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The Ishkinino Bronze Age Mining Complex in the Southern Urals: Radiocarbon Dating

This article presents the results of radiocarbon dating of buried soils beneath the dumps of ancient mines in the Ishkinino cobalt and copper pyrite deposit area, in the Southern Urals. The conserved upper horizons of stratigraphic sequences underlying the dumps of four mines were subjected to radiocarbon analysis. For comparison, samples from Bronze Age sites in the same area were used. Chronological ranges of the Yamnaya, Sintashta cultures, and Kozhumberdy cultural group were evaluated. Calibrated intervals of the buried soils from the Ishkinino mines show a good agreement with the respective intervals relating to human and animal bones from nearby Bronze Age cemeteries and settlements. The early stage of the mines (2200–1840 BC) corresponds to the Sintashta culture. Most geological and archaeological features at Ishkinino date to 1780–1130 BC, the same as the Kozhumberdy settlement and cemeteries representing the Alakul tradition. As the results suggest, radiocarbon dating of the buried soils underlying the mine dumps is relevant to the absolute and relative chronology of ancient mining—especially when archaeological contexts are of little help.

Keywords: *Bronze Age, Southern Urals, Ishkinino archaeological area, copper mine, radiocarbon dating.*

Introduction

Dating of geoarchaeological features relating to mining and primary processing of copper ores is one of the most complicated research issues in studying Bronze Age metal production. Usually, researchers have to deal with indirect data obtained by archaeometry methods. In exceptional cases, archaeologists excavating ancient mines manage to discover cultural layers or separate artifacts, including tunneling tools that directly point to the development of mining sites in the Bronze Age.

This necessitates the elaboration of an effective method for comprehensive research of ore-mining, which would make it possible to define objective criteria for the functioning of ancient mines during the Bronze Age. A positive research experience was obtained when studying the Ishkinino archaeological microregion in the eastern part of Orenburg region, the Southern Urals. This article is devoted to solution of the said problem, relating to radiocarbon dating of buried soils beneath the dumps of ancient mines.

Brief description of the research range

A cycle of special studies is devoted to the characteristics of the Ishkinino archaeological microregion sites (Tkachev, 2005, 2011, 2012; Zaykov, Yuminov, Tkachev, 2012; Plekhanova, Tkachev, 2013; and others). This obviates the need for detailed description of them. Therefore, I confine myself to some brief remarks on the complexes that constitute the source base for radiocarbon dating.

The Ishkinino archaeological microregion is situated in the middle reaches of the Sukhaya Guberlya River,

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near the Ishkinino village of the Gaisky District of the Orenburg Region. It is formed by a compact group of sites: the Ishkinovka settlement, the Ishkinovka I–III cemeteries, and a series of localities containing Bronze Age ceramics of Aulgan I–IV and Sukhaya Guberlya I–IV (Fig. 1). The studies have demonstrated that all of these are interrelated and confined to the Ishkinino copper mines, being in this case the dominant element of the ore-mining and -smelting production structure. The Ishkinino mining complex of the Bronze Age is the largest and most structurally complicated geoarchaeological feature in the Southern Urals. At least 10 ancient mine-openings, and a production and processing site (Fig. 2, *1*), have been revealed within the ore field*.

The dumps of mines No. 6–8 and vertical opening No. 9 (possibly, a narrow slit-like mining ditch) were cut by trenches that opened buried soils (Fig. 2, *2–5*). Collected samples were used to conduct paleosol and palynological studies, as well as radiocarbon dating of the upper horizons of soils buried under the mine dumps.

The development of the Ishkinino copper mines in the Bronze Age was associated with the Ishkinovka settlement located 500 m north-northwest, on the opposite bank of the Aulgan creek. This settlement belongs to the Kozhumberdy cultural group representing the Alakul tradition (Fig. 3, *11–35*). Samples of animal bones were collected from the cultural layer of the site for radiocarbon dating.

Funerary complexes belonging to the Yamnaya (Pit-Grave) culture of the Early Bronze Age (EBA) (Fig. 3, *1–3*), the Sintashta culture of the Middle/Late Bronze Age (Fig. 3, *4–6*), and the Kozhumberdy cultural group of the Late Bronze Age (LBA) (Fig. 3, *7–10*) were studied at the Ishkinovka I–III cemeteries. For radiocarbon dating, one burial was selected from each of the said cultural formations at Ishkinovka I. As a result, six dates were obtained.

