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Metallographic analysis of objects of the Bronze Age and early Iron Age from the territory of the Kokshetau Upland

M. Radivojevic[a], **I. Calgaro**[a]
[a]*University College London, London, United Kingdom*
ilaria.calgaro.19@ucl.ac.uk

Abstract. The article presents the results of metallographic analysis of metal objects and rock fragments discovered in the territory of the Kokshetau Upland, which is administratively located within the Akmola region of the Republic of Kazakhstan. The area is of interest since it was a developed mining and metallurgical centre from the second millennium BC, part of the large Eurasian metallurgical province. Judging by the available data, it functioned for a long time. The objective of the study was to identify the features of the metal of products of different historical stages, to determine the continuity and features of the development of metallurgy in a specific and local territory of Northern Eurasia. A total of thirty-six artifacts from sites where stationary excavations or exploration activities were carried out in the period from 2010 to 2022 were analysed. The chronology of the sites from which they were selected refers to a wide period of time from the Late Bronze Age to the Early Saka time and the Hunno-Sarmatian period. Artifacts for analysis were collected in seven sites, which are located in the main mountain forest massifs of the Kokshetau Upland. In the Zerenda Mountains – settlement Shagalaly II and burial mound Shagalaly IV. In the Sandyktau Mountains, three mine workings, near the settlement of the Late Bronze Age. In the Burabay mountain forest massif – burial mound Ulkensor, settlement Akkain, mine working Madeniet, settlement Saule. The largest collections are represented by materials from two settlements of the Late Bronze Age (beginning - second half of the 2nd millennium BC). Six items were from the settlement Shagalaly II - two metal ingots, two bronze jewellery tools, a needle from a bronze rod, a bronze chisel, and a dagger with a plastic blade. A metal sickle-shaped tool, a single-edged plate sickle knife, two single-edged knives with a distinct handle, a single-edged plate knife, a dagger knife belonging to the category of handled knives, and a fragment of a metal knife were from the Akkain settlement. The list includes a knife from a mine working near the village of Madeniet and a defective product from the Saule settlement. In addition, artifacts associated with the metallurgical cycle were analysed – pieces of waste rock, defects, and slag. The Early Saka period (VII - VI centuries BC) is represented by seven arrowheads from a burial in the Ulkensor mound studied in the Burabay district. Also, jewellery from a female late Sarmatian burial in a stone mound studied in the Zerenda district belongs to the Hunno-Sarmatian period (II - IV centuries AD). Thus, all the main historical and chronological periods characterized by bronze metallurgy were presented.

Keywords: metal; Bronze Age; Early Iron Age; Hunno-Sarmatian period; Kokshetau Upland; Kazakhstan

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Металлографический анализ предметов эпохи бронзы и раннего железного века с территории Кокшетауской возвышенности

М. Радивоевич[a], **И. Калгаро**[a]

[a]*Университетский колледж Лондона, Лондон, Великобритания*

Аннотация. В статье публикуются материалы металлографического анализа металлических предметов и кусков породы, обнаруженных на территории Кокшетауской возвышенности, административно расположенной на территории Акмолинской области Республики Казахстан. Регион представляет интерес, так как являлся со второго тысячелетия до н.э. развитым горнометаллургическим центром входящем в большую Евразийскую металлургическую провинцию. Судя по имеющимся данным, он функционировал продолжительное время. В задачу исследования входило выявить особенности металла изделий разных исторических этапов, определить преемственность и особенности развития металлургии на конкретной и локальной территории Северной Евразии. Всего проанализировано тридцать шесть единиц с памятников, на которых проводились стационарные раскопки или разведочные мероприятия в период с 2010 по 2022 гг. Хронология памятников, с которых они отобраны, относится к широкому отрезку от эпохи позднего бронзового века до раннесакского времени и гунно-сарматского периода. Артефакты для анализа собраны в семи пунктах, которые расположены в основных горнолесных массивах Кокшетауской возвышенности. Горы Зеренды – поселение Шагалалы II, курган Шагалалы IV. Горы Сандыктау – три горных выработки, рядом с поселением эпохи поздней бронзы. Горнолесной массив Бурабай – курган Улькенсор, поселение Аккаин; выработка Мадениет; поселение Сауле. Самые крупные коллекции представлены материалами двух поселений позднего бронзового века (начало – вторая половины II тыс. до н.э.). С поселения Шагалалы II шесть единиц - два металлических слитка, два бронзовых ювелирных инструмента, игла из бронзового стержня, бронзовая стамеска, кинжал с пластичным клинком. С поселения Аккаин – металлическое серповидное орудие, однолезвийный пластинчатый нож-серп, два однолезвийных ножа с выделенной рукоятью, нож – пластинчатый, однолезвийный, нож-кинжал, относящийся к разряду черенковых и обломок металлического ножа. В перечень включен нож с горной выработки у села Мадениет и брак изделия с поселения Сауле. Кроме этого, проанализированы артефакты, связанные с металлургическим циклом – куски отработанной породы, брак и шлак. Раннесакское время (VII–VI вв. до н.э.) представлено семью наконечниками стрел из погребения в кургане Улькенсор, исследованного в Бурабайском районе. Гунно-сарматский период (II–IV вв. н.э.) – украшениями из женского позднесарматского погребения в каменном кургане, исследованного в Зерендинском районе. Таким образом, были представлены все основные историко-хронологические периоды, для которых характерна бронзовая металлургия.

Ключевые слова: металл; бронзовый век; ранний железный век; гунно-сарматский период; Кокшетауская возвышенность; Казахстан

Көкшетау таулы аймағының қола және ерте темір дәуірінің заттарына металлографиялық талдау жасау

М. Радивоевич[a], **И. Калгаро**[a]
[a]*Лондон университеттік колледжі, Лондон, Ұлыбритания*

Андатпа. Мақалада Қазақстан Республикасының Ақмола облысының аумағында орналасқан Көкшетау таулы аймағында табылған металл заттарына металлографиялық талдау материалдары жарияланған. Бұл аймақ қызығушылық тудырады, өйткені біздің дәуірімізге дейінгі II мыңжылдықтан бастап ол дамыған тау-кен металлургия орталығы, ірі Еуразиялық металлургиялық провинцияның бөлігі болды. Қолда бар деректерге сүйене отырып, металлургиялық орталық ұзақ уақыт жұмыс істегені дәлелденді. Зерттеудің мақсаты әртүрлі тарихи кезеңдердегі металл бұйымдарының сипаттамаларын анықтау, Солтүстік Еуразияның нақты және жергілікті аймағында металлургияның дамуының үздіксіздігі мен ерекшеліктерін анықтау болды. 2010 және 2022 жылдар аралығында тұрақты қазбалар немесе археологиялық барлау жұмыстары жүргізілген жерлерден табылған 66 затқа талдау жасалды. Олар іріктеліп алынған ескерткіштердің хронологиясы кейінгі қола дәуірінен, ерте сақ дәуірі мен ғұн-сармат кезеңіне дейінгі кең тарихи уақытты қамтиды. Талдау үшін заттар Көкшетау таулы орман алқаптарында орналасқан жеті нүктеден жиналды. Зеренді тауларында – Шағалалы II қола дәуірінің қонысы, Шағалалы IV қорғаны. Сандытау тауларында – кейінгі қола дәуіріндегі қонысына жақын орналасқан үш кен орны. Бурабай таулы аймағында – Үлкенсор қорғаны, Аққайың елді мекені; Мәдениет туындыларында; Сәуле қола дәуірінің қонысы. Ең үлкен заттар коллекциясы қола дәуірінің екі қонысының материалдарымен ұсынылған (б.з.д. II мыңжылдықтың басы – екінші жартысы). Шағалалы II қонысынан алты зат табылды: екі металл құйма, екі қола зергерлік құрал, қола сырықтан жасалған ине, қоладан жасалған қашау және қанжар. Аққайың қонысынан – қоладан жасалған орақ, бір жүзді орақ пышақ, сабы айқын екі жүзді пышақ, қола пластинадан жасалған пышақ, бір жүзді пышақ, сапты пышақтар санатына жататын қанжар. Тізімде Мәдениет ауылы маңындағы шахтадан табылған пышақ пен Сәуле елді мекенінен табылған ақауы бар қоладан жасалған заттар. Сонымен қатар, металлургиялық циклге байланысты артефактілер – порода, руда бөліктері және шлактар талданды. Ерте сақ дәуірі (б.з.б. 7–6 ғасырлар) Бурабай өңірінде зерттелген Үлкенсор қорғанындағы қорымнан жеті жебенің ұшымен бейнеленген. Ғұн-сармат кезеңі (б.з. 2–4 ғғ.) – Зеренді өңірінде зерттелген тас қорғандағы кейінгі сарматтардың әйел қорымынан алынған зергерлік бұйымдар. Қорытындыға сәйкес металлографиялық талдаудан өткен заттардың негізгі тарихи және хронологиялық кезеңдері ұсынылды.
Түйін сөздер: металл; қола дәуірі; ерте темір дәуірі; ғұн-сармат кезеңі; Көкшетау тауы; Қазақстан

Introduction

The study of ancient metallurgy consists of several main areas: the study of mining, including mine workings and quarries, the process of ore processing and smelting metal products;

characterization of external signs of artifacts as final products; analysis of hidden signs - chemical composition and production technology.

