Radiocarbon, Vol 57, Nr 4, 2015, p 595–610 DOI: 10.2458/azu_rc.57.18435

PALEODIET, RADIOCARBON CHRONOLOGY, AND THE POSSIBILITY OF FRESHWATER RESERVOIR EFFECT FOR PREOBRAZHENKA 6 BURIAL GROUND, WESTERN SIBERIA: PRELIMINARY RESULTS

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ABSTRACT. This article presents the results of radiocarbon dating and a chronology of the Preobrazhenka 6 site of the Odino culture (Baraba forest steppe, western Siberia). Currently available ^{14}C data for the necropolis do not allow accurate determination of the presence or absence of reservoir effects, and as such, further research is needed. Accelerator mass spectrometry (AMS) ^{14}C dating of paired samples of terrestrial faunal and fish remains from a Neolithic pit suggest the absence of a reservoir effect in fish bone collagen. Middle Bronze Age burials have therefore been estimated to date to the 23rd–20th centuries cal BC. Pits with fish remains are dated earlier than burials, to the 63rd–61st centuries cal BC. Stable isotope measurements of human bone collagen (high $\delta^{15}N$ and low $\delta^{13}C$ values) indicate diets based on C_3 plants and fish. Apparently, the role of animal protein in the diet was not significant. Dental paleopathology analysis has confirmed the important role of wild plants in human diet. Neolithic fish bones are elevated in $\delta^{13}C$ [–13.5‰, average mean (n = 4)]. They are significantly different from the associated values of fish from the Late Bronze Age settlement of Chicha 1 [–22.5‰, average mean (n = 10)], which is also located in the Baraba forest steppe. The difference in $\delta^{13}C$ values in fish bones may be determined by the origin of the samples, being derived either from lakes or rivers.

INTRODUCTION

Presently, reliable chronological frameworks, based on radiocarbon dating, are only available for a limited number of Siberian regions, including Cis-Baikal, Upper Angara River Valley (Weber et al. 2006), and Minusinsk Basin (Görsdorf et al. 2001; Svyatko et al. 2009). Research for south of western Siberia has been conducted on the materials from the Upper Ob River Valley and Altai (Kiryushin et al. 2009) and Baraba forest steppe (Schneeweiss 2007; Molodin et al. 2012b). A comparison of ^{14}C chronologies has also been recently carried out for Siberian and Ural Bronze Age cultures (Molodin et al. 2014). So far, only a few western Siberian cultures have been securely ^{14}C dated, namely the Irmen (Schneeweiss 2007) and Andronovo (Matveev 1998; Molodin et al. 2012b) cultures. It is therefore highly important to ^{14}C date the pre-Andronovo sites, as existing dates are largely isolated and inconsistent. Moreover, it is crucial to assess the presence of the freshwater reservoir effect in various regions of Eurasia, as this will allow correction of ^{14}C age determinations for ancient archaeological complexes.

Biochemical methods of paleodietary research represent a common aspect of modern archaeology. They are essential when there is no or little archaeological evidence for the subsistence strategies of humans and fauna. For example, there are a large number of lakes and rivers in the territory of the Baraba forest steppe, but, within archaeological sites, fish bones and fishing tools are found extremely rarely. That is why alternative methods for dietary assessment are extremely significant for correct modeling of the subsistence of the ancient population. Paleozoological determinations, the analysis of artifacts, associated plant remains (traces of cultivated grains on ceramic and wheat pollen in cultural layer), and charred residues on ceramic vessels are usually used to study ancient food and economy (e.g. Matveev and Anoshko 2009). Paleodietary research based on the analysis of carbon and nitrogen stable isotopes has been performed on the materials from Cis-Baikal (e.g. Katzenberg and Weber 1999; Katzenberg et al. 2009), Altai Mountains (O'Connell et al. 2003), and the

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Proceedings of *Radiocarbon and Diet: Aquatic Food Resources and Reservoir Effects*
First International Conference, 24–26 September 2014, Kiel, Germany
Edited by Ricardo Fernandes, John Meadows, and Alexander Dreves

southern part of the Baraba forest steppe (Privat et al. 2005). Complex studies of diet based on isotopic methods and dental paleopathology have been conducted on materials from the Minusinsk Basin (Svyatko et al. 2013; Svyatko 2014) and northern Kazakhstan (Ventresca Miller et al. 2014a,b). The present article reports the first results of ^{14}C and isotopic and dental paleopathology analyses of the Preobrazhenka 6 site. To date, this research represents the first complex paleodietary study of the Middle Bronze Age populations of Western Siberia.

STUDY SITE

The Preobrazhenka 6 site (55°30.1′N, 77°00.9′E) is located in the southwestern part of the Siberian Lowland (Ob-Irtysh Basin, central Baraba forest steppe; Figure 1). At present, the Baraba forest steppe contains bogs and a large number of salt and freshwater lakes. Because of its geomorphologic characteristics, almost all rivers in the region originate from the Vasyugan swamps and run from the northeast to the southwest. The Om, Tartas, Kargat, and Chulym are the main rivers. The Preobrazhenka 6 cemetery is located on the edge of the first terrace above the floodplain on the right bank of the Om River. The necropolis was repeatedly ploughed in the 20th century. Geophysical monitoring was undertaken to find buried landscape features. From 2003 to 2009, an area of 33,720 m^2 was examined using different geophysical methods; subsequently, a magnetogram was elaborated, which allowed the discovery of the cemetery (Epov and Chemyakina 2009). Within the site, the Neolithic settlement; burial complexes of the Early Bronze Age, Early Iron Age, and the Medieval period; and also a considerable part of the Middle Bronze Age necropolis were studied in 2004–2010 (e.g. Molodin et al. 2004, 2007).

Figure 1 Location of the analyzed sites and regions: A - Caspian steppe; B - Baraba Forest steppe; C - Kulunda steppe; D - Altai Mountains; E - Minusinsk Basin; 1 - Preobrazhenka 6; 2 - Chicha 1; 3 - Lisakovsk; 4 - Bestamak; 5 - Ust'-Ida; 6 - Obkhoi; 7 - Borki; 8 - Khuzhir.

The Middle Bronze Age cemetery complex of the Preobrazhenka 6 site comprises 63 burials of the Odino culture (Figure 2), which represents one of the local community of cultures with “comb-pits” pottery (Molodin 2012). The individuals were buried in shallow oval pits, stretched on their back. Sometimes, there are traces of fire in the graves (skeletal remains show an evidence of burning). A sharp object (such as a bone or bronze awl) placed into individuals' hands is a characteristic feature of the cemetery. The majority of the adult burials have been disturbed in antiquity: the position of a number of bones (including faunal) and tools have been changed. However, even undisturbed graves contain few or no artifacts. Most of the finds in the fill and at the base of the burials are stone objects (flakes, scrapers) and ceramic fragments. A bronze earring, pottery (Figure 3, items 8 and 9), and items related to bronze metallurgy, horn combs, and a fragment of a tool in the form of a bird head (Figure 3, item 3) are unique finds. Bird and animal (horse, cow, sheep, and dog) bones have been found mostly in the grave fills. Male burial 24 (Figure 3, item 1; Table 1) clearly stands out, as it contains a bronze spearhead and bone and stone arrowheads (Figure 3, items 2 and 4–7). The spearhead belongs to the Seyma-Turbino type of the Middle (according to the regional western Siberian periodization; e.g. Matyushchenko 1973; Kosarev 1981) or Late Bronze Age (according to the eastern European periodization; Chernykh 1992). Traditionally, Seyma-Turbino items are dated to the second half of the 2nd millennium BC (Chernykh 1970).

