Marmot incisors and bear tooth pendants in Volosovo hunter-gatherer burials: New radiocarbon and stable isotope data from the Sakhtysh complex, Upper-Volga region

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Abstract
This article examines Volosovo period chronology at the hunter-gatherer settlement and burial sites Sakhtysh II and IIa (Upper-Volga area, Russia) by presenting 15 new AMS and stable bulk isotope (EA-IRMS; \(\delta^{13}C\), \(\delta^{15}N\), %C, %N, C:N ratio) measurements of animal bones and teeth from ritual contexts, as well as the first published AMS-dated charred organic residues on Volosovo pottery. The results confirm some recently presented views about chronology and further contradict the use sequence previously proposed for the sites. The discrepancies may be partially related to freshwater reservoir effect (FRE), but mostly to the problems in the quality and context of the conventional datings. The results are also briefly discussed in the background of general Volosovo chronology.

Keywords: Hunter-gatherer burials, Stone Age, central European Russia, radiocarbon dating, stable bulk isotopes, Volosovo culture

1 Introduction
The Sakhtysh peat bog in the Upper-Volga area (Russia) is one of the key micro-regions in the hunter-gatherer archaeology of the north-European boreal zone. In addition to numerous stratified settlement sites, some of the largest hunter-gatherer cemeteries of European Russia are situated in the area. Extensive studies have revealed ca. 150 burials dating to the Lyalovo (Pit-Comb) and Volosovo phases of the 5\(^{th}\) and 4\(^{th}\) millennia cal BC – these comprise half of all the prehistoric burials known in the Volga-Oka interfluve (Kostyleva and Utkin, 2010). Rich finds from domestic and ritual contexts include, among others, unique discoveries like burials furnished with hundreds of amber or bone adornments, and a life-size mask made of elk antler (Kraynov et al. 1994).

The Sakhtysh complex has been pivotal in the creation of periodization and absolute chronology of the Volosovo culture (Kraynov et al. 1991; Kostyleva and Utkin, 2010). A comprehensive dating program was pursued at the site Sakhtysh IIa, and human bone samples from 29 Volosovo graves were sent for conventional dating in the 1980s and 1990s. However, 15 samples could not be dated due to insufficient collagen, and seven datings were later discarded due to their perceived incompatibility with the archaeological chronology (Kostyleva and Utkin, 2010). The first published AMS dates and stable isotope measurements of individuals from the Sakhtysh IIa site (Piezonka et al. 2013), nevertheless, raised questions concerning the internal chronology of the site and the compatibility of absolute chronology and some typological sequences. This study, together with AMS datings of charred organic residues on the 6\(^{th}\) millennium cal BC Upper Volga pottery (Hartz et al. 2012; Piezonka et al. 2016; also Dolbunova et al. 2017), indicated also a hunter-gatherer diet based on aquatic resources and potential freshwater reservoir effect (FRE) in the area.

The current paper examines further the Volosovo chronology at the sites Sakhtysh II and IIa by presenting 15 new AMS and stable bulk isotope measurements. It aims to shed light on the recently-raised questions and contradictions between different chronologies and interpretations: in old publications, the radiocarbon years are often non-calibrated, treated similarly to calendar years and without paying attention to the uncertainties, or "BC" years
may be formed just by subtracting 1950 years from the measured BP value. The results are also briefly discussed in the context of general chronology of the Volosovo culture, which has been placed varyingly between the later 4th and the 2nd millennia BC (Kraynov, 1987; Nikitin, 2012).

The new measurements were obtained within a PhD-project focusing on the human-animal relationships in the Stone Age hunter-gatherer burials of northern Europe (see Macânê, 2018). Consequently, the dated materials consist of animal tooth pendants and bones from graves and hoards. In addition, five carbonized organic residues – also known as foodcrusts – adhering to pottery were analysed, being the first AMS-dated Volosovo foodcrusts. The BP values of two datings have been previously given out without any supplementary information (Kostyleva and Macânê, 2018a, 2018b), but all dates are published here for the first time with the full isotopic, contextual and other information.