The importance of these scientific directions is connected with the fact that the emergence of metallurgy and metalworking led to a completely new stage of development of ancient societies. Population growth, the emergence of early states and religion, and the formation of transcontinental trade networks. The territory of the Republic of Kazakhstan is one of the most important regions, since within its borders there were several independent mining and metallurgical regions, which in the second millennium BC were included in the Eurasian metallurgical province. One of the largest regions of ore mining and metalworking is Central Kazakhstan, within its structure, there are several separate centres – Kokshetau, Bayanaul, Uspeno-Karkaralinsk, Zhezkazgan-Ulytau, North-Betpakdala, and Balkhash. The main part of the cultural and historical processes that took place in the centre of the Eurasian continent were associated with these centres. On their territory, in places where minerals were found and deposited, communities of miners, metallurgists and cattle breeders were formed, and large trading and redistribution centres appeared.

The study of individual segments of mining and metalworking allows us to consider their regional characteristics, depending on the composition of the ore or the level of development of technologies and specific communities. To conduct this study, 36 artifacts were analysed, including rock, slag, metal ingots, tools, weapons, and jewellery. The materials were obtained as a result of stationary excavations and exploration work on the territory of the Kokshetau mining and metallurgical centre in the period from 2010 to 2022.

The collection is collected from seven archaeological sites, which are located in three mountain forest massifs and adjacent territories – Mount Zerenda, Mount

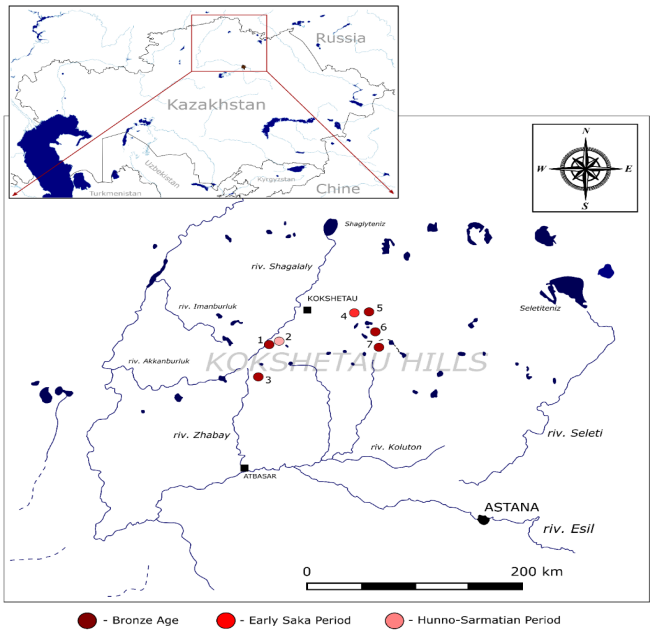

Fig. 1. Location of the monuments: 1. Shagagaly settlement; 2. Shagalaly burial mound; 3. Sandyktau mine working; 4. Ulkensor burial mound; 5. Karabaur ridge; 6. Akkain settlement and Madeniet mine working; 7. Saule settlement

Sandyktau and the Burabay massif, which are part of the Kokshetau Upland. Geographically, the sites are distributed as follows. In the Zerenda region, there is the Shagalaly II settlement and the Shagalaly IV burial mound. In the Sandyktau region, there is the Sandyktau mine working. In the Burabay region, there is the Ulkensor burial mound, the Akkain settlement, the Madeniet mine working and the Saule settlement.

Chronologically, the artifacts are divided into three groups: 1) Late Bronze Age (16th – 11th centuries BC) – rock from the working (2 items), slag, splashes, ingots, whole and fragments of tools (16 items); 2) Early Saka period (7th – 6th centuries BC) - arrowheads (5 items); 3) Hunno-Sarmatian period (2nd – 4th centuries AD) – two bells and parts of a fibula (4 items).

Methods and Materials

One of the pressing issues of modern archaeological science is the development of physicochemical methods for studying ancient finds, including metal products. Archaeometallography is the science of the internal structure and structural features of ancient metals and alloys, the nature of which is determined by both the metallurgical processes of their production and the methods of their processing. It is part of a large field of knowledge, which is collectively united into 'archaeometallurgy' and is associated with the reconstruction of the history of ancient metallurgy – methods of obtaining metal from ores, the composition of these ores, the structure of ancient furnaces, the composition of crucibles, slags, and smelted metal. This method allows us to answer important questions – the place of manufacture of the object, the composition of the alloy, including intentional or accidental, individual aspects of technology, and the production process.

The analysis of artifacts from monuments on the territory of the Kokshetau Upland was carried out using a portable X-ray fluorescence analyzer. The XRF method is based on the phenomenon of absorption of X-rays by an atom and the transfer of energy to an internal electron. If the primary X-rays have sufficient energy, electrons are ejected from the inner shells and form vacancies. Such vacancies create an unstable atom, and when it returns to a stable state, electrons from the outer shells pass into the inner ones. During this process, characteristic X-rays are emitted with an energy equal to the difference between the two binding energies of the corresponding atomic shells. Since each element contains a unique set of energy levels, each produces X-rays with a unique set of energies (Vanhoof et al. 2022). Calibration was carried out using the samples - Standard BCR 691a and Standard BCR 691e. A total of 25 chemical elements are taken into account in the table. The code of artifacts in the table was carried out in accordance with the photograph number of each analysed unit.

Zerenda. The Bronze Age settlement of Shagalaly II is located on the right bank of the river of the same name. The area of the monument is more than 15 hectares. In the valley of the Shagalaly River, there are many archaeological sites, the largest and most studied of which is the settlement we are studying. The river flows through the territory of the Akmola and North Kazakhstan regions and originates at the foot of Mount Ak-Shoky, not far from the Imantau rural district of the Aiyrtau region.

The valley of the Shagalaly River runs along the Kokshetau Upland and the North Kazakhstan Plain. In its middle reaches, the river flows into the southwestern part of Lake Kopa and flows out from the northern side of the lake. Thus, the lake regulates the flow of water from the

Shagalaly in its lower reaches. After leaving Lake, the Shagalaly becomes a typical steppe river and flows into the endorheic lake Shagalalyteniz. The settlement of Shagalaly II, represented by several dozen depressions ranging in size from 40 to 160 square meters, is located at the foot of a hill (cape). On the southern and southeastern sides, the settlement is separated from the burial field by depressions of the Adyr ridges. On the northern side, it is surrounded by the Shagalaly River. Topographical analysis has shown that the river flowed very close to the cape. Two depressions, located close to each other, recorded near the settlement are the remains of the old river bed. Near the settlement, the water flow divided into two branches, one of which crossed the modern river terrace, and the second flowed along the foot of the hill. Today, the first of the two branches is still clearly visible, and the second is almost completely covered with alluvial deposits that rolled down the slopes.