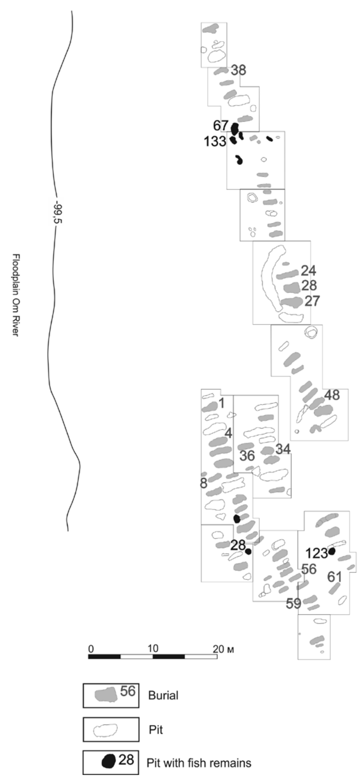

Figure 2 Plan of the burial ground Preobrazhenka 6

Because the burials have been disturbed, it is not possible to securely correlate finds with either the burials or earlier cultural layers. The only case of animal bones being found at the base of the grave is in burial 56 (Table 1). The single case of ^{14}C dating of osteological remains from the burial fill (UBA-27426; Table 1) indicates an earlier (Late Neolithic) period of the bone. But the grave undoubtedly relates to the Middle Bronze Age, and it was found that the bone derived from the earlier cultural layer.

Table 1 Results of radiocarbon dating and stable isotope analysis of human, animal and fish bones from Preobrazhenka 6 (MBA – Middle Bronze Age; NP – Neolithic period; Ad. – Adultus; Mat.- Maturus; *tooth dated, **scale dated, in other cases bone dated).

Burial (B), Pit (P) nr	Period	Species	Sex/Age	Lab ID	^{14}C date (BP)	Calibrated age range (2σ), BC	δ^{13}C (‰)	δ^{15}N (‰)	C/N$_{at.}$	% collagen
B1	MBA	Human	♂/30–35	SOAN-7234	3765 ± 65	2460 (5.6%) 2360 2350 (88.7%) 2010 2000 (1.1%) 1970	—	—	—	—
B4	MBA	Human	♂/40–50	Bln-5842L	3727 ± 34	2280 (4.5%) 2250 2210 (66.1%) 2110 2100 (24.8%) 2030	–22.7	—	—	—
B8	MBA	Human	♂/30–35	SOAN-7232	3710 ± 85	2450 (95.4%) 1850	—	—	—	—
B24	MBA	Human	♂/30–35	UBA-25804	3797 ± 29	2340 (1.8%) 2320 2310 (93.6%) 2130	–20.7	13.7	3.2	2.2
B24	MBA	Human	♂/30–35	NSKA-IV-8-3	—	—	–20.7	14.2	2.9	9.8
B27	MBA	Human	♂/35–40	NSKA-IV-8-2	—	—	–20.6	13.5	3.0	9.5
B28	MBA	Human	♂/Ad.	NSKA-IV-8-4	—	—	–20.1	14.0	3.0	8.6
B28	MBA	Human	♂/Ad.	UBA-27423	3793 ± 38	2410 (1.4%) 2380 2350 (90.9%) 2120 2090 (3.1%) 2040	–20.2	13.1	3.2	5.1
B34	MBA	Human	♂?/16–18	SOAN-7235	3800 ± 85	2480 (95.4%) 2010	—	—	—	—
B36	MBA	Human	♂/40–45	SOAN-7233	3690 ± 85	2400 (95.4%) 1750	—	—	—	—
B36	MBA	Human	♂/40–45	NSKA-IV-6-3	—	—	–22.2	13.3	2.9	4.3
B38	NP	Horse (*Equus*)*		UBA-27426	5157 ± 42	4050 (76.0%) 3910 3880 (19.4%) 3800	–19.7	5.1	3.3	3.0
B38	NP	Horse (*Equus*)*		NSKA-IV-10-1	—	—	–20.7	5.9	3.0	9.1
B48	MBA	Human	♂/Mat.	SOAN-8700	3800 ± 100	2550 (95.4%) 1950	—	—	—	—
B48	MBA	Human	♂/Mat.	NSKA-IV-6-4	—	—	–20.9	13.9	2.8	4.7
B56	MBA	*Ovis/Capra*		UBA-25085	3698 ± 29	2200 (7.4%) 2160 2150 (85.5%) 2010 2000 (2.6%) 1970	–19.3	6.9	3.2	6.7
B59	MBA	Charcoal		SOAN-8008	3680 ± 65	2280 (2.2%) 2250 2210 (93.2%) 1890	—	—	—	—
B59	MBA	Human	♂/25–30	NSKA-IV-6-5	—		–21.5	13.4	2.9	5.1
B61	MBA	Charcoal		SOAN-8010	3605 ± 80	2200 (2.5%) 2160 2150 (92.9%) 1740	—	—	—	—
B61	MBA	Human	♂/45–50	NSKA-IV-8-1	—	—	–20.8	14.8	3.2	9.6
P28	NP	Horse (*Equus*)		NSKA-IV-10-3	—	—	–20.4	7.7	3.0	8.4
P28	NP	Elk (*Alces alces*)		NSKA-IV-10-4	—	—	–20.2	5.5	3.0	8.9
P28	NP	Bear (*Ursus arctos*)		NSKA-IV-10-5	—	—	–18.5	9.3	2.9	6.4
P67	NP	Perch (*Perca fluviatilis*)**		NSKA-IV-14-1	—	—	–12.6	8.1	2.8	4.4
P123	NP	Pike (*Esox lucius*)		NSKA-IV-14-2	—	—	–13.4	9.7	3.0	5
P133	NP	Crusian (*Carassius carassius*)		NSKA-IV-14-3	—	—	–14.3	8.3	3.0	5.2
P133	NP	Crusian (*Carassius carassius*)		UBA-25086	7252 ± 37	6220 (95.4%) 6030	–15.2	6.8	3.3	1.4
P133	NP	Dog (*Canis*)		NSKA-IV-10-2	—	—	–17.5	11.0	3.1	5.2
P133	NP	Horse (*Equus*)		UBA-27425	7214 ± 63	6220 (95.4%) 5990	–20.2	5.4	3.2	5.5

Besides burials, 55 pits in the cemetery have been studied. These belong to the Odino complex; their shape and size vary. The majority of pits are similar to the burials in size and are located in the same rows (Figure 2). Unlike the graves, the pits have homogeneous humus fills, which may reflect their natural filling over a long period of time. Cattle, horse, and sheep bones have been found in the pit fills, as in the graves. Furthermore, nine pits of the Neolithic period have been discovered. They do not fit the alignment of the Odino burial rows and in two cases are overlain by them. In the fill of these pits, fish bones and scales, and stone and bone tools, which can be used in scaling (for example, a horn knife with inlaid stone blade) have been found. Poor-quality undecorated pottery, flakes, scrapers, and horse, dog, bear, and elk bones have also been discovered in these pits. One of the pits contained the upper jaw of an Early Holocene *Megaloceros giganteus* (van der Plicht et al. 2015).

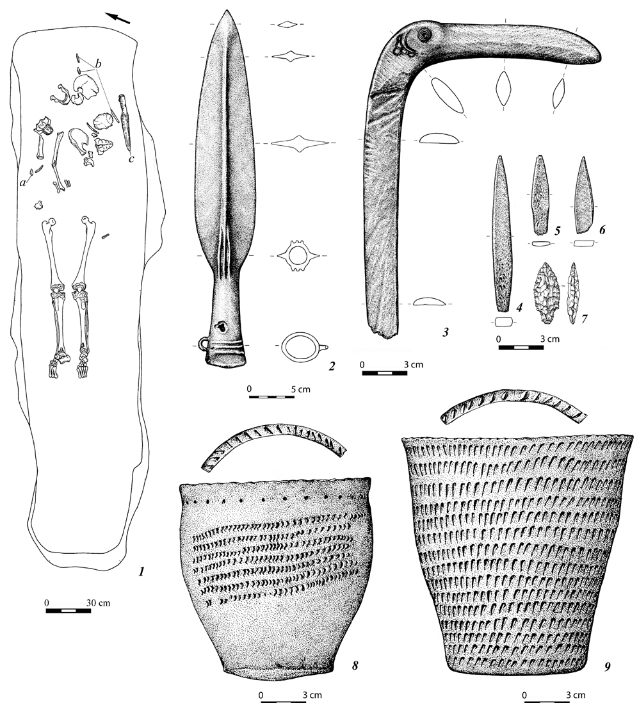

Figure 3 Artifacts from the Preobrazhenka 6 graveyard: 1. Plan of grave 24 (a – stone arrowhead, b – bone arrowheads, c – bronze spearhead); 2 – bronze spearhead (burial 24); 3 – horn pommel in the shape of a bird's head (burial 37); 4–6 – bone arrowheads (burial 24); 7 – stone arrowhead (burial 24); 8, 9 – ceramic vessels (burials 49, 42).