2 The Sakhtysh complex

The Sakhtysh micro-region is located in the Volga-Oka interfluve, along the headwaters of the Koyka River in the Ivanovo Region, central European Russia (Fig. 1). The area has evidence of human habitation from the Early Mesolithic to the Iron Age, and includes altogether 11 long-term and seasonal settlements (Sakhtysh I–II, IIA, III–IV, VII–XI, XIV) and four artefact scatters (sites V–VI, XII–XIII), in addition to which burials have been detected at five sites (I–II, IIA, VII, VIII) (Kostyleva and Utkin, 2010). The locations have been known since the 1930s and intensively studied since the 1960s under the leadership of D.A. Kraynov, M.G. Zhilin, E.L. Kostyleva, and A.V. Utkin.

Sakhtysh II and IIA are the most extensively studied sites of the complex, with ca. 1500 m² and around 800 m² excavated, respectively. The burial grounds at both sites are considered as fully investigated.

The site Sakhtysh II, excavated between 1963 and 2001, contained four Lyalovo and 19 Volosovo burials, including three collective graves (Fig. 2). Furthermore, three dog burials, 14 hoards, and what the excavators have interpreted as “sanctuary" and two “ritual platforms" have been connected with the ritual use of the site (Kraynov, 1982; Kostyleva and Utkin, 2010).

The site Sakhtysh IIa is located just on the opposite side of a small creek from Sakhtysh II, and was excavated in 1987–2015. The multilayer settlement site is accompanied by a cemetery of 15 Lyalovo and 57 Volosovo burials, as well as by two “sanctuaries" or "ritual pits" and two hoards (Kraynov et al. 1994; Kostyleva and Utkin, 2010; Piezonka et al. 2013) (Fig. 3).

3 Methods and results

3.1 Methods

Eighteen samples, including 13 samples of bone and tooth and five samples of charred organic residues were analysed in the 14th Chrono Centre, Queen’s University, Belfast. All radiocarbon ages were measured in the AMS (accelerator mass spectrometry). Collagen was
extracted through a modified Longin method (Longin, 1971) developed by Brown et al. (1988). Pre-treatment of bone samples and charred organic residues was done following the protocols described by Reimer et al. (2015). The bulk stable isotopes ($\delta^{13}$C, $\delta^{15}$N, %C, %N, C:N ratio) were analysed in duplicate on a Thermo Delta V elemental analyser-isotope ratio mass spectrometer (EA-IRMS). All $^{14}$C ages were calibrated using OxCal v4.3.2 (Bronk Ramsey, 2009) with the IntCal13 atmospheric curve (Reimer et al. 2013), and are given in the text with 95.4% probability.

3.2 Bone and tooth
In total, 13 animal tooth and bone samples were sent for dating, but two mammal bone samples from hoard 10 at Sakhtysh II (UBA-34094 and 34095) and an elk (Alces alces) tooth pendant from burial 66 at Sakhtysh IIa (UBA-34991) did not provide results due to the poor preservation of collagen. The selection of samples was determined by the availability of animal remains, as well as the requests of the excavators. For example, the aim of the unsuccessful date UBA-34991 was to verify the old age obtained for another elk tooth pendant from the same burial (AAR-21042; see Piezonka et al. 2016). All dated samples were generally of good quality with proper collagen yield (1.0–10.3%) and acceptable C:N ratios (3.1–3.56), although three of the five bear teeth presented values slightly over the recommended limit of 3.5 (van Klinken, 1999; cf. DeNiro, 1985) (Tables 1–2).

Six datings were obtained from Sakhtysh II. Two bone beads were dated from a collective burial 12 of four individuals, equipped with some amber ornaments and hundreds of bone beads. These gave practically identical results, 4050–3811 cal BC (UBA-34097) and 4046–3811 cal BC (UBA-40193) (Fig. 4). However, the identification of the bones is only tentative. The dated thoracic vertebra of a badger (Meles meles) from hoard 11, associated with the "sanctuary" and containing flint, stone, bone, and antler fragments and artefacts, and ochre gave a result 3335–2931 cal BC (UBA-34096).