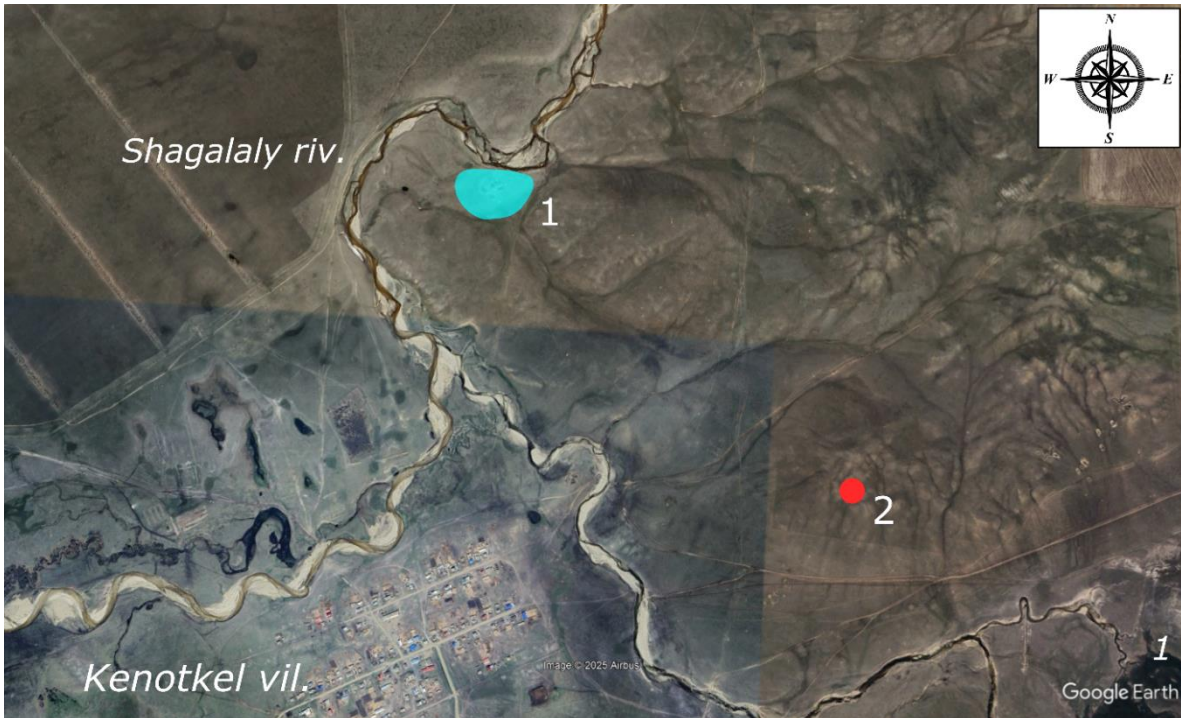

Fig. 2. Monuments in the Shagalaly River basin: 1. Shagalaly II settlement; 2. Shagalaly IV burial mound

Entry and exit could be carried out through the ascent to the hill and cape through the central part of the slope. The topographic plan highlights another feature of the strategic location of the monument: the river, flowing around the settlement and directing its waters from west to east, swamps the territory to the west of the residential development, creating a natural barrier to invasion. According to the topographic plan, the area occupied by the settlement is from 25,000 to 27,500 sq. m. The settlement extends 200 m from north to south and 120-130 m from east to west. However, judging by the available data, part of the settlement was destroyed by the river flow in ancient times. During the Bronze Age, the size of the settlement was larger than today. Focusing on the topography and surrounding landscape of the Shagalaly II settlement, we come to the following conclusions. The settlement occupies a dominant position on the Shagalaly River, occupying the upper section of the river. The settlement belongs to the category of large and multi-layered. Stratigraphy demonstrates the presence of cultural layers of the early

Alakul, early Fyodorovo, Alakul, Fyodorovo, mixed and Sargara-Alekseyev cultural types. The peculiarity of the cultural layer of the settlement of Shagalaly II is the presence, in addition to local traditional ceramics, of imported easel ceramics from the ancient agricultural oases of Central Asia and the existence of construction horizons of the transition period from the late Bronze Age to the early Iron Age.

Items discovered during the exploration of the Shagalaly II settlement:

1) Two metal ingots were found in dwelling №5 in a layer with ceramics of the Fyodorovo archaeological culture (DSC00784, DSC00786).

2) A bronze jewellery tool in the form of a rod, 5.6 cm long. Square in cross-section, 0.4 cm thick. Both ends are flattened and sharpened. Found in dwelling #4, square A/1, depth 40 cm (DSC00788).

3) A needle made of a bronze rod, round in cross-section, 0.3 cm in diameter, 7.5 cm long. Pointed on both sides. Found in the cultural layer of dwelling №6. Excavation VII, sq. B-4, depth 45 cm (DSC00790 a).

4) A bronze jewellery tool in the form of a rod, 5.6 cm long. Square in cross-section, 0.4 cm thick. Both ends are flattened and sharpened (b) Excavation VI, sq. I-6, depth 75 cm (DSC00790 b).

5) A narrow bronze chisel with a straight working end. There are borders - stiffening ribs along the edges. Total length 12.3 cm, width in the middle part 1.1 cm, thickness 0.5 cm; thickness along the edges (borders) 0.6 cm. The working part is in the form of a blade 1.4 cm wide; traces of wear are clearly visible. Excavation V, sq. L-6, depth 55 cm. Dwelling No. 5, second construction horizon (DSC00790 c).

6) A dagger with a plastic blade broken into three parts and an elongated ringed handle. The handle is made in the form of a plate folded inward on both sides. The resulting ridges served as stiffeners. The handle ended with a pommel in the form of a weakly expressed ring formed by a round hole with a diameter of 0.8 cm. The total length of the dagger is 19.4 cm, the blade length is 10.9 cm, the width is 3 cm, and the thickness is 0.3 cm. The length of the handle is 8.5 cm, the width is 1.7–2.1 cm, and the thickness is 0.6 cm. Found in the cultural layer of excavation VII, sq. D-2, depth 60 cm (DSC00792 a, b, c) (Sakenov 2017: 221, Fig. 6.3. 2).

Shagalaly IV burial mound (Fig. 1.2) is situated to the east of the Bronze Age settlement on a hillock north of the Koshkarbay River. Contained a female burial of the late Sarmatian period. The accompanying inventory included various ornaments, including a fibula and bells (DSC00791 a, b, c, d) (Table 1. No. 33, 34, 35, 36).

Sandyktau. Sandyktau mine working (Fig. 1.3). The object was discovered and studied in 2023 on the territory of the Sandyktau district of the Akmola region during archaeological excavations at a Bronze Age settlement in the Zhabay River basin. During a reconnaissance survey of the area 2 km south of the main ridge of Sandyktau, 0.9 km east-southeast of the settlement, traces of mining activity were discovered. Four mine workings in the form of three open pits and a quarry were recorded on the top of a treeless hill.

Quarry No. 1 occupies the first ridge with granite block outcrops on the surface. Traces of block uprooting and granite slab harvesting have been discovered. The working pits occupy the rocky peaks of the central and eastern ridges. The workings are a series of pits of varying length and width, the walls and bottom of which consist of rock with traces of green oxide and rubble. Mine working No. 2 is located on the ridge of a hill 1 km southeast of the settlement. The length of the selected area is 275 m. Several main pits associated with the extraction of concentrated

ore deposits are recorded along the line of the workings. The dimensions of the largest are 6 × 62 m, and the depth is 2 m. From the west and east, there are two dumps. In the central part of the pit, there is a platform littered with waste rock. Working No. 3 is located 58 m to the west of working No. 2, 37 m long, 5 m wide. Working No. 4 is the largest; the length of the rocky outcrop along which it goes is 468 m. It is located 1.4 km southeast of the settlement. It consists of two main large pits and more than a dozen smaller ones. The first is located at the top of the hill, its length is 84 m, width is 6 m. The second is 25 meters to the south and below. Its length is 77 m, width is 7 m. Around the pits, there are waste rock heaps up to 2 m wide, about 1 m high. The average depth of the pits is about 1 - 1.5 m. The maximum is up to 2.5 m. Ore workings, the presence of identical