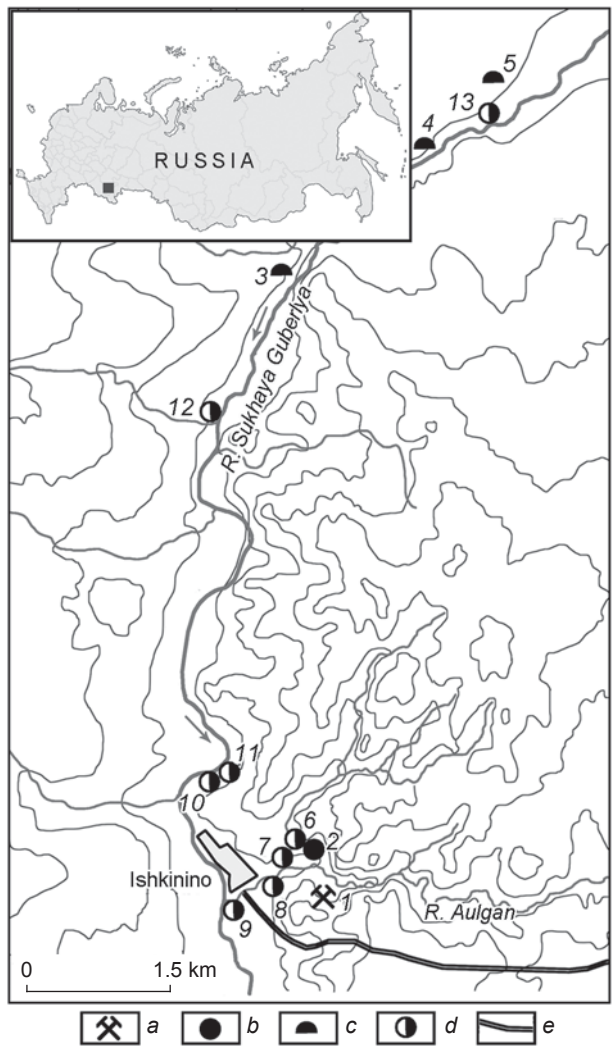

Fig. 1. Locations of the Ishkinino archaeological microregion sites.
a – mines; *b* – settlement; *c* – cemetery; *d* – location of artifacts; *e* – road. *1* – Ishkinino mines; *2* – Ishkinovka; *3* – Ishkinovka I; *4* – Ishkinovka II; *5* – Ishkinovka III; *6* – Aulgan I; *7* – Aulgan II; *8* – Aulgan III; *9* – Aulgan IV; *10* – Sukhaya Guberlya I; *11* – Sukhaya Guberlya II; *12* – Sukhaya Guberlya III; *13* – Sukhaya Guberlya IV.

Results of radiocarbon dating

During the studies under my supervision in the Ishkinino archaeological microregion, we managed to form a series of 13 radiocarbon dates (see *Table*). All dates are being published for the first time, which constitutes independent scientific value. Thus, we turn to the issue of determining the radiocarbon age of the mine-openings at the Ishkinino copper mines. This is a nontrivial research procedure for the mining sites.

Radiocarbon dates obtained by measuring various organic materials were used for comparative analysis. Human and animal bones, ceramics, and buried soils served as dated samples. The fact that the majority of analyses were performed by G.I. Zaitseva in the Archaeological Technology Laboratory of the Institute for the History of Material Culture RAS according to a common methodology (the analyses are designated by the Le code in the table and graphs) can be considered as a positive point. One date on ceramics was obtained through the mediation of P.F. Kuznetsov in the Kiev Radiocarbon Laboratory (Ki index). The only AMS-date (Hela index) obtained in the Dating Laboratory (now Laboratory of Chronology), Finnish Museum of Natural

*Notably, this article uses a revised numbering of the Ishkinino mining features, which is somewhat different from the earlier published one (Zaykov, Yuminov, Tkachev, 2012: Fig. 3).