Two datings were obtained from burial 18, a young female buried with stone, bone and tooth adornments. An elk incisor pendant was dated to 3711–3536 cal BC (UBA-40191) and a pendant of brown bear (Ursus arctos) maxillary incisor to 3636–3378 cal BC (UBA-40192). The last dating from Sakhtysh II originates in hoard 9, interpreted to be a solitary deposition close to the "ritual platform 1" (Kostyleva and Utkin, 2010). This charcoal-rich feature included some sherds of Volosovo pottery, several flint and stone artefacts, as well as animal tooth pendants. One pendant of brown bear mandibular canine was dated to 3635–3376 cal BC (UBA-34992).

Three of the four new AMS datings from Sakhtysh IIa derive from bear tooth pendants. A third maxillary incisor in burial 76, a male with numerous animal tooth pendants, gave an age 3635–3373 cal BC (UBA-34099). A pendant of another third upper incisor from burial 19, a female with a few tooth pendants, was dated to 3766–3539 cal BC (UBA-34990). The third pendant, made of second lower incisor and found in burial 63 of an adolescent richly equipped with tooth, bone and stone pendants, was dated to 3649–3377 cal BC (UBA-34989). Finally, the fourth date comes from burial 24, a young female interred with at least 40 incisors of marmot (Marmota bobak) and other items of foreign origin, like serpentine pendants and rock crystal (Kostyleva et al. 2018). One lower marmot incisor was dated to 3642–3382 cal BC (UBA-34098) (Fig. 5).
The stable isotope values obtained for the dated specimens do not present big surprises (Fig. 6). The marmot (UBA-34098) from Sakhtysh IIa and the elk (UBA-40191) from Sakhtysh II have isotope values characteristic for terrestrial herbivores (Eriksson, 2006; Wood et al. 2013; Eriksson et al. 2018; Robson et al. 2019). The isotopic values obtained for the brown bear samples (UBA-34099, 34989, 34990, 34992, 40192) correspond to those of terrestrial omnivores and bears measured elsewhere (Eriksson, 2006; Eriksson et al. 2018; Robson et al. 2019). The elevated stable isotope values indicate trophic level increase due to consumption of terrestrial meat in addition to plant foods. Also the stable isotope values of the badger vertebra (UBA-34096) from Sakhtysh II correspond to those obtained for such animals in another places (Eriksson, 2006; Olsen et al. 2010).

The only remaining question pertains to the samples of bone beads (UBA-34097, 40193) whose isotopic values partially overlap with those of freshwater fish. The dated bones have not been possible to identify to taxon but they were found amidst over 450 small tubular beads, allegedly of bird bones, although their large amount and other properties suggest that a rather large fish could have been used as the raw material. To resolve this question, two beads were analysed with ZooMS in the University of York (England). Unfortunately, non-destructive extraction did not produce any results, and the dated beads also show the lowest collagen yields in the present material (1.0 and 1.9).

3.3 Pottery
Organic surface residues on four pottery sherds were dated. Two of these originate in Sakhtysh II and two in Sakhtysh IIa, all recovered in cultural layer without clear association to any particular feature. The vessels from Sakhtysh II represent, according to the definition by E.L. Kostyleva, Early Volosovo, and the sherds from Sakhtysh IIa – Late Volosovo (Fig. 7).

The dated sherds of Sakhtysh II originate from vessels that were found broken in situ. They are tempered with abundant crushed shell, have striated inner surfaces, and are decorated with wide rectangular two-rowed toothed stamps forming loose vertical zig-zags or nearly horizontal lines. A sample from the inner surface of a body sherd found in 1979 gave the result 4041–3952 cal BC (UBA-36690). The samples from the inner (UBA-36692) and outer (UBA-36691) surfaces of a sherd with a straight rim, discovered in 1987, gave results 4461–4340 cal BC and 3975–3800 cal BC, respectively.

The specimens dated from Sakhtysh IIa are two solitary organic-tempered pieces with straight, slightly outwards-thickening rims. The sample taken from the inner surface of a sherd found in 1988, decorated with loose vertical zig-zag lines of toothed stamp, was dated to 3712–3639 cal BC (UBA-36693). Crust on the inner side of a small shard, discovered in 1990 and decorated with dense horizontal lines of overlapping oval (bone?) impressions, gave the age 3943–3705 cal BC (UBA-36694).