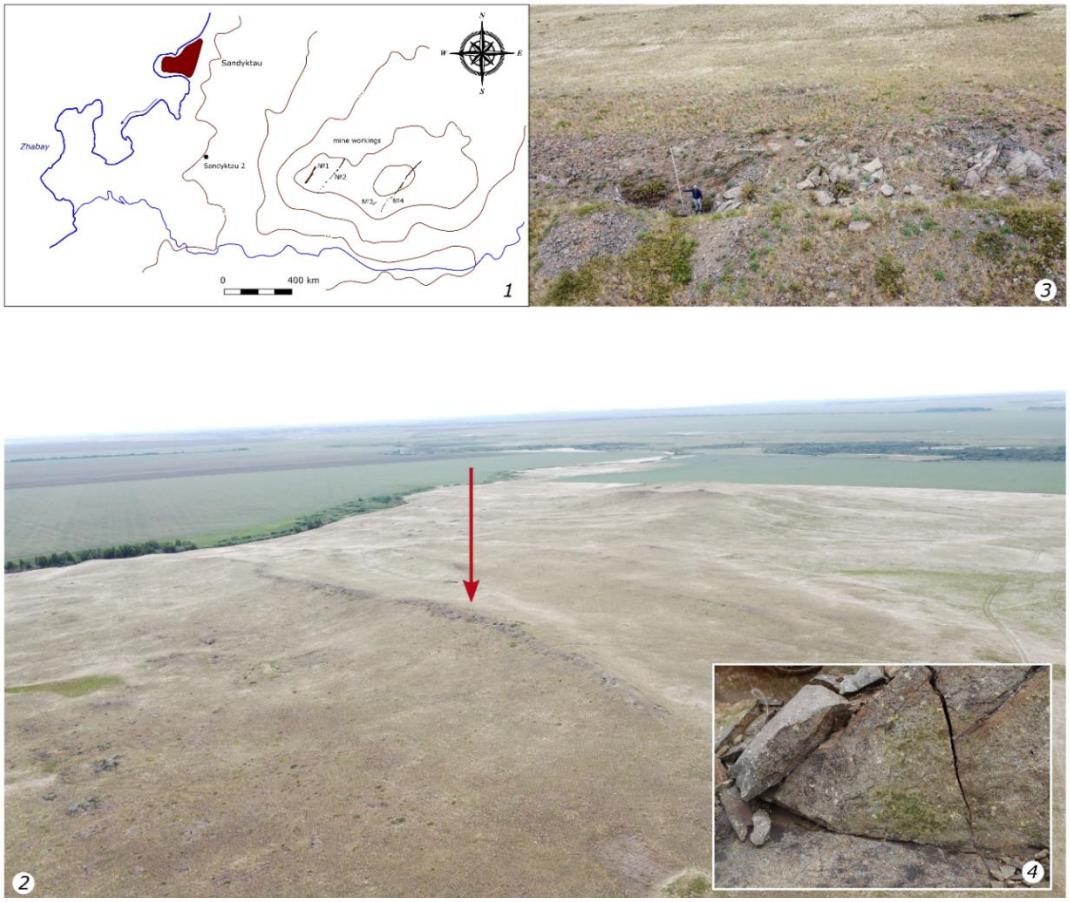

Fig. 3. Mine workings: 1. Layout of the monuments; 2. Mine workings No. 3. 3. Working pit in the central part; 4. Rock with remains of green mineral

rock, including traces of temperature effects and slags in the settlement, allows us to confidently say that the inhabitants of the settlement were involved in the process of metal mining and processing. Two rock samples (DSC00780 a, b) were taken from the territory of the workings (Table 1. 3, 4).

Burabay. Ulkensor burial mound (Fig. 1.4). The monument is located in the Burabay district of the Akmola region, 5.5 km northeast of the village of Ablaikhan, 60 meters west of the shore

of Lake Ulkensor, between the lake and the Kishisor salt marsh. The area is a plain north of the Karabaur ridge, dissected by hills, salt marshes, and small steppe lakes.

The mound is made of stone and earth, round in plan and flattened in cross-section. The diameter is 12 m, the height is 0.3 m. Judging by stratigraphic observations, the burial was done in a side chamber of the pit. The deceased was laid on his back, head to the west, face to the north. During the clearing, various burial items were found: a dagger, a whetstone, a knife, arrowheads, horn parts of a composite belt, a hanging clip for a quiver, parts of a whip, a pin of a clasp, and a clasp (Yarygin et al, 2023: 135). Arrowhead remains were found under the left hand. A total of nine bronze arrowheads with decayed shafts were found. The arrows were lying with their tips toward the feet. The length of the surviving shafts is 19.8 cm, the average length

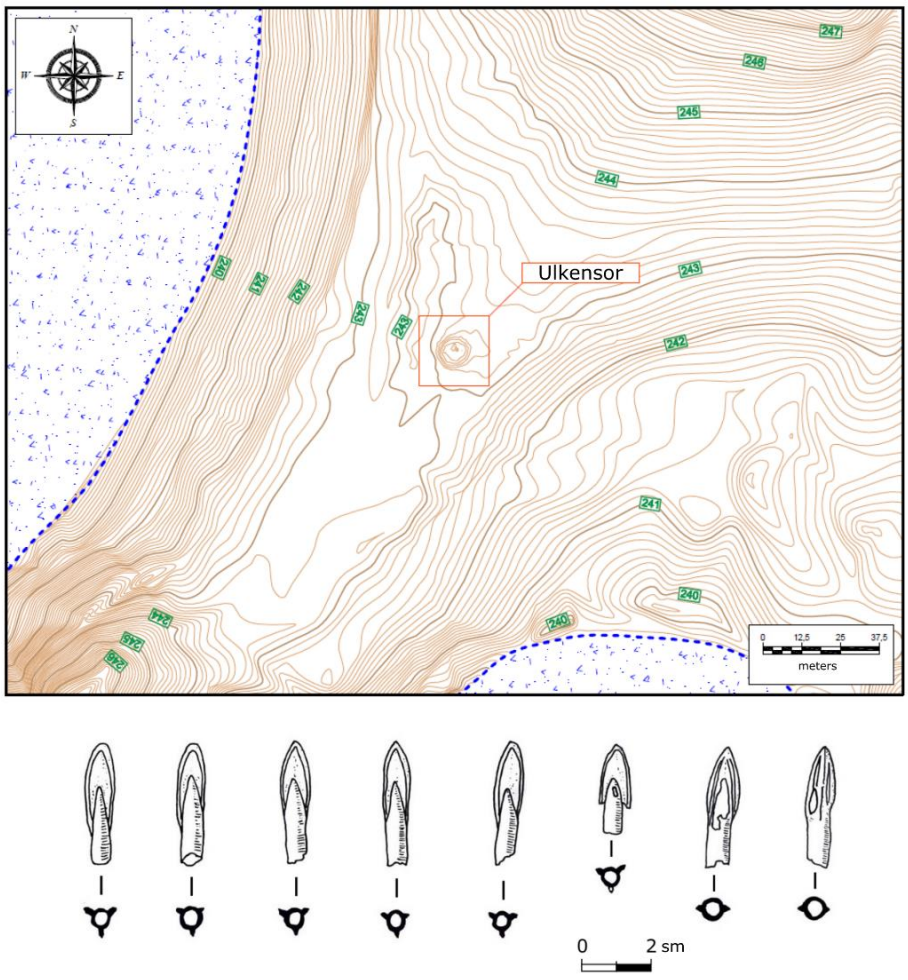

Fig. 4. Ulkensor burial mound. Arrowheads from the burial

of the arrowheads is 3.7 cm. The width of the bundle is about 5 cm. The arrowheads belong to two types: five three-bladed and four two-bladed, with distinct bushings. The burial dates back to the 7th–6th centuries BC. (Valchak et al. 2017: 142–154; Margulan et al. 1966: 337–338, Fig. 32; Beisenov, Chotbaev 2001: 290–293). Seven arrowheads (DSC00799 a, b, c, d, e, f, g) were selected for analysis (Table 1, 26–32).

In 2019–2022, a number of items that were accidentally discovered at different times in the vicinity of the Burabay mountain forest massif of the Akmola region of the Republic of Kazakhstan came into the possession of research fellows of the A.Kh. Margulan Institute of Archaeology (Burabay Archaeological Squad). Eight items were found in the vicinity of the village of Madeniet in the Burabay district of the Akmola region (Fig. 1.6). This location is interesting because in the mid-20th century, two Bronze Age burial grounds were explored here – Obaly and Buyrekkol (Orazbaev 1958: 240–241). Inspection of the find sites in 2022 revealed two new sites – the Bronze Age settlement of Akkain and the Madeniet mine working.