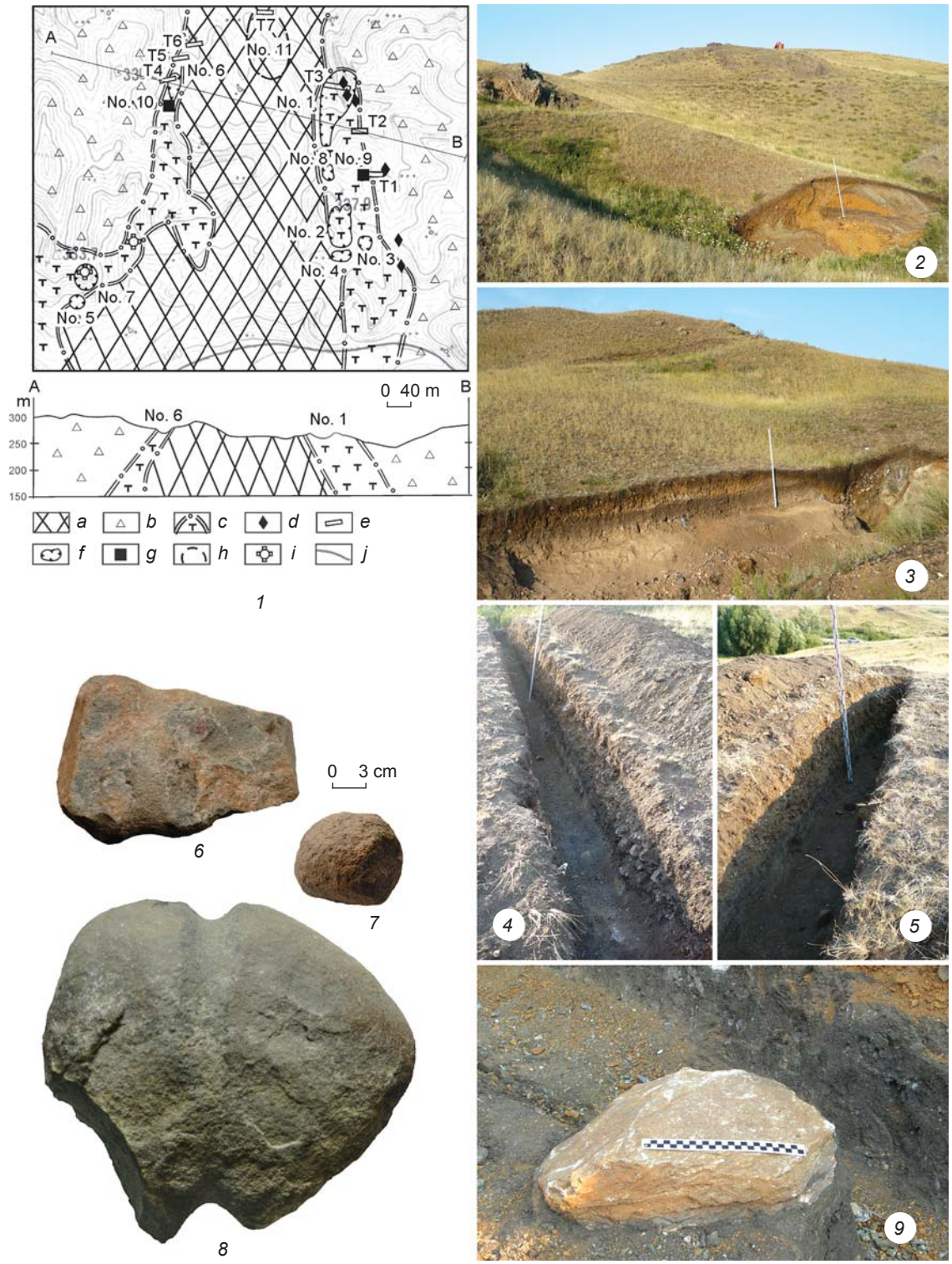

Fig. 2. Ishkinino ore-mining complex.

1 – location map of ancient mine-openings, an enrichment site and ore-bearing zones at the Ishkinino deposit area (after (Zaykov, Yuminov, Tkachev, 2012, Fig. 3) as supplemented) (*a* – ultrabasic rocks, *b* – volcanomictic breccias, *c* – contours of ore-bearing zones with accompanying talc-carbonate rocks, *d* – sampling points of ore grab samples, *e* – trenches dug out in 2001, *f* – contours of ancient mines, *g* – vertical mine-openings, *h* – enrichment site, *i* – locations of single gold grains, *j* – Gai– Ishkinino motorway; *2–5* – stratigraphic sequences of the dumps of mine-openings: *2* – mine No. 6, *3* – vertical opening No. 9, *4* – mine No. 8, *5* – mine No. 7; *6–9* – stone tools from the Ishkinino mines: *6*, *8* – hammers, *7* – ore-breaker stone, *9* – anvil.

