлургического центра // Вестник Челябинского государственного университета. 2015. № 24. История. Выпуск 66. С. 9–16.

Ankusheva P. S., Alaeva I. P., Ankushev M. N., Fomichev A. V., Zazovskaya E. P., Blinov I. A. From Ore to Metal: Exploitation of the Novotemirsky Mine, Southern Trans-Urals, in the Second Millennium BC // Archaeology, Ethnology & Anthropology of Eurasia. 2021a. 49/1. Pp. 30–38. DOI: 10.17746/1563-0110.2021.49.1.030-038.

Chernykh E. N. Formation of the Eurasian “Steppe Belt” of Stockbreeding Cultures: Viewed through the Prism of Archaeometallurgy and Radiocarbon Dating // Archaeology, Ethnology & Anthropology of Eurasia. 35/3. 2008. Pp. 36–53 DOI: 10.1016/j.aeae.2008.11.003

Craddock B. R., Cartwright C. R., Craddock P. T., Wray W. B. Hafted stone mining hammer from Chuquicamata, Chile // Mining and metal production. Through the ages. Edited by Paul Craddock and Janet Lang. London : The British Museum Press, 2003. Pp. 52–68.

Grigoriev S. Metallurgical Production in Northern Eurasia in the Bronze Age. Oxford : Archaeopress Publishing Ltd, 2015. 831 p.

Kolev J. I. Das Bergbau- und Verhüttungszentrumder Bronzezeit in Michael-Ovsânka an dermittleren Wolfgang // Der Anschnitt 62. 2010. 1–12. P. 2–19.

Koryakova L. N., Epimakhov A. V. The Urals and western Siberia in the Bronze and Iron Ages. Cambridge : Cambridge University Press, 2007. 383 p. DOI: 10.1017/CBO9780511618451

Molchanov V. Ivan. and Molchanova V. Vlada. Catalogue of inventory from the Kamennyi Ambar settlement (excavation unit 6) // in R. Krause and L.Koryakova (ed.). Culture, Environment and Economy of the Bronze Age in the Karagaily-Ayat microregion (South Urals, Russia) (в печати).

Shishlina N., Roslyakova N., Kolev Y., Bachura O., Kuznetsova O., Kiseleva D., Retivov V., Tereschenko E. Animals, metal and isotopes: Mikhailo-Ovsyanka I, the Late Bronze Age mining site of the steppe Volga region. Archaeological Research in Asia. 24. 2020. 100229. DOI: 10.1016/j.ara.2020.100229.

Yuminov A. M., Zaykov V. V., Korobkov V. F., Tkachev V. V. Bronze Age copper mining in the Mugodzhary // Archaeology, Ethnology & Anthropology of Eurasia. 2013. 3/41. Pp. 87–96. DOI: 10.1016/j.aeae.2012.08.004

INFORMATION ABOUT THE AUTHORS / ИНФОРМАЦИЯ ОБ АВТОРАХ

Irina Pavlovna Alaeva, Candidate of Historical Sciences, Senior Researcher of the Archaeological Laboratory, South Ural State Humanitarian Pedagogical University, Chelyabinsk, Russian Federation.

Алаева Ирина Павловна, кандидат исторических наук, старший научный сотрудник археологической лаборатории Южно-Уральского государственного гуманитарно-педагогического университета, г. Челябинск, Российская Федерация.

Ivan Vladimirovich Molchanov, Candidate of Historical Sciences, Researcher of the Archaeology Center of the Metal Age, Institute of History and Archaeology, Ural Branch of the Russian Academy of Sciences, Yekaterburg, Russia.

Молчанов Иван Владимирович, кандидат исторических наук, научный сотрудник Центра археологии эпохи металла, Институт истории и археологии УрО РАН, г. Екатерибург, Российская Федерация.

Alexander Viktorovich Fomichev, Candidate of Historical Sciences, Associate Professor of the Department of History, Philosophy and Social Sciences and Humanities of the Orsk Humanitarian-Technological Institute (branch) of Orenburg State University, Orsk, Russia.

Фомичев Александр Викторович, кандидат исторических наук, доцент кафедры истории, философии и социально-гуманитарных наук Орского гуманитарно-технологического института (филиала) Оренбургского государственного университета, г. Орск, Российская Федерация.

Maksim Nikolaevich Ankushev, Candidate of Geological-Mineralogical Sciences, Junior Researcher, Institute of Mineralogy of South Urals Federal Research Center of Mineralogy and Geoecology, Ural Branch of the Russian Academy of Sciences, Miass, Russia.

Анкушев Максим Николаевич, кандидат геолого-минералогических наук, младший научный сотрудник Института минералогии Южно-Уральского федерального научного центра минералогии и геоэкологии УрО РАН, г. Миасс, Российская Федерация.

Polina Sergeevna Ankusheva, Candidate of Historical Sciences, Senior Researcher of the Archaeological Laboratory, South Ural State Humanitarian Pedagogical University, Chelyabinsk, Russia; Junior Researcher, Institute of Mineralogy of South Urals Federal Research Center of Mineralogy and Geoecology, Ural Branch of the Russian Academy of Sciences, Miass, Russia.

Анкушева Полина Сергеевна, кандидат исторических наук, старший научный сотрудник археологической лаборатории Южно-Уральского государственного гуманитарно-педагогического университета, г. Челябинск, Российская Федерация; младший научный сотрудник Института минералогии Южно-Уральского федерального научного центра минералогии и геоэкологии УрО РАН, г. Миасс, Российская Федерация.

Материал поступил в редколлегию 15.06. 2021.
Статья принята в номер 30.08.2021.