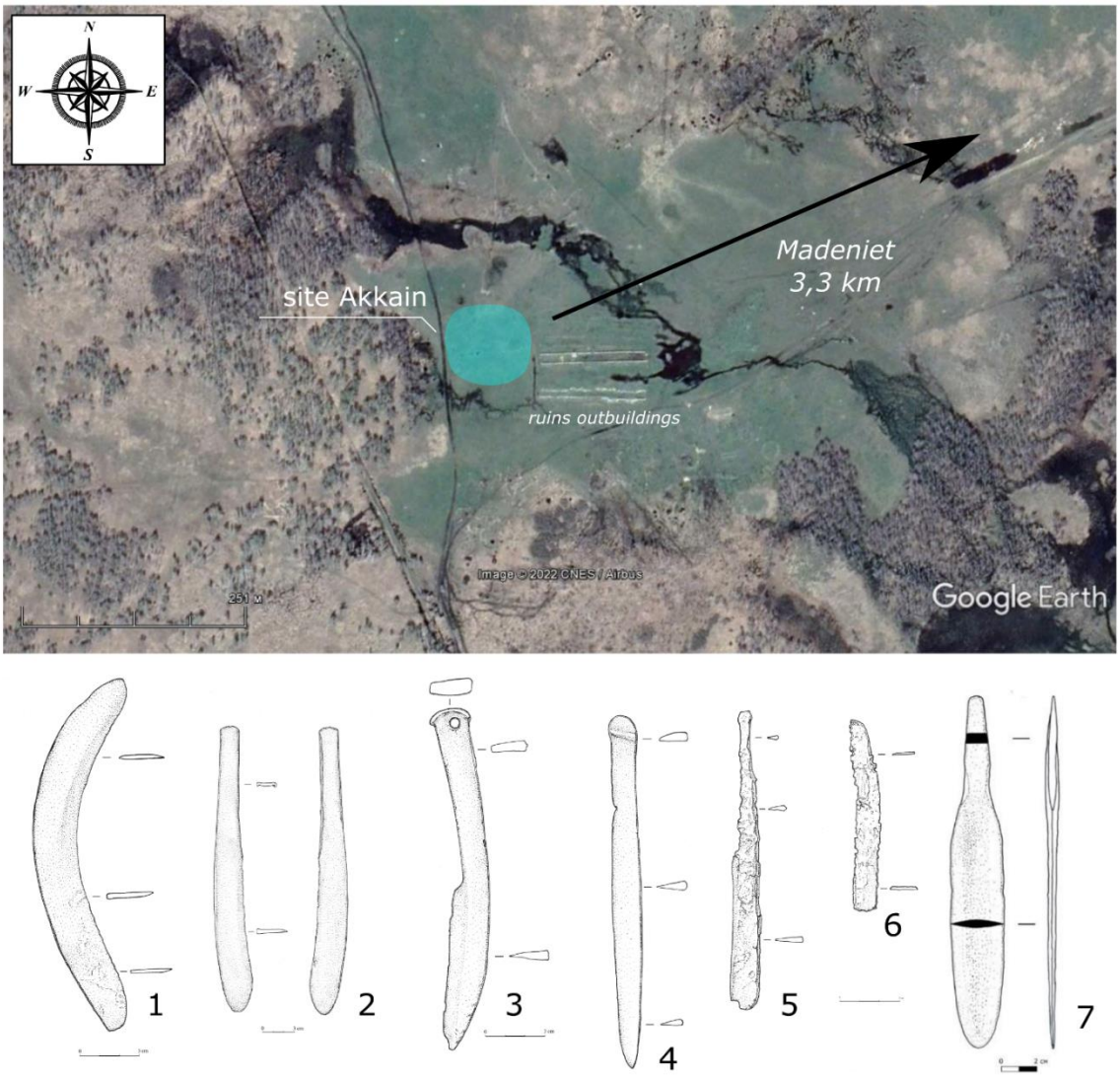

Fig. 5. Finds from the Akkain settlement

Items discovered during the study of the Akkain settlement (Musaeva et al. 2024):

1) A metal sickle-shaped tool, lamellar, symmetrical, with an expansion in the middle part (Fig. 5.1). The length of the item is 18 cm, the maximum width is 2.2 cm. The degree of curvature of the working part is average. Both ends are rounded. The cross-section is wedge-shaped.

The tool is made of a metal plate. This item belongs to type B - a scraper-plane according to the classification of N.A. Avanesova (Avanesova 1991: 22). According to the classification of V.A. Dergachev and V.S. Bochkarev, the artifact belongs to the Petrovka type of sickles of the Ural group of settlements. The very name of this type reflects the cultural and chronological attribution of the item. The closest analogies can be found among similar objects from the materials of settlements of the Ural-Kazakhstan region (Avanesova 1991: pl. 18:18, 20; ibid.: pl. 19:26, 30,34; Ankushev et al. 2021: 72, fig. 2:1; Dergachev, Bochkarev, 2002: 38, pl. 33; Evdokimov 1983: 37, fig. 2:9; Degtyareva 2023: 42, fig. 1: 3, 6, 7; Zdanovich et al. 1970: 14, fig. 21; Zdanovich 1988: 168, pl. 10A:20, 21; Kuzminykh et al. 2023: 56, fig. 2: 1–10; Potemkina 1985: 99, fig. 33:1; ibid.: 163, fig. 53:4) (DSC00797 a) (Table 1.20).

2) Single-blade plate sickle knife with a handle (Fig. 5.2). Length 21.4 cm. Made from one plate. The blade is slightly curved, and the end is rounded. Blade length 12.4 cm, width 3 cm. The thickness of the spine is 0.35 cm. The blade is sharpened on one side only. The width of the blade edge is 0.5 cm. The handle is straight, 9 cm long, 2 cm wide, and 0.3 cm thick. There is a slightly pronounced ledge between the blade and the handle. The edges of the handle are bent in the opposite direction in relation to the sharpened side of the blade, forming a small rib on top and a ridge with a diameter of 0.5 cm at the bottom. The entire plate is covered with a dark green patina. Knives of this type are usually about 22–24 cm long, with a wide blade and a massive cast handle. This group of knives is quite numerous and variable. According to N.A. Avanesova, all variants by the type of handle can be divided into three subtypes: flat-handled, grooved-handled, and with a slotted handle. The knife from the vicinity of the village of Madeniet, judging by the handle, occupies an intermediate position between the first and second subtypes. Finds of this group of knives in the closed complexes of the settlements of Kamyshnoye II, Yavlenka I, Chaglinka, Sargara, Karkaralinskoye, and Malo-Krasnoyarskoye, together with "roller" ceramics, allow us to date them no later than the 12th-9th centuries BC (Avanesova 1991: 27-28). Some distant analogies are demonstrated by a single-bladed knife from random finds in the Southern Trans-Urals (Epimakhov 2011: 15-17). The closest analogs of knives of this type were discovered at the Bronze Age site of Chelkar near the city of Stepnyak. Fragments of Alakul and Fyodorovo vessels were found at the site, but the largest group of fragments belongs to the Sargara-Alekseyev culture (Orazbaev 1958: 292, pl. X. 4–5) (DSC00795) (Table 1. 19).

3) A metal knife with a distinct handle, single-edged, with an asymmetrical blade configuration, with a rounded mount on the handle (Fig. 5.3). The length of the tool is 17 cm, the length of the handle is 9 cm, the length of the blade is 8 cm, the greatest width of the blade is 1.7 cm, the greatest width of the handle is 1.5 cm, the diameter of the mount is 0.5 cm. The knife has a handle that widens towards the pommel, separated from the blade by a small ledge. The cross-section of the handle is oval. The pommel has an irregular shape. Probably after casting, the pommel was rounded, and an excess of metal was formed on the sides. The rounded hole is shifted to the right side, possibly for the correct distribution of the weight of the tool when hanging it from clothing. The blade edge is straight (DSC00797 b) (Table 1. 21).

4) A metal knife with a distinct handle, single-edged, with a symmetrical blade configuration (Fig. 5.4). The length of the tool is 17.7 cm, the length of the handle is 4.6 cm, the length of the blade is 13.1 cm, the greatest width of the blade is 1.5 cm, and the width of the handle is 1 cm. The knife has a straight handle, separated from the blade by a small notch, which can be taken

for an emerging ledge. The handle is wedge-rounded in cross-section, has a rounded, thickened pommel. The blade edge is slightly curved, and the cross-section is wedge-shaped. The knife is cast. According to the classification of N.A. Avanesova, it belongs to type B1 – flat-handled knives (Avanesova 1991: 28). According to the classification of A.D. According to Degtyareva and N.V. Ryndina, this tool belongs to type I-2 (Degtyareva, Ryndina 2020: 20, Fig. 2). Similar knives were widespread at Bronze Age sites in the Ural-Kazakhstan region (Avanesova 1991: pl. 33, Krivtsova-Grakova 1947: fig. 27:1; Potemkina 1985: 267). The similarity of morphological features allows us to attribute it to the Petrovka culture (DSC00797 d) (Table 1. 23).

5) A metal knife, single-edged, plate-shaped, with a distinct handle and a symmetrical blade configuration (Fig. 5.5). The length of the tool is 15 cm, the length of the handle is 7 cm, the length of the blade is 8 cm, the width of the blade is 1.3 cm, the greatest width of the handle is 1 cm. The knife has a straight handle, tapering towards the pommel, separated from the blade by a small ledge. Perhaps the handle was wider than its surviving part. The cross-section of the handle is wedge-shaped; the pommel was probably originally oval. The blade part is rectangular, the cross-section is wedge-shaped, and the end is rounded and broken off. The knife is made of a metal plate. The tool is heavily deformed. According to the classification of N.A. Avanesova, it belongs to type B2 – handle knives with a ledge (Avanesova 1991: 27). According to the classification of A.D. Degtyareva and N.V. Ryndina, this weapon belongs to type I-2 (Degtyareva, Ryndina 2020: 20, Fig. 2:8). Similar tools are found in the materials of the Bronze Age sites of the Ural-Kazakhstan region (Avanesova 1991: pl. 30: 3–10, pl. 31: 1, 4, 6–10; Zdanovich et al. 1971: 13, fig. 19: 1, 2; Zdanovich 1988: fig. 28:1, pl. 10A: 17; Kuzminykh et al. 2023: fig. 2: 11–16; Potemkina 1985: fig. 33:2, fig. 48:6, fig. 51:4) (DSC00797 e) (Table 1. 24).