All organic residues dated in this study have moderate or depleted $\delta^{13}C$ values, apart from the inner crust UBA-36692 with very depleted $\delta^{13}C$ value and undisputed freshwater origin; in a previous study, the range of terrestrial ingredients in the Sakhtysh area was placed between -24‰ and -28‰ $\delta^{13}C$ according to data from the surrounding areas (see Piezonka et al. 2016). All crusts have enriched $\delta^{15}N$ values mirroring a probable aquatic component,
with the exception of the inner crust UBA-36690 with a more moderate figure. In general, aquatic species are seen to present values >7.0‰, while terrestrial animals (herbivores) and plants are characteristically below this (Craig et al. 2007). Four samples have low or moderate C:N ratio and likely derive from high-protein ingredients (Philippsen, 2012), and only the outer-surface crust UBA-36691 with a high C:N ratio indicates a possible plant origin (but see below).

4 Discussion

4.1 The reliability of the dates
Carriers of the Volosovo culture were hunter-gatherers, whose subsistence was largely based on freshwater fishing, as evidenced by the material culture and osteological assemblages (Kraynov, 1987; Nikitin, 1991). An analysis of stable bulk isotope values of two individuals buried in Sakhtysh IIA proved the presence of aquatic component in Volosovo diet (Piezonka et al. 2013; see also Shishlina et al. 2016), and the consequent reservoir offset in the datings (Fischer and Heinemeyer, 2003; Philippsen, 2012). No proper local baseline exists so far, but three modern fish samples from the Sakhtysh area indicated only a moderate offset of ca. 270 years (Dolbunova et al. 2017). In the neighbouring regions, offsets of ca. 500 years have been observed (Wood et al. 2013; also Piezonka et al. 2013; Meadows et al. 2015).

The grass-eating marmot from Sakhtysh IIa (UBA-34098) should be free of FRE. This is the case also with the fully herbivorous elks from Sakhtysh II (UBA-40191) and Sakhtysh IIa (AAR-21042). However, the latter specimen produced an old age; the deceased exhumed from the same grave and with isotopic values indicating aquatic diet (AAR-15053), has been dated ca. 220 radiocarbon years younger. It is possible that the elk tooth pendant would have been curated for centuries before its deposition, although another explanation is that the pendant ended up in the grave from an earlier layer at the site.

The brown bear teeth from the two sites date largely coeval (UBA-34099, 34989, 34990, 34992, 40192), and their isotope values allow to suggest that the dates do not present large offsets. The remaining AMS-dated animal bones from Sakhtysh II are less-clear. The date of the vertebra of a badger (UBA-34096) may have some offset, as the diet of these omnivorous animals can include components from aquatic environment, like amphibians. Finally, the considerable age obtained for the bone beads (UBA-34097, 40193) can be tentatively accounted for FRE, as the isotopic values cannot exclude freshwater fish.

Previous research on carbonised residues adhered on Upper-Volga pottery from Sakhtysh IIA (Hartz et al. 2012; Piezonka et al. 2016; Dolbunova et al. 2017) identified aquatic components in the crusts. Nevertheless, FRE was not similarly visible in all residues and neither the isotope values correlated directly with the offset. The varying isotopic values and trophic levels of the different carbon and nitrogen sources, as well as the differing uses of the pots and the mixing of ingredients during several cooking episodes can be given as possible explanations (Wood et al. 2013; Heron and Craig, 2015; Meadows et al. 2015). Isotope fractionation during food preparation or post-depositional diagenesis may also affect the results (Philippsen, 2012; Heron and Craig, 2015; Royer et al. 2017).
The dates obtained from the outer and inner surfaces of the same sherd from Sakhtysh II have ca. 450 radiocarbon year difference. In previous studies, the outer crusts have been noted to consist of soot or mixtures of foods and soot, and thus potentially be subject to smaller offsets than the food-derived inner crusts on the same pots (Fischer and Heinemeyer, 2003; Philippson, 2012; Teetaert et al. 2017; Mäkkönen and Nordqvist, 2019). The depleted $\delta^{13}C$ and enriched $\delta^{15}N$ values of the inner crust UBA-36692 point towards aquatic origins. The high C:N ratio of the outer surface residue UBA-36691 could indicate low-protein ingredients, most likely plants, but combined with the enriched $\delta^{15}N$ and depleted $\delta^{13}C$, the presence of FRE cannot be excluded, as elevated C:N ratios can result from aquatic fats or oils as well (Heron et al. 2015).