MATERIALS AND METHODS

Paleodietary reconstruction using stable isotope analysis has been widely used for the past several decades, and the main principles of the technique are well described in modern literature (e.g. Lee-Thorp et al. 1989; Ambrose 1991; Ambrose and Norr 1993). Briefly, the analysis of nitrogen stable isotopes indicates the position of an individual within the foodchain, with values increasing by 3–5‰ for each trophic level (Hedges and Reynard 2007; O'Connell et al. 2012). Carbon isotopes primarily distinguish the proportions of the so-called C_3 and C_4 plants in an individual's diet (Pate 1994), and indicate the consumption of marine organisms (Schoeninger and DeNiro 1984).

For reconstructing the diet of the Preobrazhenka 6 population, eight human (adult male) and three animal (including two teeth) individuals have been sampled from burials, and four fish and five animal individuals have been sampled from pits. The analyzed material is collagen. For comparative analysis of diet, data from a number of Eurasian steppe regions have been taken as well (Katzenberg and Weber 1999; Privat et al. 2005; Shishlina et al. 2012; Svyatko et al. 2013; Ventresca Miller et al. 2014a).

For ^{14}C dating, 12 samples from graves (including two herbivorous animal bones and two charcoals) and two samples from pits (horse and fish bones) have been used. Seven ^{14}C measurements were obtained at the Institute of Geology and Mineralogy of the Siberian Branch of the Russian Academy of Sciences (Novosibirsk; lab code SOAN) using liquid scintillation counting (LSC). Other ^{14}C and stable isotope measurements were made in the 14CHRONO Centre for Climate, the Environment and Chronology, Queen's University Belfast (n = 6, lab code UBA), using accelerator mass spectrometry (AMS), and at the German Archaeological Institute (n = 1, lab code Bln), using LSC. Calibration was performed using OxCal v 4.2.4 software (Bronk Ramsey 1995, 2001) and the IntCal13 curve (Reimer et al. 2013).

The majority of stable isotope ratio measurements (n = 15) were made in the Centre of Cenozoic Geochronology, Siberian Branch of the Russian Academy of Sciences (Novosibirsk, NSKA), using the isotope ratio mass spectrometer DELTA V Advantage (Thermo Finnigan) coupled with a Flash EA 2000 HT elemental analyzer. The routine acid-base-acid (ABA) procedure for collagen extraction, following Brock et al. (2010), included gelatinization (75°C, pH = 3, 20 hr) and filtration without ultrafiltration. Two samples (NSKA-IV-6-4, NSKA-IV-14-1) have a C/N ratio below normal (Table 1) (van Klinken 1999). Each sample was measured in duplicate with an analytical error of ±0.2‰ for δ^{13}C and ±0.3‰ for δ^{15}N.

Despite the disturbance of the upper parts of the bodies, and absence of craniums in the graves in many cases, it was possible to collect representative samples for dental analysis. These includes 20 adult individuals: 6 female (30%) and 14 male (70%). Grades of enamel wear were defined using Smith's (1984) scale, and the following pathological changes were recorded: caries, enamel hypoplasia, periodontal diseases, dental calculus, and antemortem damages of teeth. This allows reconstruction of the population's diet and general quality of food supply to be made. A combination of high frequencies of calculus, periodontal diseases, and caries is typical for populations with high contents of carbohydrates in their diet (e.g. Lukacs 1989; Roberts and Manchester 2005; Keenleyside 2008; Svyatko 2014). Usually, in those groups where protein food prevails, only calculus and periodontal disease are observed (e.g. Ventresca Miller et al. 2014b). The frequency of tooth enamel hypoplasia, which indicates stresses caused by continuous starvation, was recorded to diagnose the adequacy of the population's food supply (Afanaseva 2011).

Only adult individuals younger than 50 years of age have been examined to avoid age factor influences on the results. Children were excluded from the analysis because their diet can be different from that of the adult population. For comparative analysis, dental pathology data for Bronze Age populations in the Minusinsk Basin (Okunevo and Afanasievo cultures), Altai Mountains (Afanasievo culture), Kazakhstan, Kulunda steppe, and Baraba forest steppe (Andronovo cultural-historical community) was used (unpublished data and Svyatko 2014; Ventresca Miller et al. 2014b).

RESULTS AND DISCUSSION

Radiocarbon Chronology and Freshwater Reservoir Effect

The ^{14}C dates from human bones are quite consistent (Table 1, Figure 4). The majority of the 2σ calibrated dates fall in the 25th–19th centuries cal BC. The large age intervals for a number of dates are the result of large ^{14}C standard deviations (65–100 yr). Dates SOAN-8008 and SOAN-8010 from charcoal and UBA-25805 from *Ovis/Capra* bone are younger, falling in the 23rd–18th centuries BC, possibly because of a minor reservoir effect in the human bones. Stable isotope values for human samples from Preobrazhenka 6 (see below) indicate an important role of fish in people's diet, which may have caused the effect.

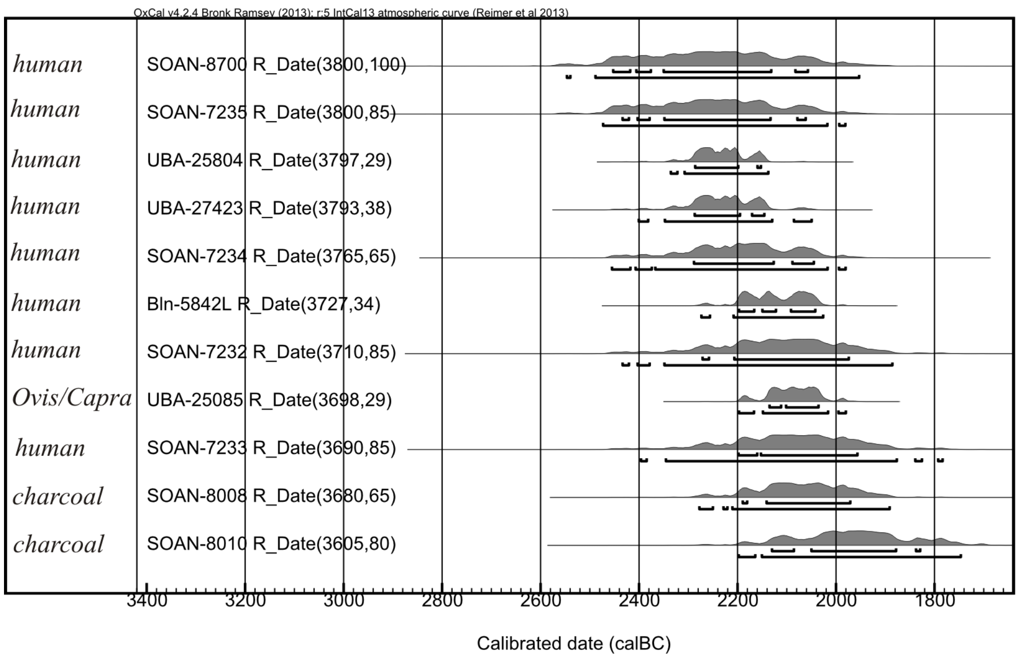

Figure 4 Calibrated ^{14}C dates of the Middle Bronze Age necropolis of Preobrazhenka 6

A comparison of ^{14}C ages with small standard deviations from human (UBA-25804 and -27423) and herbivorous animal samples (UBA-25805) shows a difference of about 100 ^{14}C yr. To ensure that the differences between the ^{14}C dates from the human and terrestrial herbivore samples are statistically significant, we used a χ^2 test, implemented in the *R_Combine* function of the OxCal program (Bronk Ramsey 1995, 1998). First, we applied the test to all dates belonging to the 3rd millennium BC (SOAN-7232–7235, -8008, and -8010; Bln-5842L; UBA-25804, -27423, and -25085). The results indicate that the differences are statistically not significant ($T < 18.3$; 5%, $df = 10$; Figure 5a). We have also applied the χ^2 test to the dates from human bone (UBA-25084 and -27423) and the herbivore (UBA-25085) with a small mean square error (Figure 5b), which indicated a significant difference between the two samples ($T > 6.0$; 5%; $df = 2$). This difference can be explained by the influence of a reservoir effect on human bones. The recent samples come from three burials; therefore, the last ^{14}C dates may reflect a really slight difference in age associated with the duration of burial ground.