Fig. 3. Materials of the Ishkinino archaeological microregion sites dated by the radiocarbon method.
7–3 – Ishkinovka I, kurgan 3, burial 7 (Yamnaya culture); *4–6* – Ishkinovka I, kurgan 3, burial 6 (Sintashta culture); *7–10* – Ishkinovka I, kurgan 2, burial 1 (Kozhumberdy cultural group); *11–35* – the Ishkinovka settlement (Kozhumberdy cultural group).

Results of radiocarbon dating of the Ishkinino archaeological microregion sites

No.	Locality (cultural attribution)	Laboratory code	Material	^{14}C-date, BP	Calibrated values, yrs BP	
					σ (68.2 %)	2σ (95.4 %)
1	Ishkinovka I, kurgan 3, burial 7 (Yamnaya culture, EBA)	Le-8839	Human bone	4040 ± 100	2860–2810 (8.9 %) 2750–2720 (4.0 %) 2700–2460 (55.3 %)	2890–2300 (95.4 %)
2	″	Hela-3560 (AMS)	″	3927 ± 74	2560–2530 (5.7 %) 2500–2290 (62.5 %)	2620–2190 (95.4 %)
3	Ishkinovka I, kurgan 3, burial 6 (Sintashta culture, LBA)	Le-8924	Animal bone	3421 ± 120	1900–1600 (65.1 %) 1590–1560 (3.1 %)	2040–1440 (95.4 %)
4	″	Le-8925	Human bone	3560 ± 110	2110–2100 (0.9 %) 2040–1740 (67.3 %)	2210–1620 (95.4 %)
5	″	Ki-18021	Ceramics	3870 ± 70	2470–2280 (63.6 %) 2250–2230 (4.6 %)	2570–2530 (1.8 %) 2500–2140 (93.6 %)
6	Ishkinovka settlement, square Г-2, level 35 (Kozhumberdy cultural group, LBA)	Le-8854	Animal bone	3020 ± 150	1430–1050 (68.2 %)	1620–890 (95.4 %)
7	Ishkinovka settlement, square Г-2, level 70 (Kozhumberdy cultural group, LBA)	Le-8855	″	3190 ± 100	1620–1380 (63.2 %) 1340–1310 (5.0 %)	1730–1720 (0.3 %) 1700–1210 (95.1 %)
8	Ishkinovka settlement, excavation 3 (Kozhumberdy cultural group, LBA)	Le-9342	″	2940 ± 200	1400–920 (68.2 %)	1690–760 (95.4 %)
9	Ishkinovka I, kurgan 2, burial 1 (Kozhumberdy cultural group, LBA)	Le-9680	Human bone	3380 ± 110	1880–1840 (4.9 %) 1820–1800 (1.3 %) 1780–1520 (62.0 %)	1950–1430 (95.4 %)
10	Ishkinino mines, mine No. 6	Le-8849	Buried soil	4240 (3240)* ± 100	1640–1410 (68.2 %)	1760–1260 (95.4 %)
11	″ , mine No. 8	Le-8851	″	4030 (3030)* ± 100	1410–1120 (68.2 %)	1510–1000 (95.4 %)
12	″ , mine No. 7	Le-8852	″	4370 (3370)* ± 100	1870–1850 (1.4 %) 1780–1520 (66.8 %)	1920–1440 (95.4 %)
13	″ , mine No. 9	Le-8853	″	4730 (3730)* ± 120	2300–1950 (68.2 %)	2480–1870 (93.2 %) 1850–1770 (2.1 %)

*Values corrected for the radiocarbon age of the ten-centimeter layer of the chernozem upper horizon (ca 1000 years) are specified in brackets (Chichagova, 1985: 84, 85, tab. 26).