In the case of other analysed crusts from Sakhtysh, the presence of aquatic component seems plausible (UBA-36693, 36694) or cannot be completely ruled out (UBA-36690). Even a previous study from Sakhtysh indicated only a moderate offset of some centuries (Dolbunova et al. 2017), here a possible offset of ca. 500 years is indicated by the two datings from the same pot. Until more detailed isotopic data on the prehistoric (or modern) flora and fauna in the area is acquired, an offset of 250–500 years can be assumed for samples of aquatic origin – this does not, however, exclude the presence of potentially much larger offsets in individual cases.

4.2 The chronology of the Sakhtysh II and IIa sites
The histories of the Sakhtysh II and IIa sites have been divided into two main use phases based on stratigraphic observations, typology, and conventional radiocarbon dates. At Sakhtysh II, the settlement site is seen to predate the ritual use, whereas at Sakhtysh IIa, the situation is the opposite (Kostyleva and Utkin, 2010). The results presented here contradict this earlier view on periodization and chronology.

At Sakhtysh II, the oldest ages come from a problematic series of conventional charcoal dates from the “sanctuary” (Le-1550, 1552, 1554, 1589, 5984, GIN-9134): covering a wide time period, many have been considered unreliable on archaeological grounds (see Table 1; Fig. 8). Also the possibly FRE-influenced dating from hoard 11, directly linked with the “sanctuary”, dates much younger. Neither the other datings support the idea of a singular settlement phase followed by distinct ritual use. The next oldest ages come from the FRE-influenced AMS datings of foodcrusts (from cultural layer) and beads from burial 12 – applying the low-resolution correction of 500 years makes them still older than or overlapping with the charcoal dates for the settlement structures (Le-1892, 1893, 1900; also Le-3084, 3091). These settlement dates are also younger than the AMS dates for hoard 9 and burial 18, which clearly predate the conventional dates obtained for burial 18 and the adjoining “ritual area 1” (Le-2613, 2615, 2617; GIN-5239), too.

Similarly, the AMS datings from Sakhtysh IIa alter the previous internal chronology of the burial ground (see Table 2; Fig. 9). The Volosovo burials excavated at the site have been divided into early (burial rows A, Б, Е) and late (rows В, Г, Д, Ж) groups according to typology and the series of conventional $^{14}C$ datings (Kostyleva and Utkin, 2010). All AMS datings derive from burials connected with the latter group (see Fig. 3), but are older than or contemporaneous with the dated burials belonging to the early group (GIN-6234, 6237, 7187, 7190, 7276, 7490). In other words, the AMS data indicates potential discrepancies in
the typological division, as well as in the previous rejection of dates on archaeological grounds (also Piezonka et al. 2013). Charcoal dates from the “sanctuary” or “ritual pit” (GIN-6555, 6556, 6787) overlap with most of these datings, as does the only charcoal sample from cultural layer (GIN-5892).

The quality-related issues are actual especially in Sakhtysh IIa, where more than half of the conventional dates have a measurement error larger than 100 and even as much as 350 years. Many uncertainties are connected also with the contexts of the conventionally dated samples (also Chernykh et al. 2011) and reduce their usability in the construction of site chronology: for example, samples from overlaying burials 32a and 32b gave the second-youngest (GIN-7271) and the oldest (GIN-7274) age of the original Sakhtysh IIa series, also contradicting their mutual stratigraphic position. At Sakhtysh II, the quality-issues may be indicated by the wide total calibrated age ranges for the datings connected with particular ritual and settlement activities (ca. a millennium each).

In general, the AMS datings tend to date older than the conventional ones – the deviations are commonly 500–1000 years (also Piezonka et al. 2013). This cannot be the result of FRE only (cf. Kostyleva and Utkin, 2014). Many AMS datings have been obtained from terrestrial species or from humans belonging to the same population (and, assumedly, with the same diet) of which the conventional bone datings were obtained. Therefore the difference must be explained mostly by the development of dating techniques and better preparation and cleaning of samples of contaminating (younger) components, as well as better control of the dated samples and their contexts (also Piezonka et al. 2013; 2016). A clear example of this is burial 18 at Sakhtysh II where the conventional date of human bone is ca. 650 and 790 radiocarbon years younger than the AMS dates of elk and bear teeth.