Therefore, at present we cannot confirm the existence of the reservoir effect in the graveyard materials. The Middle Bronze Age cemetery is likely to date to the 23rd–20th centuries BC because all calibrated (2σ) ^{14}C dates are fully or partly within this period, including the date from an *Ovis/Capra* (UBA-25085), which is not susceptible to reservoir effect and has a small standard deviation.

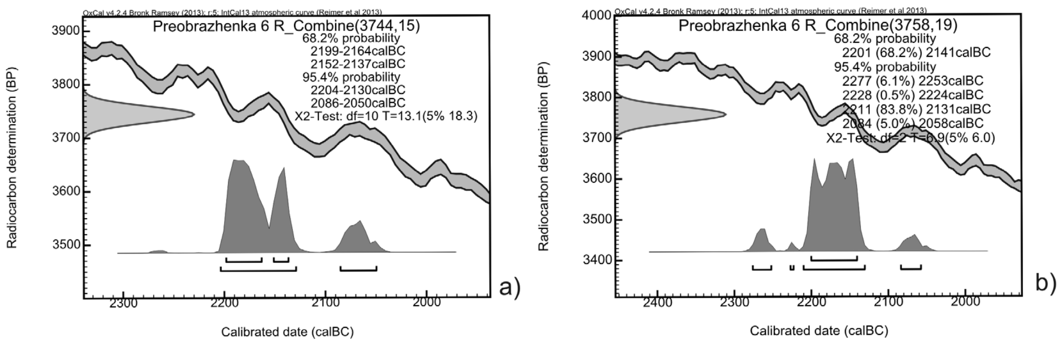

Figure 5 χ^2 test applied to (a) all dates of Middle Bronze Age (*n* = 11) and (b) dates with small standard deviation (*n* = 3)

Dates from fish and horse bones from pit 133 suggest that this pit belongs to the Neolithic period, specifically, the 63rd–61st centuries cal BC (Table 1, Figure 2). This contradicts the assumptions of the excavators who suggest that the pit belongs to the cemetery and has a ritual purpose (Molodin et al. 2012a). We can now suggest that, within the necropolis, the pits with fish remains date to the Neolithic period. This hypothesis is also supported by other findings in the pits, including wild fauna bones, Neolithic and Early Paleometal Age ceramic fragments, and the absence of metal objects. ^{14}C dating of two samples from the pit 133 (fish and horse; Table 1) indicates that they both belong to the same period, i.e. Neolithic, and that the fish bones are not affected by a significant reservoir effect.

Paleodiet and Stable Isotope Analysis

With the exception of one Middle Bronze Age sample (ovicaprid), the analyzed fauna mostly belong to the Neolithic period and include wild species such as elk, bear, and horse. There is no direct evidence for horse domestication for this period in western Siberia, but wild horse was a common object of hunting for steppe populations in the Neolithic period. Probably only the dog was domesticated. The average isotopic values for the Neolithic terrestrial herbivore samples (horses and elk) are $\delta^{13}C = -20.2‰$ and $\delta^{15}N = 5.9‰$ (Table 1, Figure 6). These data correspond to the isotopic measurements of herbivorous animals from the Chicha 1 site in the Baraba forest steppe in the Late Bronze Age (Privat et al. 2005) and several sites of the Minusinsk Basin (Svyatko et al. 2013). Carbon isotopic values indicate consumption of mostly C_3 plants (Pate 1994). Omnivorous animals, such as bears, usually occupy a higher position in the foodchain. The one trophic level (3.4‰) increase in nitrogen values seen in the bear sample, relative to the mean $\delta^{15}N$ of herbivores, suggests that the bear's diet largely included meat of these herbivores. A trophic level increase (1.7–1.9‰) is also observed in the carbon value of the bear. The highest nitrogen (11‰) and carbon (–17.5‰) values are observed in the canine sample (Table 1, Figure 6). The difference in isotopic values between herbivores and the dog analyzed (5.1‰ in $\delta^{15}N$ and 2.7‰ in $\delta^{13}C$) is larger than the commonly observed one trophic level increase (3–5‰ with each step of a foodchain; e.g. Hedges and Reynard 2007), and suggests that the diet of the dog also included fish. Research in the continental regions of Eurasia shows that the highest $\delta^{15}N$ value is characteristic for marine mammals and fish (Katzenberg and Weber 1999; O'Connell et al. 2003; Shishlina et al. 2009). Probably, the dog shared the fish component of its diet with humans, or was fed by waste containing fish and animal protein in the Neolithic site of Preobrazhenka 6.

The comparison of isotopic data of the Neolithic (horse, elk) and Bronze Age (*Ovis/Capra*) herbivores shows that *Ovis/Capra* $\delta^{13}C$ and $\delta^{15}N$ values are slightly higher (Table 1, Figure 6). This may either be evidence of aridity in the Baraba forest steppe during the Bronze Age (Heaton et al. 1986), or indicate that this animal fed on plants different from those of the Baraba forest steppe. For example, for the Bronze Age of the Caspian region, Shishlina (2014) assumed that sheep grazed on variable pastures. We can also suppose that this particular *Ovis/Capra* might have had a different origin. This animal could have been an exchange product with southeast neighbors, for example, with the contemporary Elunino culture from the Upper Ob River valley. Ovicaprid bones were found in 13 of 36 burials of the Elunino Teleutskiy Vzvoz I cemetery (Kiryushin et al. 2003).

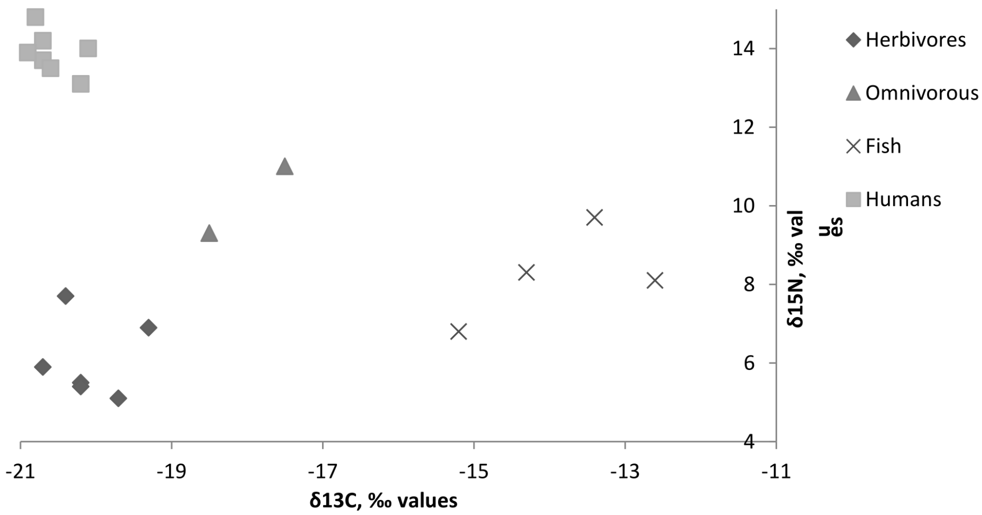

Figure 6 $\delta^{13}C$ and $\delta^{15}N$ isotopic values of human, faunal, and fish samples

The isotopic results for fish bones from the Neolithic complex were unexpected. Carbon isotopes varied between –12.6‰ and –15.2‰ (Tables 1, 2 and Figure 6), which is substantially different from those of archaeological fish remains from the Chicha 1 settlement ($\delta^{13}C$ –22.5‰), located 137 km to the southeast, near Lake Malaya Chicha (Privat et al. 2005). Modern fish samples from the Minusinsk Basin have similar $\delta^{13}C$ values to Chicha 1 (Svyatko et al. 2013). Modern fish from Lake Baikal is highly variable in $\delta^{13}C$ values, ranging from –24.6‰ to –14.2‰. High values are typical for some species of littoral fish (Katzenberg et al. 1999).

Table 2 Averaged $\delta^{13}C$ and $\delta^{15}N$ values of archaeological and modern fish bones in various regions of Siberia.