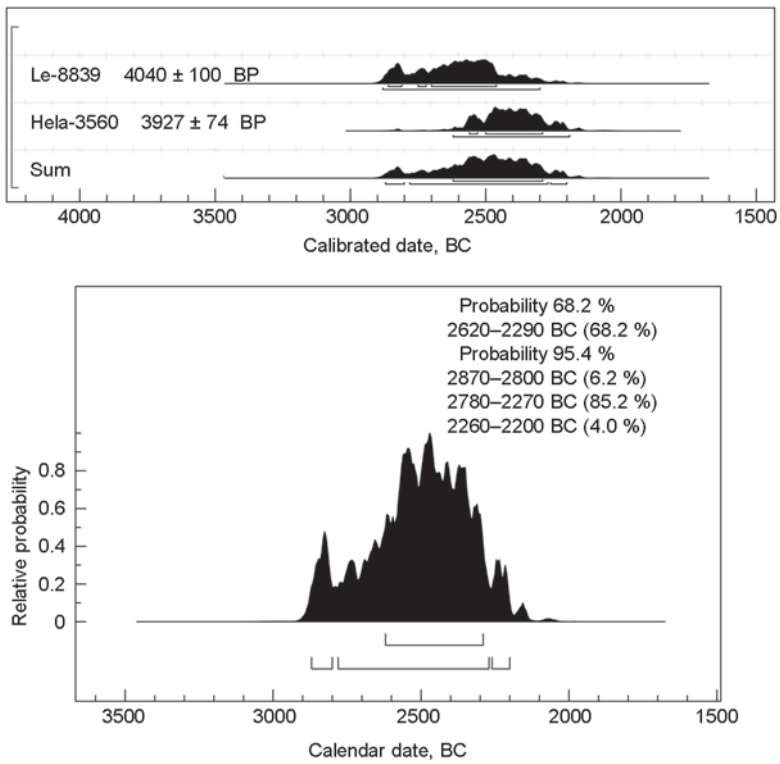

Fig. 4. Graphs of summation of probabilities for calibrated radiocarbon dates on burial 7, kurgan 3 of the Ishkinovka I cemetery (Yamnaya culture).

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The radiocarbon dates were calibrated with the OxCal 4.3.2 program of the Oxford Laboratory (Bronk Ramsey, 2017). The statistical procedures used values with a probability of 68.2 %, which produced more compact intervals. Summation of the obtained intervals available in the previous version of the OxCal 3.10 program proved to very efficient (Bronk Ramsey, 2005). In these cases, to achieve better results, more accurate calibration curve IntCal13 was used (Reimer et al., 2013).

Comparative materials

Before turning to the results of radiocarbon dating of buried soils beneath the dumps of the Ishkinino mines, it is necessary to consider a series of dates obtained for funerary and settlement complexes in their neighborhood. The initial stage of the Bronze Age is presented in our sample by two radiocarbon dates for a Yamnaya culture burial (see *Table*, Ishkinovka I, kurgan 3, burial 7). The results of measurements using conventional benzene technology (Le-8839) virtually coincide with the mass series of radiocarbon dates obtained by the same procedure for the Late Yamnaya sites (developed stage B) in the Cis-Urals steppe region (Morgunova, 2014: Tab. 16). The second date (Hela-3560), determined by the AMS-method, proved to be 90 years younger, and it has a narrower confidence interval. Meanwhile, they demonstrate reasonably good convergence, which is clearly illustrated by partial coincidence of the calibrated age intervals. This allowed us the use a function for summing conventional dates. A quite symmetrical graph of probability sums (2620–2290 / 2870–2200 BC), which was finally obtained*, generally corresponds to the normal distribution (Fig. 4). Obtaining a combined date in the OxCal 4.3.2 program led to comparable results (2580–2340 / 2840–2280 BC), which made it possible to do away with this procedure as a duplicate in this case.

The next chronological echelon is composed of the dates obtained for the Sintashta burial (see *Table*, Ishkinovka I, kurgan 3, burial 6). The use of a summation algorithm has allowed us to build a double-peaked asymmetric graph with two calibrated intervals of 2470–2230 and 2010–1640 BC, with a probability of 68.2 % (Fig. 5). The first of these was obtained through the date on ceramics, and the second one by summing two dates on human and animal bones. The last interval actually coincides with the Sintashta

*The first interval – σ (68.2 %), the second interval – 2σ (95.4 %).