6) A fragment of a metal knife, plate-shaped, single-edged, probably with a distinct handle (Fig. 5.6). The handle is broken, only the blade is preserved. The blade is 9.5 cm long and 1 cm wide. The blade is slightly curved, the end is pointed and rounded, and the cross-section is wedge-shaped. The knife is made of a metal plate. This tool is similar to the previous one in the morphological features of the blade, so it can belong to type B2 - handled knives with a ledge, like the previous specimen (Avanesova 1991: 27). According to the classification of A.D. Degtyareva and N.V. Ryndina, this tool belongs to type I-2 (Degtyareva, Ryndina 2020: 20, Fig. 2:2) (DSC00797 c) (Table 1. 22).

7) A knife-dagger, related to the category of handled knives (Fig. 5.7). It has an elongated handle without a stop roller. A symmetrical lens-shaped laurel blade with sloping shoulders. The length of the dagger is 20 cm. The length of the blade is 14 cm, the width is 3 cm, and the thickness is 3.5 cm. In the centre of the blade, there is a thickening in the form of a weakly expressed rib. The end is rounded. The length of the handle is 6 cm, the maximum width is 1.4 cm, and the thickness is 0.5 cm. The handle is rectangular in cross-section, flattened, and narrowed at the pommel. In the central part, it has an expansion, giving it a diamond-shaped outline. The colour of the metal in places of contemporary damage is red. Judging by its shape, it goes back to daggers with lateral notches along the wedge, probably being a derivative of the Fyodorovo tradition, which is characterized by the placement of notches closer to the handle (Avanesova 1991: 22–23; Chernykh 2002: 20, Fig. 15; Chernykh 2008: 36–53; Mei, Shell 1999: 570–578). The close similarity of the blade shape and the absence of a stop are demonstrated by the knife-daggers of the Sargara-Alekseev culture discovered in the Altai Territory. Similar ones are known from finds at the early Sargara settlement of Sovetsky Put'-1 (12th (11th)–9th

centuries BC) (Sitnikov 2015: 31–37, Fig. 57, 1; Papin et al. 2006: 107–116). In the west of the Roller Pottery culture community, similar types of daggers are known from sites of the Ivanovo (Khvalynsk) culture (15th/14th–13th/12th centuries BC). These are handled knives with a leaf-shaped blade without a crossguard, characteristic of complexes such as the Loboikovo deposit of bronze objects and other sites (Kolev, 2008: 208–240, Table 5, 7–9; Dergachev, Bochkarev, 2002: 322; Tab. 112. 2). Similar forms are known in the Central Kazakhstan monuments of the late Bronze Age (Beisenov, Varfolomeev 2008) (DSC00793) (Table 1. 16).

A single-edged lamellar knife was found 7 km south of the Akkain settlement and 3 km southwest of the Buyrekkol burial ground in the Madeniet mine. The handle and the tip of the blade were broken off in ancient times. The length of the preserved part is 10.9 cm. The width of the spine is 0.5 cm. The length of the blade is 5.6 cm. The width of the blade is 2 cm. The width of the handle is 1.6 cm, and the thickness is 0.2 cm. The upper part of the blade (spine) and the handle are located on the same line. The end is arcuately lowered to the blade, forming smoothed wedge-shaped outlines. On the lower part of the handle, where it joins the blade, traces of forging are visible. A large series of knives of this type were discovered during the study of Andronovo (Fyodorovo) burials at the Elovka II burial ground in the Tomsk Ob region. All knives

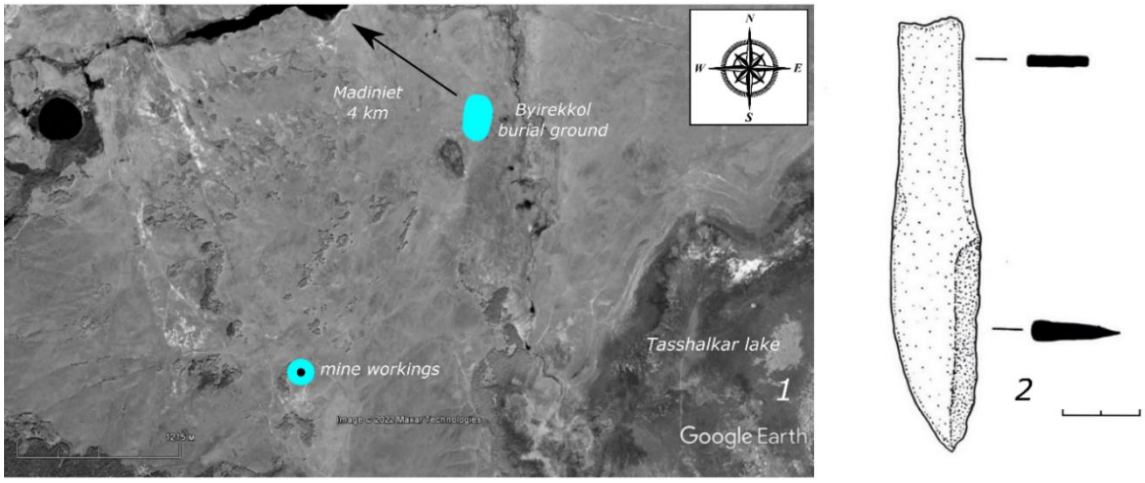

Fig. 6. Madeniet: 1. Location of monuments; 2. Plate knife from the mining area

were cast on one side, many of which have clearly visible traces of blade forging. The sizes of the items vary from 7 to 18 cm. The first group has a distinctive handle, which is separated from the blade by a ledge. The second group has a handle that is not completely separated from the blade or is weakly separated. The Andronovo monuments of the region are dated no later than the middle of the 2nd millennium BC (Matyushchenko 1973: 12–13, 42. Fig. 8, 1–13) (DSC00795) (Table 1. 18).

The following artifact was discovered on the territory of the monument, which is part of a cluster of Bronze Age objects associated with large mining centers that existed in the 2nd millennium BC in Burabay and Stepnyak. This is a metal ingot - a defective item. It was discovered at the Bronze Age settlement of Saule, located in the Burabay district of the Akmola region. The monument occupies a natural cape on the bend of the Beketkenozek stream flowing into Lake

Kotyrkol, 3.5 km west of the village of Saule and 11 km southwest of the city of Stepnyak. The area of the monument is about 150,000 square meters. During the inspection of the settlement, traces of metallurgical activity were discovered in the form of remains of furnaces (DSC00798) (Table 1. 25).

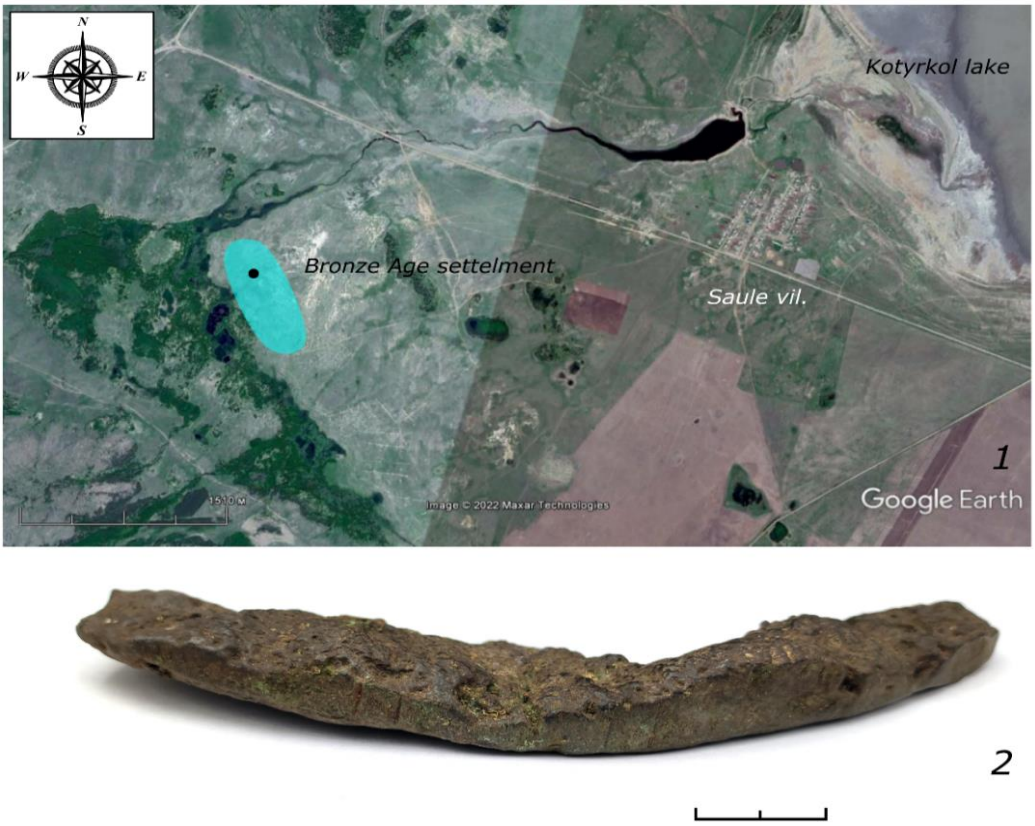

Fig. 7. Saule settlement. Defective product

Discussion

The integration of archaeology with natural sciences and the use of methods of these sciences opens up serious opportunities for deepening knowledge in the field of technological development of ancient societies. This is the purpose of metallography. From the perspective of natural science methods, bronze is the most informative material.