Region	Site	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	Source
Baraba forest steppe	Preobrazhenka 6	–13.9	8.2	this study
Baraba forest steppe	Chicha 1	–22.5	10.5	Privat et al. 2005
Minusinsk Basin	modern samples	–23.9	11.4	Svyatko et al. 2013
Lake Baikal	modern samples	–24.6 to –14.2	7.3 to 13.7	Katzenberg et al. 1999

Preliminarily, we explain the high $\delta^{13}C$ values of the Neolithic fish samples by a possible difference in carbon composition between the lakes and rivers of the Baraba forest steppe, with the $\delta^{13}C$ values in lakes lower than those in rivers. To test the hypothesis, a comparative analysis of isotope values in modern fish bones from different aquatic systems of the Baraba forest steppe (rivers and saline and freshwater lakes) should be conducted.

Human samples from Preobrazhenka 6 show a range of $\delta^{13}C$ values, varying between –22.7‰ and –20.1‰ (the average value is –21‰). The variation in $\delta^{15}N$ values is smaller, between 13.3‰ and 14.0‰ (the average value is 13.8‰; Table 1, Figure 6). High $\delta^{15}N$ values of human samples suggest the significant role of fish in the diet of the population, which seems to be characteristic for all Eurasian steppe populations who used products of marine or freshwater origin (Table 3).

Table 3 Comparative data on $\delta^{13}C$ and $\delta^{15}N$ values in human bone collagen and modeled diets of various Bronze Age populations of the Eurasian steppe.

Provenance	Period (cal BC)	Archaeological culture	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	Modeled diet	Source
Baraba forest steppe						
Preobrazhenka 6	2300–2000	Odino	–21	13.8	Primarily freshwater (and/or saltwater lake?) fish, wild C_3 plants, followed by terrestrial herbivores	this study
Chicha 1	1400–1100	Irmen	–19.5	14.5	Freshwater fish and terrestrial herbivores	Privat et al. 2005
Minusinsk Basin						
—	2500–1900	Okunevo	–18.7	11.6	C_3-based diet (terrestrial herbivore and plant), minor proportion of C_4 plants and/or animals that grazed on them, freshwater fish	Svyatko et al. 2013
Caspian steppe						
—	2200–2000	Lola and Krivaya Luka	–21 to –17	11 to 15	Flesh/milk of herbivore animals; river and lake aquatic products, wild C_3 plants	Shishlina et al. 2012
	2500–2200	East Manych Catacomb	–17 to –15	15 to 18	Marine products	
Northern Kazakhstan						
Bestamak	2100–1700	Andronovo	–19.0	11.8	Primarily flesh/milk herbivore animals	Ventresca Miller et al. 2014a
Lisakovsk			–18.8	12.0	Secondary role of wild C_3 or/and C_4 seeds and grains	
Angara River						
Ust'-Ida	3400–1700	—	–19.9	10.2	Terrestrial herbivores with minor proportion of riverine fish	Katzenberg et al. 1999
Lake Baikal						
Khuzhir		—	–18.4	14.3	Lake fish and seals	Katzenberg et al. 1999
Upper Lena River						
Obkhoi, Borki		—	–19.5	10.1	Terrestrial herbivores with minor proportion of riverine fish	Katzenberg et al. 1999

The majority of analyzed humans from Preobrazhenka 6 have similar or slightly lower $\delta^{13}C$ values than the Neolithic herbivores analyzed, and much lower values than the bear (which possibly subsisted on animal meat and plants) and dog (possibly fed by fish and meat; Table 1). Firstly, this indicates that people and herbivores had the same source of plant food, mainly C_3 plants. Secondly, plants apparently were more important in human diets than in that of the bear. As there is not much archaeological evidence for cereal cultivation, we can suggest that humans consumed local wild plants. The 2.6‰ range in human $\delta^{13}C$ values probably indicates differences in proportion of plant and animal food in the diet of the group members. Notably, the δ^{13}C of an adult male from grave 24, which also included a range of arrowheads and a bronze spear, is higher than that of other males from the cemetery (Table 1).

There could be a number of explanations for the differences in human diet, such as means of getting food, the foodstuff itself, and social differentiation. Data from the Chicha 1 settlement suggest human dietary reliance on freshwater fish, wild animals, and domestic herbivorous species (Privat et al. 2005). People from Preobrazhenka 6 have similarly high δ^{15}N values, but on average, 1.5‰ lower carbon values. This indicates that the diet of people from Preobrazhenka 6 included foods of low trophic level (i.e. plants). The Preobrazhenka 6 population have the lowest δ^{13}C values among all analyzed Bronze Age populations in the Eurasian steppe zone, which have terrestrial animal protein in their (Table 3). Therefore, we suppose that the proportion of animal protein in the diet of Preobrazhenka 6 people was relatively small. Moreover, elevated δ^{13}C values in Neolithic fish bones from the site (–13.5‰) indicate that people of the Odino culture ate fish originating from other areas (as their carbon values are relatively low, δ^{13}C = –21‰). We assume that the Neolithic pits with animal and fish remains represent local fishing in the Om River, whereas the Bronze Age population fished in nearby lakes like Lake Malaya Chicha. These first isotope results allow a model of main components of the people's diet to be developed, which included lake fish and wild C_3 plants, with terrestrial animals playing a secondary role.

Dental Pathology

Dental pathological lesions of the Odino culture population from Preobrazhenka 6 are suggestive of food deficiency and generally of a diet rich in carbohydrates. The frequency of caries and enamel hypoplasia are high, while the frequency of calculus, periodontal disease, and enamel fracture is not higher than in other series (Figure 7; Table 4). The frequency of antemortem tooth loss is also similar to that of other Bronze Age populations. They occur more often than in the Andronovo culture of the Kulunda steppe, but are rare in the Afanasievo, Okunevo, and Andronovo cultures of the Baraba forest steppe.

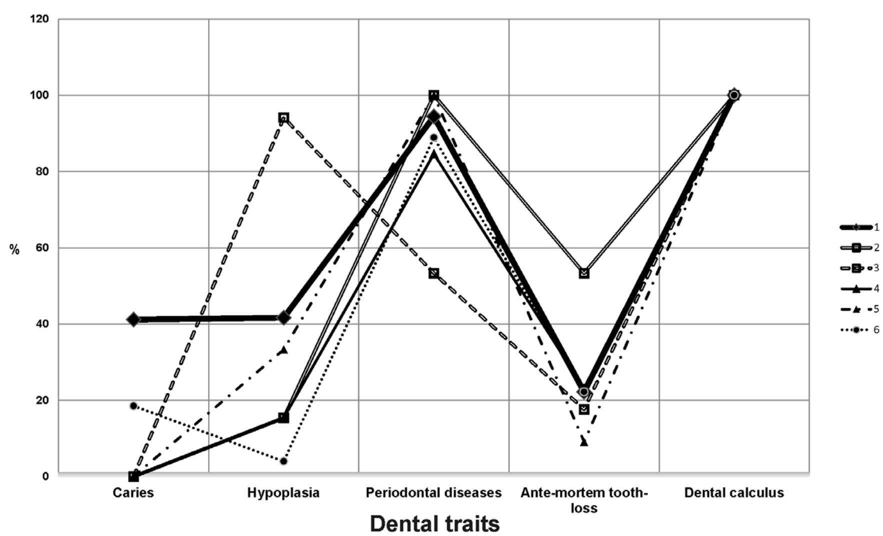

Figure 7 Frequencies of dental pathological lesions in Bronze Age populations (Table 4). [1]Preobrazhenka 6; [2]Afanasievo culture (Altai Mountains); [3]Afanasievo culture (Minusinsk Basin); [4]Andronovo culture (Baraba Forest steppe); [5]Andronovo culture (Kulunda steppe); [6]Okunevo culture.

Table 4 Dental pathological lesions in the Bronze Age population (number of affected individuals per total number of individuals with dentition within the group, with percentages shown in parentheses). Archaeological sites analyzed: [1]Nizhniy Tumechin 1, 5, Semisart, Elo-bashi, Kara-koba 1, Ozernoe 2, Tenga 4 (unpublished data); [2]Afanasieva gora, Karasuk 3 (Svyatko 2014); [3]Tartas 1, preliminary data (unpublished data); [4]Rublevo 8 (unpublished data); [5]Bestamak, Lisakowsk combined (Ventresca Miller et al. 2014b); [6]Verh-Askiz 1, Ujbat 5 (unpublished data).