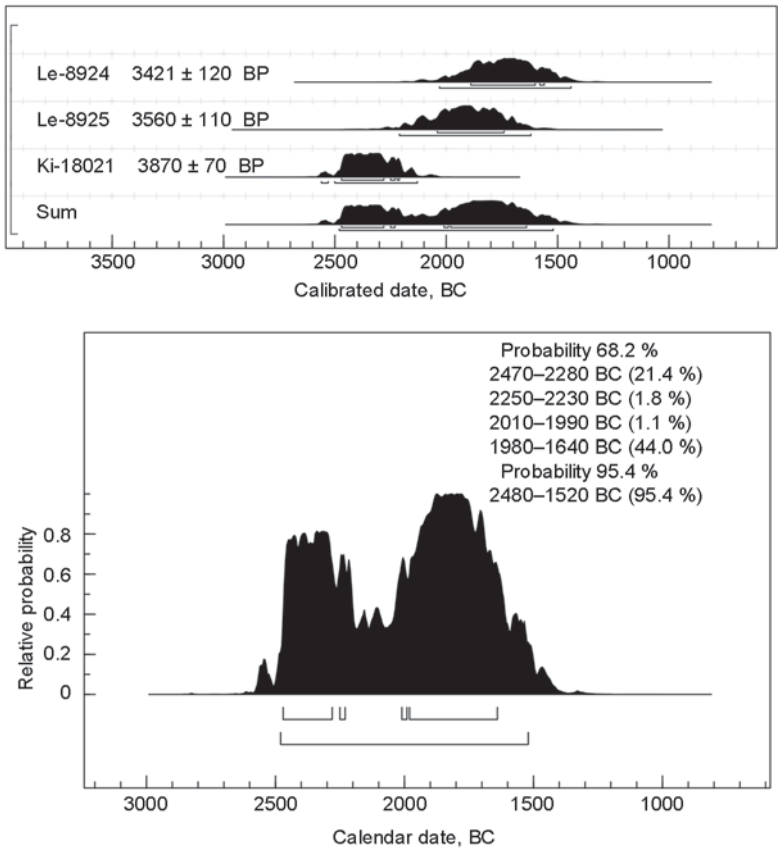

Fig. 5. Graphs of summation of probabilities for calibrated radiocarbon dates on burial 6, kurgan 3 of the Ishkinovka I cemetery (Sintashta culture).

chronological framework that was reliably established on the basis of mass data (30 dates) (Epimakhov, 2007: 403, fig. 1, *I)*. At the same time, the obtained results once again compel us to pay attention to the difficulties that arise during radiocarbon dating of ceramics, which are related to the presence of different carbon sources (Kulkova, 2014).

Using human and animal bones, it was possible to obtain four dates (see *Table*) for the Kozhumberdy cultural group complexes of the Alakul tradition (see Fig. 3, *7–35*). Summation of probabilities of the calibrated values resulted in building a uniform symmetric graph and determining the interval of 1690–1120 BC (Fig. 6). At the same time, these four dates form two non-contemporaneous pairs, which is in good agreement with the radiocarbon chronology of Kozhumberdy antiquities of the Ural-Mugodzhar region. The chronological framework for these antiquities was determined to be within 1750–1100 BC, with the possibility of distinguishing two phases delimited by approximately 1400 BC (Tkachev, 2016).

Thus, the following calibrated intervals were obtained by the results of radiocarbon dating of the Bronze Age sites of the Ishkinino archaeological microregion: the Yamnaya culture (EBA) – 2620–2290 BC, the Sintashta culture (LBA) – 2010–1640 BC, and the Kozhumberdy cultural group (LBA) – 1690–1120 BC.

Archaeological context and radiocarbon dating of geoarchaeological features

Notably, there is archaeological evidence of the functioning of the Ishkinino mines in the Bronze Age. At the dumps of ancient mines and enrichment site, stone hammers, a grinder, and an anvil were found (see Fig. 2, *6–9*). Ore fragments, smelter slags, stone anvils, pestles, hammers, blanks for tunneling bone wedges, and other evidence of ore-mining and -smelting production were discovered in the Ishkinovka settlement cultural layer (see Fig. 3, *11–13*, *20–22*). Archaeometric studies have revealed the identity of composition of chromite ores and slugs, as well as the presence of copper sulphides and iron phosphides with increased nickel content in the reguli found in slags. This confirmed the use of the Ishkinino deposit ores by the Ishkinovka population (Zaykov, Yuminov, Tkachev, 2012).