The described collection comes from seven separate places located within the boundaries of one geographical province, this and the chronological difference in origin are a source for further research of the ancient metallurgy of the region using modern natural science methods. Based on the data obtained, it is clear that in the Late Bronze Age and Early Saka time, the same types of alloys with natural impurities prevailed. This allows us to assert about local production and preservation of traditions in the 2nd - 1st millennia BC. Interareal differences are present. This is clearly seen from the data on the settlements of Shagalaly II and Akkain. Items from Zerenda demonstrate a large admixture of tin (Sn) in the percentage ratio: 3.1; 3.8; 4.3; 4.4; 6.2; 9.7. Accordingly, the objects from eastern Burabay are more copper, and tin is present in smaller

proportions: 0.1; 0.6; 1.1; 1.6; 1.9. In addition, in the objects from Shagalala II, the content of silicon (Si) is increased in percentage: 12.3; 13.6; 14.3; 15.3; 16.6; 19.4; 21.1.

In the early Iron Age, compared to the previous stage, the proportion of phosphorus (P) increases. In the arrowheads of the early Saka period, in percentage: 1.0; 1.4; 1.5; 1.6; 1.9; 2.2; 2.4. In the products of the Hunno-Sarmatian period: 3.7; 3.8; 5.2; 7.4.

The data on the Hunno-Sarmatian period, although insignificant against the background of previous historical periods, allow us to talk about the production of objects in another region. They have a different percentage of silicon (Si), a large proportion of phosphorus (P). The proportion of copper (Cu) is from 50 to 75%. This is confirmed by archaeological analysis - the burial rite and accompanying inventory indicate a non-local origin of the buried individual. It is obvious that the fibula, bells, following the wearer, arrived in Kokshetau from the area of the late Sarmatian culture of Western Kazakhstan or the Southern Trans-Urals.

The conducted metallographic analyses were carried out on objects from the indicated archaeological sites for the first time. They significantly supplement the existing ideas about the metallurgy of the 2nd - 1st millennia BC on the territory of the Kokshetau Upland.

Conclusion

The analyses presented were made on thirty-six separate samples – metal tools, weapons and costume parts. The artifacts are dated in a wide range from the Late Bronze Age to the Hunno-Sarmatian period (18th century BC – 3rd century AD). The samples are associated with finds at sites studied in and around the mountain forest massifs of Zerenda, Sandyktau and Burabay, which are part of the Kokshetau Upland. The area of the region is 9360 km^2. All the tools examined were made of copper or copper-based alloys in percentages from 44.4 to 99.6.

There are both chronological and intraregional differences. The first is explained by the different ethnocultural composition of the region's population, which is confirmed by archaeological data – changes in the appearance of material culture and burial rites from the Bronze Age to the early Saka period and from the early Saka to the Hunno-Sarmatian period. The second type of difference is more complex. The region's metallurgical technology largely derives from ancient Circumpontic traditions, which underwent different regional developments. In the territory of Northern Kazakhstan in the Late Bronze Age, two groups of the population associated with the Alakul line of development and the Fyodorovo line can be distinguished, but most of the objects date back to the period when the differences between them had already been overcome within the formation of the Sargara-Alekseyev culture. Most likely, the difference between the manufactured objects from the settlements of Shagalaly II and Akkain is associated with the difference in the composition of the original minerals. At the same time, the preservation of some different principles of creating copper alloys among the metallurgists of Burabay and Zerenda cannot be ruled out.

The conclusions drawn from this analysis are preliminary. Further understanding of the material and expansion of the analysed group of objects, territorially, chronologically, and typologically, are required. In addition, work is needed to study the elemental composition, especially of Bronze Age tools, which requires the use of a uniform approach to classification, including strict metric and chemical-metallurgical parameters.

Table 1. *Beginning*

Sample	**Reading #**	**Unit**	**Al**	**Si**	**P**	**S**	**Sc**	**Ti**	**V**	**Cr**	**Mn**	**Fe**	**Ni**	**Cu**
Standard BCR 691a	-	wt%	bdl	bdl	bdl	bdl	bdl	0,1	bdl	bdl	0,2	0,2	0,1	77,3
Standard BCR 691e	-	wt%	bdl	bdl	bdl	0,0	bdl	0,0	bdl	bdl	0,3	0,3	0,5	91,7
Bronze Age														
DSC00779 a	1	wt%	0,8	6,4	0,3	bdl	bdl	0,1	0,0	bdl	0,0	0,7	0,0	48,3
DSC00779 b	2	wt%	4,8	11,7	0,0	bdl	bdl	0,2	bdl	bdl	0,1	3,6	0,0	50,5
DSC00780 a	3	wt%	22,2	41,2	bdl	bdl	2,1	1,4	0,2	bdl	0,6	29,3	bdl	1,6
DSC00780 a	4	wt%	19,6	42,8	0,6	bdl	1,8	1,9	0,2	0,1	0,3	29,8	0,0	0,4
DSC00780 b	5	wt%	0,8	6,9	bdl	2,6	bdl	bdl	bdl	bdl	bdl	0,4	bdl	88,7
DSC00780 b	6	wt%	0,1	4,8	bdl	0,8	bdl	bdl	bdl	bdl	0,0	0,5	bdl	93,4
DSC00784	7	wt%	0,4	10,1	0,1	0,2	bdl	bdl	0,0	bdl	0,0	0,2	bdl	88,8
DSC00786	8	wt%	0,6	14,5	1,2	0,5	bdl	bdl	bdl	bdl	0,0	0,2	bdl	82,8
DSC00788	9	wt%	1,0	19,4	0,4	bdl	bdl	bdl	0,1	bdl	0,0	0,6	bdl	73,4
DSC00790 a	10	wt%	0,4	16,6	0,1	bdl	bdl	0,1	bdl	bdl	bdl	0,1	0,0	77,9
DSC00790 b	11	wt%	bdl	21,1	0,5	bdl	bdl	bdl	bdl	bdl	0,1	0,8	bdl	70,4
DSC00790 c	12	wt%	bdl	14,3	bdl	bdl	bdl	bdl	bdl	bdl	bdl	0,5	bdl	81,4
DSC00792 a	13	wt%	0,5	12,3	0,2	0,2	bdl	bdl	bdl	bdl	0,0	0,1	bdl	86,6
DSC00792 b	14	wt%	1,2	13,6	0,2	bdl	bdl	0,1	bdl	bdl	0,0	0,5	bdl	80,5
DSC00792 c	15	wt%	0,8	15,3	0,2	0,0	bdl	bdl	0,1	bdl	0,0	0,2	bdl	73,3
DSC00793	16	wt%	7,1	18,0	0,3	bdl	bdl	0,8	0,1	bdl	0,0	3,0	0,0	44,4
DSC00794	17	wt%	0,5	1,6	0,8	bdl	bdl	bdl	bdl	bdl	bdl	0,0	bdl	97,1
DSC00795	18	wt%	12,2	21,3	bdl	bdl	bdl	0,3	0,1	0,0	0,0	22,3	0,0	40,8
DSC00796	19	wt%	bdl	0,1	bdl	0,0	bdl	bdl	bdl	bdl	bdl	bdl	bdl	99,1
DSC00797 a	20	wt%	bdl	0,0	bdl	bdl	bdl	bdl	bdl	bdl	bdl	0,1	0,0	99,6
DSC00797 b	21	wt%	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	0,0	0,1	98,1
DSC00797 c	22	wt%	bdl	2,2	bdl	bdl	bdl	0,1	bdl	bdl	bdl	bdl	0,0	95,4
DSC00797 d	23	wt%	bdl	0,3	bdl	bdl	bdl	0,0	bdl	bdl	bdl	bdl	0,0	97,3
DSC00797 e	24	wt%	bdl	0,4	bdl	0,0	bdl	0,0	bdl	bdl	bdl	0,0	0,0	96,9
DSC00798	25	wt%	3,9	9,6	2,4	bdl	bdl	0,2	bdl	bdl	0,1	4,9	0,0	68,2