Dental lesion/culture	♂	♀	?	Total
Caries				
Preobrazhenka 6	6/13 (46.2)	1/4 (25)	0/0 (0)	7/17 (41.2)
Afanasievo (Altai Mountains)[1]	0/8 (0)	0/3 (0)	0/1 (0)	0/12 (0)
Afanasievo (Minusinsk Basin)[2]	0/ - (0)	0/ - (0)	0/ - (0)	0/ - (0)
Andronovo (Baraba forest steppe)[3]	0/6 (0)	0/7 (0)	0/0 (0)	0/13 (0)
Andronovo (Kulunda steppe)[4]	0/5 (0)	0/6 (0)	0/0 (0)	0/11 (0)
Andronovo (Kazakhstan)[5]	0/10 (0)	0/12 (0)	0/24 (0)	0/46 (0)
Okunevo (Minusinsk Basin)[6]	2/15 (13.3)	3/9 (33.3)	0/3 (0)	5/27 (18.5)
Enamel hypoplasia				
Preobrazhenka 6	4/8 (50)	1/3 (33.3)	0/0 (0)	5/12 (41.7)
Afanasievo (Altai Mountains)	2/9 (22.2)	0/3 (0)	0/1 (0)	2/13 (15.4)
Afanasievo (Minusinsk Basin)	6/7 (85.7)	8/9 (88.9)	1/1 (100)	16/17 (94.1)
Andronovo (Baraba forest steppe)	1/6 (16.7)	1/7 (14.3)	0/0 (0)	2/13 (15.4)
Andronovo (Kulunda steppe)	3/3 (100)	0/6 (0)	0/0 (0)	3/9 (33.3)
Andronovo (Kazakhstan)	—	—	—	—
Okunevo (Minusinsk Basin)	1/14 (7.1)	0/8 (0)	0/3 (0)	1/25 (4)
Periodontal diseases				
Preobrazhenka 6	12/13 (92.3)	5/5 (100)	0/0 (0)	17/18 (94.4)
Afanasievo (Altai Mountains)	10/10 (100)	3/3 (100)	1/1 (100)	14/14 (100)
Afanasievo (Minusinsk Basin)	4/7 (57.1)	4/8 (50)	0/0 (0)	8/15 (53.3)
Andronovo (Baraba forest steppe)	6/6 (100)	5/7 (71.4)	0/0 (0)	1/13 (84.6)
Andronovo (Kulunda steppe)	5/5 (100)	5/5 (100)	0/0 (0)	0/10 (100)
Andronovo (Kazakhstan)	7/8 (87.5)	9/10 (90)	6/7 (85.7)	22/25 (88)
Okunevo (Minusinsk Basin)	14/15 (93.3)	7/9 (77.8)	3/3 (100)	24/27 (88.9)
Antemortem tooth loss				
Preobrazhenka 6	4/13 (30.8)	0/5 (0)	0/0 (0)	4/18 (22.2)
Afanasievo (Altai Mountains)	6/10 (60)	2/4 (50)	0/1 (0)	8/15 (53.3)
Afanasievo (Minusinsk Basin)	1/7 (14.3)	2/9 (22.2)	0/1 (0)	3/17 (17.7)
Andronovo (Baraba forest steppe)	2/6 (33.3)	1/7 (14.3)	0/0 (0)	3/13 (23.1)
Andronovo (Kulunda steppe)	1/5 (20)	0/6 (0)	0/0 (0)	1/11 (9.1)
Andronovo (Kazakhstan)	1/6 (16.7)	1/7 (14.3)	1/5 (20)	3/18 (16.7)
Okunevo (Minusinsk Basin)	2/15 (13.3)	2/9 (22.2)	2/3 (66.7)	6/27 (22.2)
Dental calculus				
Preobrazhenka 6	13/13 (100)	4/4 (100)	0/0 (0)	17/17 (100)
Afanasievo (Altai Mountains)	8/8 (100)	3/3 (100)	1/1 (100)	2/12 (100)
Afanasievo (Minusinsk Basin)	7/7 (100)	8/9 (100)	1/1 (100)	7/17 (100)
Andronovo (Baraba forest steppe)	6/6 (100)	7/7 (100)	0/0 (0)	13/13 (100)
Andronovo (Kulunda steppe)	5/5 (100)	6/6 (100)	0/0 (0)	1/11 (100)
Andronovo (Kazakhstan)	10/10 (100)	10/11 (90.9)	17/23 (73.9)	37/44 (84.1)
Okunevo (Minusinsk Basin)	15/15 (100)	9/9 (100)	3/3 (100)	27/27 (100)
Enamel fracture				
Preobrazhenka 6	7/13 (53.9)	4/5 (80)	0/0 (0)	11/18 (61.1)
Afanasievo (Altai Mountains)	6/8 (75)	2/3 (66.7)	1/1 (100)	9/12 (75)
Afanasievo (Minusinsk Basin)	—	—	—	—
Andronovo (Baraba forest steppe)	3/6 (50)	3/7 (42.9)	0/0 (0)	6/13 (46.2)
Andronovo (Kulunda steppe)	3/5 (60)	1/5 (20)	0/0 (0)	4/10 (40)
Andronovo (Kazakhstan)	—	—	—	—
Okunevo (Minusinsk Basin)	14/15 (93.3)	6/9 (66.7)	3/3 (100)	23/27 (85.2)

The distribution of enamel wear grades in different teeth of the Preobrazhenka 6 population demonstrates dietary variation. Generally, in pastoral and classical agricultural populations the highest average levels of dental wear are typical for the first maxillary and mandibular molars (Machicek and Zubova 2012), whereas incisors and canines keep their occlusal surface enamel longer. The Probrazhenka 6 series has another pattern; frontal teeth of upper and lower jaws are far more worn than the molars and premolars (Table 5). There is no evidence of using frontal teeth as operating tools. The angle wear of the first molars' masticatory surface tends to flat variants in the series. In agricultural groups, the so-called "oblique" type of wear prevailed (Smith 1984). This type is characterized by a more obliterated vestibular side of teeth, and less the lingual, leading to an angle of more than 10 degrees from the basal surface (Smith 1984:Figure 5).

Table 5 Dental wear indices in the Preobrazhenka 6 sample (based on the 10-point scale by Smith 1984).

	I1	I2	C	P1	P2	M1	M2	M3
Upper jaw	4.5	4.2	5.05	3.3	3.35	4.65	3.7	3.3
Lower jaw	5	4.5	4.4	3.9	3.2	3.58	3.5	3.03

Thus, despite the fact that dental pathology frequencies show high contents of plant food in the population's diet, the nature of enamel wear is different from "classical" agricultural populations. We can suggest that these people were consuming large amounts of tubers and plant roots rather than cereals, which led to an intensive wear of frontal teeth and average wear of molars. The location of antemortem enamel fractures also supports this hypothesis. For agricultural populations, enamel fractures are mainly caused by rough unprocessed grains and stone/sand fragments, which are mixed with the food during its preparation. While chewing, these particles injure molars and generate multiple enamel fractures. For the Preobrazhenka 6 individuals, all cases of antemortem enamel injuries were found on canines and incisors of both jaws. This allows us to suggest that they appeared as a result of cracking hard foods. Possible variations include plant roots, seeds, and nut shells.

CONCLUSIONS

The obtained ^{14}C results allow us to substantially adjust the time of existence of Seyma-Turbino objects and date the cemetery of Preobrazhenka 6 to the 23rd–20th centuries BC. The Neolithic complex, which dates to the 63rd–61st centuries BC, at the moment appears as the oldest among the dated Holocene sites of the Baraba forest steppe. Previously, the earliest dated burial complexes in the region belonged to the first half of 6th millennium BC (Marchenko 2009).

Stable isotope analysis of human, animal, and fish bones indicates that determining the food sources for each population/culture in the region is essential because, depending on the origin of consumed fish, human bones may be affected by the freshwater reservoir effect. A reservoir correction obtained for a particular site cannot be applied to all archaeological cultures in the region, as it may be highly variable within the area.

The results of stable isotope and dental pathology analyses of the Middle Bronze Age population from the site suggest fish and C_3 plants were main dietary components for humans. In spite of the high carbohydrate consumption, the human diet apparently did not include a large amount of grains. Wild plants, probably nuts (e.g. pine nuts), may have played a leading role in the diet.