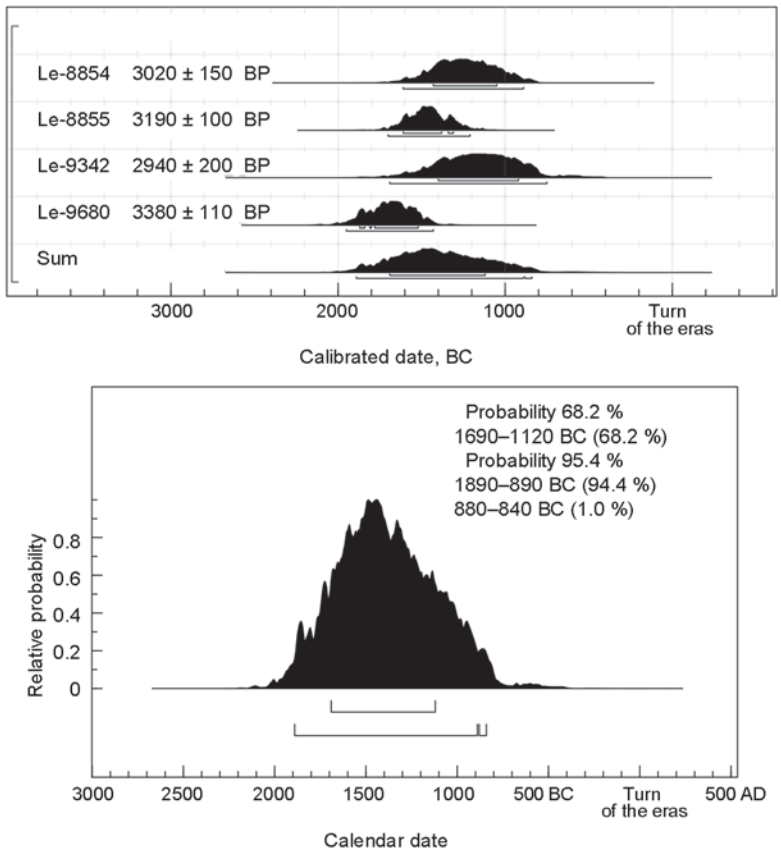

Fig. 6. Graphs of summation of probabilities for calibrated radiocarbon dates on burial 1, kurgan 2 of the Ishkinovka I cemetery (Kozhumberdy cultural group).

Preceding the presentation of buried soil radiocarbon dating results, it should be made clear that this type of source has a number of special features to be taken into account when performing statistical procedures and interpreting the obtained data. The technique of handling radiocarbon dates on buried soils differs considerably from the algorithm for actions relating to the dating results of other materials. In case of the Ishkinino samples, the problem is somewhat alleviated, since these are ordinary chernozems, whose properties have been thoroughly studied by paleopedologists. According to the procedural requirements, it is necessary to subtract the radiocarbon age of the buried soil humic substances from the obtained ^{14}C-date. It is approximately 1000 years for the upper 10 cm thickness of chernozems (Chichagova, 1985: 84, 85, tab. 26; Morgunova et al., 2003: 266–267).

As already mentioned, buried soil samples were collected beneath the dumps of four mine-openings in the Ishkinino mine area (see Fig. 2, *1–5*). These proved to be quite suitable for radiocarbon dating. All conventional dates have yielded calibrated age intervals within the Bronze Age (see *Table*). Ancient soil under the dump of small mine No. 8 (Le-8851), dated to within 1410–1120 BC, makes it possible to assign this mining-site to the late phase of the Kozhumberdy cultural group. A sample taken beneath the dump of mine No. 6 (Le-8849) has yielded an interval of calibrated values within 1640–1410 BC, which corresponds to the early phase of this group.

The results of the radiocarbon dating of two other samples cannot be interpreted so unambiguously (possibly owing to the errors in the method itself). The calibrated interval of buried soil beneath the dump of mine No. 7 (Le-8852: 1870–1520 BC) overlaps equally the late part of the Sintashta range and the early part of the Kozhumberdy. But all the same, correlation of this mine with the latter seems to be more justified. This conclusion is also confirmed by the nearly full coincidence between the conventional dates and calibrated intervals of the soil sample and Kozhumberdy burial 1, kurgan 2 of the Ishkinovka I cemetery (Le-9680: 1880–1520 BC) (see *Table*).