The AMS dates do not support the previously proposed phasing of the Sakhtysh burials to early (4750–4375 BP / 3600–3000 cal BC), late (or developed; 4375–4000 BP / 3000–2500 cal BC), and final (4000–3750 BP / 2500–2200 cal BC): the early and late burials at Sakhtysh IIa do not stand out as two separate groups, and also the burials and hoards from Sakhtysh II, connected to the final phase, are temporally overlapping with these. Neither the use sequence, where the settlement and burial phases are non-overlapping and also complementary between the sites (Kostyleva and Utkin, 2010, 2014), finds support in the present material.

The datings obtained for pottery correspond with the typological sequence given to them in general, as pottery from Sakhtysh II (Early Volosovo) dates older than pottery from Sakhtysh IIa (Late Volosovo). Still, the temporal difference between the early and late phase does not seem to be as large or exclusive as proposed earlier.

The AMS datings indicate that the Volosovo people started to bury their dead at Sakhtysh IIa after 3700 cal BC; dates earlier than this may be affected by FRE or suffer from mixed contexts and poor quality of dates. The present data questions the interpretation that the Sakhtysh IIa cemetery was used without interruptions between 4800 and 4080 BP (Kostyleva and Utkin, 2010), i.e. for a millennium between 3550 and 2600 cal BC. The AMS dates rather suggest a use period of some centuries only around the mid-4th millennium cal
At Sakhtysh II, burial activities or making the hoards starts maybe a bit after 3600 cal BC, and similarly, there is no support for the clear hiatus proposed between the settlement and ritual use of the site (cf. Kraynov et al. 1991; also Kostyleva and Utkin, 2014). Purely in the light of the AMS datings, the use periods of the both sites shorten markedly. Even acknowledging the potential FRE up to 500 years in some samples, there is little evidence of Volosovo presence at Sakhtysh II and IIa during the 3rd millennium cal BC. If this is the result of small number of AMS datings and limited sampling focusing mainly on burial contexts remains to be seen.

4.3 Sakhtysh and the general Volosovo chronology

The absolute dating of Volosovo culture was for a long time hampered by the small number of radiocarbon dates (see Kraynov, 1987). Today, more than 100 datings connected with it can be found in literature (Korolev and Shalapinin, 2010; Chernykh et al. 2011; Nikitin, 2012; Mosin et al. 2014). Unfortunately, the available dates do not form solid grounds for dating the cultural phenomenon, as many of them have quality-related issues, large measurement errors, and ambiguous cultural or physical contexts. Consequently, particular datings may be connected to different cultural phases by different scholars. Finally, a large part of the newly-published datings are obtained through direct dating of potsherds (Kovaliukh and Skripkin, 2007; Zaitseva et al. 2009), and therefore, their cogency must be faced with reservation (see van der Plicht et al. 2016; Dolbunova et al. 2017).

The datings connected with Volosovo cover a wide time range between ca. 5500 BP (4400 cal BC) and ca. 3700 BP (2100 cal BC). However, datings from secure contexts, with good quality (error ca. 50 years or below) and no probable FRE, place the beginning of Volosovo culture to the first half of the 4th millennium cal BC, around 3700–3600 cal BC. This is also supported by the roughly coeval terminal dates given for the preceding Lyalovo (Zaretskaya and Kostyleva, 2011) and Volga-Kama cultures (Lychagina, 2018), as well as the appearance of related neighbouring cultures, for example, in the Kama region (Nikitin, 2012; Lychagina, 2018), the southern forest steppe area (Korolev and Shalapinin, 2014), and north-western Russia and Finland (Nordqvist, 2018). Still, the dating of many of these cultural phases suffers from the same problems as of Volosovo.

A handful of contested datings place the end of Volosovo culture to the final centuries of the 3rd millennium cal BC, or even later (Kostyleva and Utkin, 2010; Chernykh et al. 2011; Nikitin, 2012). On the other hand, the new AMS dates indicate that Volosovo activities at Sakhtysh II and IIa ceased before or towards the early 3rd millennium cal BC; if this reflects the general decline of Volosovo culture must be still confirmed by more dates from Sakhtysh and elsewhere. In this context, the general cultural development must be accounted for. To what extent – if at all – the Volosovo people were present after the arrival of the Corded Ware culture-related Fatyanovo-Balanovo populations? Based on the current, albeit scant and inconclusive radiocarbon data this took place from ca. 2700 cal BC onwards (Krenke et al. 2013).