Further ^{14}C dating of bones from pits is needed to find Bronze Age domestic fauna. To assess the extent of the reservoir effect in the site, we plan to date paired samples of human bone from burial 56, where *Ovis/Capra* bone was found. Unfortunately, this is the only paired sample available from the site (the only case of the animal bone being found on the base of the grave). Other faunal remains from the cemetery come from grave fills, and therefore cannot be securely attributed to the necropolis. To assess the source of high $\delta^{13}C$ in fish, we plan to analyze $\delta^{13}C$ levels of modern fish from the Baraba forest steppe rivers and lakes. Further sampling of human and animal bones is also planned for a more detailed dietary reconstruction in the area.

ACKNOWLEDGMENTS

This research was conducted in memory of Dr Marina Chemyakina who led joint geophysical and archaeological research at the site during 2004–2009. We would like to extend our appreciation to Dr S K Vasyliev for osteologic definitions and Dr L A Koneva for ichthyologic definitions. We thank the organizers of the conference Radiocarbon and Diet for their invitation and partial financial assistance. Also, we thank Dr Svetlana Svyatko for discussion of our first results, help in finding special literature, and translating this paper. Finally, we thank three anonymous reviewers and Dr John Meadows for criticism and constructive comments. The work was supported by the Russian Foundation for Basic Sciences (Grant RFFI 14-06-00264).

REFERENCES

Afanaseva AO. 2011. Osobennosti zhiznedeyatelnosti naseleniya Krepostnogo gorodishchya v I-II vekakh novoi ery po dannym paleopatologii zubochelyustnogo apparata [Features of the population life of the Krepostnoe settlement in I - II centuries on palaeopathology data]. *Vestnik Yuzhnogo Nauchnogo Tsentra RAN* 7(4):79–82. In Russian.

Ambrose SH. 1991. Effects of diet, climate and physiology on nitrogen isotope abundances in terrestrial foodwebs. *Journal of Archaeological Science* 18(3):293–317.

Ambrose SH, Norr L. 1993. Experimental evidence for the relationship of the carbon isotope ratios of whole diet and dietary protein to those of bone collagen and carbonate. In: Lambert JB, Grupe G, editors. *Prehistoric Human Bone: Archaeology at the Molecular Level*. Berlin: Springer-Verlag. p 1–37.

Brock F, Higham T, Ditchfield P, Bronk Ramsey C. 2010. Current pretreatment methods for AMS radiocarbon dating at the Oxford Radiocarbon Accelerator Unit (ORAU). *Radiocarbon* 52(1):103–12.

Bronk Ramsey C. 1995. Radiocarbon calibration and analysis of stratigraphy: the OxCal program. *Radiocarbon* 37(2):425–30.

Bronk Ramsey C. 1998. Probability and dating. *Radiocarbon* 40(1):461–74.

Bronk Ramsey C. 2001. Development of the radiocarbon calibration program. *Radiocarbon* 43(2A):355–63.

Cherhykh EN. 1970. Drevneishaya metallurgiya Urala i Povolzhya [Ancient metallurgy of Urals and Volga River Basin]. *Materialy i Issledovaniya po Arkheologii SSSR* 172. 180 p. In Russian.

Chernykh EN. 1992. *Ancient Metallurgy in the USSR: The Early Metal Age*. Cambridge: Cambridge University Press. 335 p.

Epov MI, Chemyakina MA. 2009. Geophysical methods in the research of archaeological sites of Western Siberia and Altai: results and perspectives. *ArcheoSciences* 33:271–4.

Görsdorf J, Parzinger H, Nagler A. 2001. New radiocarbon dates of the North Asian steppe zone and its consequences for the chronology. *Radiocarbon* 43(2B):1115–20.

Heaton THE, Fogel JC, von la Chevallerie G, Collet G. 1986. Climatic influence on the isotopic consumption of bone nitrogen. *Nature* 322(6082):822–3.

Hedges REM, Reynard LM. 2007. Nitrogen isotopes and the trophic level of humans in archaeology. *Journal of Archaeological Science* 34(8):1240–51.

Katzenberg AM, Weber A. 1999. Stable isotope ecology and palaeodiet in the Lake Baikal region of Siberia. *Journal of Archaeological Science* 26(6):651–9.

Katzenberg AM, Goriunova O, Weber A. 2009. Paleodiet reconstruction of Bronze Age Siberians from the mortuary site of Khuzhir-Nuge XIV, Lake Baikal. *Journal of Archaeological Science* 36(3):663–74.

Keenleyside A. 2008. Dental pathology and diet at Apollonia, a Greek colony on the Black Sea. *International Journal of Osteoarchaeology* 18(3):262–79.

Kiryushin YF, Grushin SP, Tishkin AA. 2003. Pogrebalnyi obryad naseleniya epokhi rannei bronzy Verkhnego Priob'ya (po materialam gruntovogo mogil'nika Teleutskii Vzvoz-1) [Burial rite practiced by Early Bronze Age population in the Upper Ob River basin (based on data resulted from the study of the Teleutsky Vzvoz 1 burial ground)]. Barnaul: ASU Publishing. 333 p. In Russian.

Kiryushin YF, Grushin SP, Papin DV. 2009. Radiouglerodnaya khronologiya pamyatnikov epokhi rannego metalla Altaya [Radiocarbon chronology of Early Metal Age sites in Altai]. In: Kiryushin YF, Tishkin AA, editors. *Rol' estestvenno-nauchnykh metodov v arkheologicheskikh issledovaniyakh*. Barnaul: ASU Publishing. p 120–4. In Russian.

Kosarev MF. 1981. *Bronzovyi vek Zapadnoi Sibiri* [Bronze Age in Western Siberia]. Moscow: Nauka Publishing. 278 p. In Russian.

Lee-Thorp J, Sealy J, van der Merwe NJ. 1989. Stable carbon isotope ratio differences between bone collagen and bone apatite, and their relationship to diet. *Journal of Archaeological Science* 16(6):585–99.

Lukacs JR. 1989. Dental palaeopathology: methods for reconstructing dietary patterns. In: *Reconstruction of Life from the Skeleton*. New York: Alan Liss. p 261–86.

Machicek ML, Zubova AV. 2012. Dental wear patterns and subsistence activities in early nomadic pastoralist communities of the Central Asian steppes. *Archaeology, Ethnology & Anthropology of Eurasia* 40(3):149–57.

Marchenko ZV. 2009. Radiouglerodnaya khronologiya arkheologicheskikh pamyatnikov epokhi neolita i rannego metalla Barabinskoi lesostepi [Radiocarbon chronology of the Neolithic and Early Metal Age archaeological sites of the Baraba forest-steppe]. In: Kiryushin YF, Tishkin AA, editors. *Rol' estestvenno-nauchnykh metodov v arkheologicheskikh issledovaniyakh*. Barnaul: ASU Publishing. p 140–3. In Russian.

Matveev AV. 1998. *Pervye andronovtsy v lesakh Zaural'ya* [Earliest Andronovo groups in the forests of the Trans-Urals]. Novosibirsk: Nauka, Sibirskoe predpriyatie RAN Publishing. 417 p. In Russian.

Matveev AV, Anoshko OM. 2009. *Zaural'e posle andronovtsev: Barkhatovskaya ku'tura* [The Trans-Urals in post-Andronovo period: the Barkhatovo culture]. Tyumen: Tyumenskii dom pechati Publishing. 416 p. In Russian.

Matyushchenko VI. 1973. Drevnyaya istoriya naseleniya lesnogo i lesostepnogo Priobya (neolit i bronzovyi vek) [Ancient history of people inhabited the forest and forest-steppe areas of the Ob River basin (Neolithic Age, Bronze Age)]. *Iz Istorii Sibiri*. Vypusk 10, chast 2. Tomsk: TSU Publishing. 139 p. In Russian.

Molodin VI. 2012. *Pamyatnik Sopka 2 na reke Omi. Kul'turno-khronlogicheskii analiz pogrebal'nykh kompleksov odinovskoi kul'tury* [The Sopka 2 site on the Om River. Cultural and chronological analysis of burial complexes associated with the Odino culture]. Tom 3. Novosibirsk: IAET SO RAN Publishing. 220 p. In Russian.