Vertical opening No. 9, where sulfide ores were produced, is the most ancient site among the geoarchaeological features of the Ishkinino mining complex. The interval of calibrated values of buried soil sample collected beneath its dump (Le-8853: 2300–1950 BC)

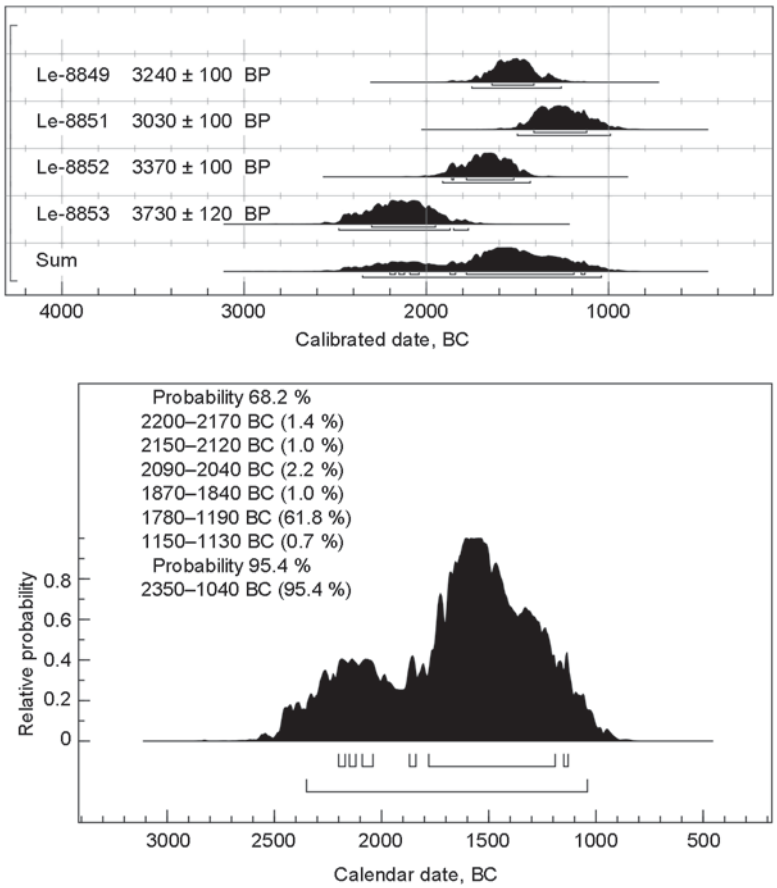

Fig. 7. Graphs of summation of probabilities for calibrated radiocarbon dates on buried soils beneath the dumps of Ishkinino mine-openings.

overlaps the early phase of the Sintashta range only in its later part. And yet, it is most realistic to define this opening as belonging to the Sintashta culture.

Summation of probabilities for calibrated radiocarbon dates on buried soils became the next stage of analysis. As a result of this procedure, a double-peaked asymmetric graph with two intervals of values was built (Fig. 7). The first interval (2200–1840 BC) can generally be referred to the Sintashta period of Ishkinino mining complex use, while the second (1780–1130 BC) refers to the Kozhumberdy one.

The existence of at least two developmental stages of the Ishkinino cobalt and copper pyrite deposit area in the Bronze Age is also confirmed by the stratigraphy of the northern dump of mine No. 1; this is the largest dump wherein inter-overlapping dumped strata were recorded. These latter are divided by the buried soil interlayer that had been formed during a long interval between the operational stages (Zaykov et al., 2005: 107–108, fig. 8; Zaykov, Yuminov, Tkachev, 2012: 40–41, fig. 4, 5).

Conclusions

To sum up the above, a number of resulting propositions can be stated.

1. Radiocarbon dating of buried soils beneath the dumps of mine-openings has confirmed the development of the Ishkinino cobalt and copper pyrite deposit area in the Late Bronze Age. The initial stage of mines' functioning is associated with the Sintashta culture of the turn of the middle and late periods of the Bronze Age, while the next stage belongs to the time of the Kozhumberdy cultural group representing the Alakul tradition.

2. The obtained data on the radiocarbon age of buried soils from geoarchaeological production features correlate well with the radiocarbon dating results (from human and animal bones) of the funerary sites and the settlement relating to the Ishkinino mines.

3. Radiocarbon dating of buried soils preserved under man-made strata of mining complexes can be employed as an efficient universal method for determining the age and functioning stages of mining sites irrespective of their

cultural and chronological position; which is particularly relevant in cases of the uncertain archaeological context of such features.

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