Early Saka Period														
DSC00799 a	26	wt%	bdl	0,7	1,6	bdl	bdl	0,0	bdl	bdl	0,0	0,5	bdl	93,4
DSC00799 b	27	wt%	1,0	3,0	1,5	0,0	bdl	0,1	0,1	bdl	bdl	0,3	bdl	92,7
DSC00799 c	28	wt%	0,5	2,0	1,4	bdl	bdl	0,1	0,0	bdl	0,0	1,4	0,0	91,5
DSC00799 d	29	wt%	bdl	0,5	1,9	bdl	bdl	0,0	bdl	0,0	0,0	0,1	bdl	94,9
DSC00799 e	30	wt%	0,3	1,3	2,4	bdl	bdl	0,0	bdl	bdl	0,0	0,6	bdl	93,3
DSC00799 f	31	wt%	0,2	1,3	2,2	bdl	bdl	0,1	0,0	bdl	0,0	0,3	bdl	93,4
DSC00799 g	32	wt%	0,3	1,8	1,0	0,0	bdl	0,4	0,2	bdl	0,0	2,4	0,0	91,3
Hunno-Sarmatian Period														
DSC00791 a	33	wt%	3,8	5,0	3,7	bdl	bdl	bdl	bdl	bdl	bdl	0,5	0,1	75,4
DSC00791 b	34	wt%	bdl	7,2	7,4	bdl	bdl	bdl	bdl	bdl	bdl	0,9	0,1	68,3
DSC00791 c	35	wt%	2,7	2,8	5,2	bdl	bdl	0,5	bdl	bdl	bdl	0,5	bdl	56,1
DSC00791 d	36	wt%	2,0	2,2	3,8	bdl	bdl	0,3	bdl	bdl	bdl	0,6	bdl	50,5

Table 1. *Continuation*

Reading #	**Zn**	**As**	**Sr**	**Zr**	**Nb**	**Rh**	**Pd**	**Ag**	**Cd**	**Sn**	**Sb**	**Pb**	**Bi**	**Total**
6,3	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	6,6	0,4	8,9	bdl	100,0	6,3
0,1	0,0	bdl	bdl	bdl	bdl	bdl	bdl	bdl	6,3	0,5	0,2	bdl	100,0	0,1
Bronze Age														
1	35,5	bdl	0,0	bdl	bdl	bdl	bdl	bdl	bdl	2,8	bdl	5,0	bdl	100,0
2	0,1	0,0	0,0	bdl	bdl	bdl	bdl	bdl	bdl	29,0	bdl	0,1	0,0	100,0
3	0,5	bdl	0,5	0,1	bdl	bdl	bdl	bdl	bdl	0,2	bdl	0,0	0,0	100,0
4	0,2	bdl	2,0	0,2	0,0	bdl	bdl	bdl	bdl	0,1	bdl	0,0	0,0	100,0
5	0,1	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	0,1	bdl	0,0	0,4	100,0
6	0,0	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	0,0	0,2	100,0
7	0,0	0,0	bdl	bdl	bdl	bdl	bdl	bdl	bdl	0,1	bdl	0,0	0,0	100,0
8	0,1	bdl	0,1	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	0,1	bdl	100,0
9	0,1	bdl	0,0	bdl	bdl	bdl	bdl	0,0	bdl	4,4	0,1	0,6	0,0	100,0
10	0,0	0,1	bdl	bdl	bdl	bdl	bdl	bdl	bdl	4,3	0,3	0,1	bdl	100,0
11	0,1	0,0	0,0	bdl	bdl	0,1	bdl	0,2	bdl	6,2	0,2	0,2	bdl	100,0
12	0,1	bdl	0,0	bdl	bdl	0,2	bdl	bdl	bdl	3,1	0,4	bdl	bdl	100,0

13	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	0,0	bdl	0,0	bdl	100,0
14	0,1	0,0	bdl	bdl	bdl	bdl	bdl	bdl	bdl	3,8	bdl	bdl	bdl	100,0
15	0,1	0,0	bdl	bdl	bdl	bdl	bdl	bdl	bdl	9,7	0,1	0,0	bdl	100,0
16	0,1	0,1	0,0	0,0	bdl	bdl	bdl	0,0	bdl	23,6	0,1	2,5	0,1	100,0
17	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	100,0
18	0,1	0,0	0,0	0,0	bdl	0,0	bdl	0,0	bdl	1,6	bdl	0,6	0,6	100,0
19	bdl	0,0	bdl	bdl	bdl	bdl	bdl	0,1	bdl	0,6	bdl	0,1	0,0	100,0
20	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	0,1	bdl	0,3	bdl	100,0
21	0,1	0,2	bdl	bdl	bdl	bdl	bdl	0,1	bdl	1,1	0,1	0,3	0,0	100,0
22	bdl	0,1	bdl	bdl	bdl	bdl	bdl	0,4	bdl	0,6	0,5	0,4	0,3	100,0
23	bdl	0,3	bdl	bdl	bdl	bdl	bdl	0,1	bdl	1,6	0,1	0,3	0,1	100,0
24	bdl	0,3	bdl	bdl	bdl	bdl	bdl	0,1	bdl	1,9	0,1	0,3	0,0	100,0
25	1,4	0,0	bdl	bdl	bdl	bdl	bdl	bdl	bdl	5,6	0,1	3,6	0,0	100,0
Early Saka Period														
26	0,0	0,5	bdl	bdl	bdl	bdl	bdl	0,0	bdl	2,3	0,0	0,7	0,1	100,0
27	0,0	0,7	bdl	bdl	bdl	bdl	bdl	0,1	bdl	0,1	bdl	0,3	0,1	100,0
28	bdl	1,2	bdl	bdl	bdl	bdl	0,0	0,1	bdl	0,9	0,0	0,6	0,2	100,0
29	bdl	0,3	bdl	bdl	bdl	bdl	bdl	0,1	bdl	1,4	0,0	0,3	0,3	100,0
30	0,0	0,5	bdl	bdl	bdl	bdl	bdl	0,1	bdl	0,7	0,0	0,4	0,3	100,0
31	0,0	0,4	bdl	bdl	bdl	bdl	bdl	0,1	bdl	1,2	bdl	0,4	0,3	100,0
32	0,0	0,8	0,1	bdl	bdl	bdl	bdl	0,1	bdl	0,5	bdl	0,5	0,5	100,0
Hunno-Sarmatian Period														
33	0,5	bdl	bdl	bdl	bdl	bdl	0,0	0,1	0,0	2,3	0,0	8,5	0,1	100,0
34	8,6	0,2	bdl	bdl	bdl	bdl	bdl	0,6	0,1	5,2	0,1	1,3	bdl	100,0
35	0,5	0,0	0,0	bdl	bdl	0,0	bdl	bdl	bdl	31,5	bdl	0,1	bdl	100,0
36	0,7	0,0	0,0	bdl	bdl	bdl	bdl	bdl	bdl	39,7	bdl	0,2	bdl	100,0

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Information about authors

Miljana Radivojevic – Associate Professor in Archaeological Science, University College London, Institute of Archaeology, 31-34 Gordon Square, WC1H 0PY, London, United Kingdom, https://orcid.org/0000-0001-7329-305X, m.radivojevic@ucl.ac.uk

Ilaria Calgaro – Research Fellow, University College London, Institute of Archaeology 31-34 Gordon Square, WC1H 0PY, London, United Kingdom, https://orcid.org/0000-0002-4536-4460, ilaria.calgaro.19@ucl.ac.uk

Авторлар туралы мәліметтер

Мильяна Радивоевич – Лондон университет колледжінің археология ғылымының доценті, Археология институты, Гордон алаңы, 31-34, Лондон, Ұлыбритания, https://orcid.org/0000-0001-7329-305X, m.radivojevic@ucl.ac.uk

Илариа Калгаро – Лондон университет колледжінің ғылыми қызметкері, Археология институты, Гордон алаңы, 31-34, Лондон, Ұлыбритания, https://orcid.org/0000-0002-4536-4460, ilaria.calgaro.19@ucl.ac.uk

Сведения об авторах

Мильяна Радивоевич – ассоциированный профессор, Университетский колледж Лондона, Институт археологии, Площадь Гордона, 31-34, WC1H0PY, Лондон, Великобритания, https://orcid.org/0000-0001-7329-305X, m.radivojevic@ucl.ac.uk

Илария Калгаро – научный сотрудник постдокторантуры, Университетский колледж Лондона, Институт археологии, Площадь Гордона, 31-34, WC1H0PY, Лондон, Великобритания, https://orcid.org/0000-0002-4536-4460, ilaria.calgaro.19@ucl.ac.uk

Contributions by authors

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