Molodin VI, Chemyakina MA, Dyadkov PG, Sophekov OV, Mikheev OA, Pozdnyakova OA. 2004. Arkheologo-geophizicheskie issledovaniya pamyatnika Preobrazhenka 6 [Archaeological-geophysical researches on the Preobrazhenka 6 site]. In: Derevyanko AP, Molodin VI, editors. *Problemy Arkheologii, Etnografii, Antropologii Sibiri i Sopredelnykh Territorii*. Tom X, chast 1. Novosibirsk: IAET SO RAN Publishing. p 378–83. In Russian.

Molodin VI, Chemyakina MA, Pozdnyakova OA. 2007. Arkheologo-geofizicheskie issledovaniya pamyatnika Preobrazhenka 6 v Barabinskoi lesostepi [Archaeo-geophysical studies carried out at the site of Preobrazhenka 6 in the Baraba forest-steppe]. In: Derevyanko AP, Molodin VI, editors. *Problemy Arkheologii, Etnografii, Antropologii Sibiri i Sopredelnykh Territorii*. Tom 13. Novosibirsk: IAET SO RAN Publishing. p 339–44. In Russian.

Molodin VI, Koneva LA, Chemyakina MA, Stepanenko DV, Pozdnyakova OA. 2012a. Ichthyologic materials from ritual complexes of the Odino culture from the Preobrazhenka-6 site. *Archaeology, Ethnology & Anthropology of Eurasia* 50(2):25–36.

Molodin VI, Marchenko ZV, Kuzmin YV, Grishin AE, Van Strydonck M, Orlova LA. 2012b. ^{14}C chronology of burial grounds of the Andronovo period (Middle Bronze Age) in Baraba forest steppe, western Siberia. *Radiocarbon* 54(3–4):737–47.

Molodin VI, Epimakhov AV, Marchenko ZV. 2014. Radiouglerodnaya khronologiya kultur epokhi bronzy Urala i yuga Zapadnoi Sibiri: printsipy i podkhody, dostizheniya i problemy [Radiocarbon chronology of the south Urals and the south of western Siberia cultures: principles and approaches, achievements and problems]. *Vestnik Novosibirskogo Gosudarstvennogo Universiteta. Seriya: Istoriya, Philologiya* 13(3):136–67. In Russian.

O'Connell TC, Levine MA, Hedges REM. 2003. The importance of fish in diet of central Eurasian peoples from the Mesolithic to Iron Age. In: Levine MA, Renfrew AC, Boyle K, editors. *Prehistoric Steppe Adaptation and the Horse*. Cambridge: McDonald Institute for Archaeological Research. p 253–68.

O'Connell TC, Kneale CJ, Tasevska N, Kuhnle GGC. 2012. The diet-body offset in human nitrogen isotopic values: a controlled dietary study. *American Journal of Physical Anthropology* 149(3):426–34

Pate FD. 1994. Bone chemistry and paleodiet. *Journal of Archaeological Method and Theory* 1(2):161–209.

Privat K, Schneeweiss J, Benecke N, Vasil'ev SK, O'Connell T, Hedges R, Craig O. 2005. Economy and diet at the Late Bronze Age – Iron Age site of Chicha: artefactual, archaeozoological and biochemical analyses. *Eurasia Antiqua* 11:419–49.

Reimer PJ, Bard E, Bayliss A, Warren Beck J, Blackwell PG, Bronk Ramsey C, Buck CE, Cheng H, Edwards RL, Friedrich M, Grootes PM, Guilderson TP, Haflidason H, Hajdas I, Hatté C, Heaton TJ, Hoffmann DL, Hogg AG, Hughen KA, Kaiser KF, Kromer B, Manning SW, Niu M, Reimer RW, Richards DA, Scott EM, Southon JR, Staff RA, Turney CSM, van der Plicht J. 2013. IntCal13 and Marine13 radiocarbon age calibration curves 0–50,000 years cal BP. *Radiocarbon* 55(4):1869–87.

Roberts C, Manchester K. 2005. *The Archaeology of Disease*. Stround: Sutton Publishing. 338 p.

Schoeninger MJ, DeNiro MJ. 1984. Nitrogen and carbon isotopic composition of bone collagen from marine and terrestrial animals. *Geochimica et Cosmochimica Acta* 48(4):625–39.

Schneeweiss J. 2007. *Die Siedlung Čiča in der westsibirischen Waldsteppe I. Untersuchungen zur spät-*

bronze- bis früheisenzeitlichen Keramik, Chronologie und kulturellen Stellung. Mainz: Philipp von Zabern Verlag. 422 p.

Shishlina NI. 2014. Izotopnyi sostav azota i ugleroda kollagena kostei arkheologicheskikh zhivotnykh kak pokazatel klimaticheskikh izmeneii (na primere materialov lolinskoi kultury epokhi bronzovogo veka) [Isotope composition of nitrogen and carbon in collagen of archaeological animals' bones as an indicator of climatic changes (on the materials of Lola culture Bronze Age)]. In: *Materialy mezhdunarodnoi nauchnoi konferentsii po arkheologicheskomy pochvovedeniu, posvyashchennoi pamyati VA Demkina*. Pushchino: OOO "Foton-vek." p 180–3. In Russian.

Shishlina NI, Zazovskaya EP, van der Plicht J, Hedges REM, Sevastyanov VS, Chichagova OA. 2009. Paleoecology, subsistence, and ^{14}C chronology of the Eurasian Caspian steppe Bronze Age. *Radiocarbon* 51(2):481–99.

Shishlina N, Zazovskaya E, van der Plicht J, Sevastyanov V. 2012. Isotopes, plants, and reservoir effects: case study from the Caspian steppe Bronze Age. *Radiocarbon* 54(3–4):749–60.

Smith BH. 1984. Patterns of molar wear in hunter-gatherers and agriculturalists. *American Journal of Physical Anthropology* 63(1):39–56.

Svyatko SV. 2014. Dental palaeopathological analysis of the Eneolithic-Early Iron Age populations from the Minusinsk Basin, southern Siberia: palaeodietary implication. *Archaeology, Ethnology and Anthropology of Eurasia* 58(2):143–56.

Svyatko SV, Mallory JP, Murphy EM, Polyakov AV, Reimer PJ, Schulting RJ. 2009. New radiocarbon dates and a review of the chronology of prehistoric populations from the Minusinsk Basin, southern Siberia, Russia. *Radiocarbon* 51(1):243–73.

Svyatko SV, Schulting RJ, Mallory J, Murphy EM, Reimer PJ, Khartanovich VI, Chistov YK, Sablin MV. 2013. Stable isotope dietary analysis of prehistoric populations from the Minusinsk Basin, Southern Siberia, Russia: a new chronological framework for the introduction of millet to the eastern Eurasian steppe. *Journal of Archaeological Science* 40(11):3936–45.

van der Plicht J, Molodin VI, Kuzmin YV, Vasiliev SK, Postnov AV, Slavinsky VS. 2015. New Holocene refugia of giant deer (*Megaloceros giganteus* Blum.) in Siberia: updated extinction patterns. *Quaternary Science Reviews* 114:182–8.

van Klinken GV. 1999. Bone collagen quality indicators for palaeodietary and radiocarbon measurements. *Journal of Archaeological Science* 26(6):687–95.

Ventresca Miller A, Usmanova E, Logvin V, Kalieva S, Shevnina I, Logvin A, Kolbina A, Suslov A, Privat K, Haas K, Rosenmeier M. 2014a. Subsistence and social change in central Eurasia: stable isotope analysis of populations spanning the Bronze Age transition. *Journal of Archaeological Science* 42:525–38.

Ventresca Miller A, Usmanova E, Logvin V, Kalieva S, Shevnina I, Logvin A, Kolbina A, Suslov A. 2014b. Dental health, diet, and social transformations in the Bronze Age: comparative analysis of pastoral populations in northern Kazakhstan. *Quaternary International* 348:130–46.

Weber AW, Beukens RR, Bazaliiskii VI, Goriunova OI, Savel'ev NA. 2006. Radiocarbon dates from Neolithic and Bronze Age hunter-gatherer cemeteries in Cis-Baikal region of Siberia. *Radiocarbon* 48(1):127–66.