5 Conclusions
The 15 new AMS and stable isotope measurements from Volosovo contexts at the sites Sakhtysh II and Ila presented in this study include measurements from animal bones and teeth, as well as the first published AMS-dated charred organic residues from Volosovo pottery. The new data is not entirely compatible with the earlier periodization of the sites – this may be partially related to FRE, but even more to the problems in previous datings and typological sequences.

Differences between the AMS and conventional datings from the Sakhtysh sites are often between 500 and 1000 years. The new data does not support the internal cultural division or the long use-periods proposed earlier for the sites. Based on the current AMS datings, the working of the Sakhtysh Ila cemetery can be placed tentatively to 3650–3400 cal BC, and the use of Sakhtysh II site between ca. 3600 and the beginning of 3rd millennium cal BC.

The existing AMS data largely derives from burials and hoards only, which may distort the view on the chronology of the sites. Some bone and crust dates presented here are most likely affected by FRE, but at the moment, only a rough estimation of 250–500 years offset can be applied.

More good-quality datings from controlled contexts are needed in order to build a valid internal chronology for the Volosovo culture at the Sakhtysh sites. Local chronologies must be developed also elsewhere and the correspondence between typology and absolute time resolved. Solid chronological framework will facilitate further understanding of this eminent cultural phenomenon, as well as its interaction with the preceding and subsequent cultural phases, in the different parts of its wide territory.

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Fig. 1. The core area of Volosovo culture (after Kraynov, 1987) and the sites of the Sakhtysh complex (after Kostyleva and Utkin, 2010). Eurasian map base made with Natural Earth. Illustration: K. Nordqvist.
Fig. 2. Structures and dated contexts from Sakhtysh II (after Kostyleva and Utkin, 2010). Illustration: K. Nordqvist.
Fig. 3. Structures and dated contexts from Sakhtysh Ila (after Kostyleva and Utkin, 2010). Illustration: K. Nordqvist.
Fig. 4. AMS datings from the sites Sakhtysh II and IIa. Sampled contexts are given in parentheses (burial / hoard), “crust” indicates samples of charred organic residues on pottery from cultural layer. For data, see Tables 1–2.
Fig. 5. Marmot (*Marmota bobak*) incisors from burial 24 at Sakhtysh IIa. Marmots are not local to the Sakhtysh region, and represent import from the forest steppe or steppe areas to the south or south-east. Scale 5 cm. Illustration: A. Macâne.
Fig. 6. The stable isotope values ($\delta^{13}C$, $\delta^{15}N$) of the AMS-dated organic residues (up) and bone samples (below) from the Sakhtysh II and Sakhtysh IIa sites. The humans and one elk after Piezonka et al. (2013, 2016). Reference data for terrestrial herbivores and carnivores and freshwater fauna after Wood et al. (2013); Piezonka et al. (2016); and for bears after Eriksson (2006); Eriksson et al. (2018).
Fig. 7. The dated pottery shards from the sites Sakhtysh II and IIa. Scale 5 cm. Illustration: K. Nordqvist.
Fig. 8. Calibration figure of datings from Volosovo contexts at the Sakhtysh II site illustrates the contradiction between the AMS dates and the previously proposed use sequence for the site (first settlement, then ritual area). Samples connected with settlement contexts marked *, ritual contexts **. Charcoal samples indicated with ©, other samples are of bone and tooth, crust dates excluded. AMS datings given in black, conventional ones in grey. Dates from the same contexts are connected with a bracket. For data, see Table 1.
Fig. 9. Datings of Volosovo burials at Sakhtysh Ila present also the incompatibility of AMS-based chronology and the previous typo-chronological division. Typological classification after Kostyleva and Utkin (2010): * early burial, ** late burial. AMS datings given in black, conventional ones in grey. Dates from the same contexts are connected with a bracket. Charcoal datings (©) from the “sanctuary” are given for comparison, all other samples are of bone and tooth, crust dates excluded. For data, see Table 2.