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The Bronze Age in the Karagaily-Ayat Region (Trans-Urals, Russia)

Culture, Environment and Economy

edited by
Ludmila N. Koryakova & Rüdiger Krause

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Front cover above: Werner Keppler, Ural excavation campaign 2013, photo from July 27, 2013 during an approaching thunderstorm. – Front cover below: Kamennyi Ambar 2012–2013. Detail from the excavation plan for excavation area 5 and reconstruction of houses in excavation area 5 according to Svetlana A. Kuzmina.

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Preface of the editors

With the issue of the new collective volume entitled "The Bronze Age in the Karagaily-Ayat region (Trans-Urals, Russia). Culture, Environment and Economy", we have now succeeded in presenting four monographs in the series *Frankfurter Archäologische Forschungen* since 2013 about the joint research of the Russian-German cooperation project on the Bronze Age in the Trans-Urals, conducted in 2009–2014. With this new volume, we are proud to present comprehensive essays and topics by various contributors from our large project team.

These new studies cover topics from the second part of the project conducted between 2011 and 2014, concerning the fortified settlements of the Sintashta-Petrovka phase in the Trans-Urals, dated 2100 to ca. 1800 B.C. Through interdisciplinary research and the inclusion of various scientific disciplines such as archaeobotany, geophysics, biology, chemistry, mineralogy and their subdisciplines we have been able to achieve a wealth of new results over a period of 13 years since 2009. In many respects, the results shed new light on the natural and cultural landscape of the Bronze Age at the south-eastern end of the Ural Mountains. Nevertheless, the phenomenon and the sudden appearance of the up to 25 sites known today with fortified and structured settlements still leave plenty of room for many different observations and interpretations.

We would like to thank all our colleagues in the Russian and German teams for their excellent cooperation. The always friendly and professional cooperation was the basis for the generous support by the Russian Foundation of Fundamental Research (RFFI), the Russian Foundation for Basic Research (RFBR) and the German Research Foundation (DFG) in Bonn for many years. We would like to thank them very much for this! We have also received great support over the many years from our institutions, namely the Institute of History and Archaeology of the Russian Academy of Sciences in Ekaterinburg and the Goethe University in Frankfurt am Main. We are also grateful to students from the Ural Federal University (Ekaterinburg), the South-Ural State University (Chelyabinsk), as well as from Goethe University (Frankfurt) and our friends who added to the achievements in the field research. Thereby, important partners have always been the Eurasia Department of the German Archaeological Institute in Berlin with Prof. Dr. Dr. h.c. Svend Hansen as well as the General Consulate of the Federal Republic of Germany in Ekaterinburg.

Many persons were involved in the production and printing of this new volume.

We are very grateful to the authors for their valuable contributions. Further, there were many helping hands in the diligent preparation of the layout, primarily Mrs. Eliza Stolarczyk M.A. from Frankfurt. We would like to express our sincere thanks to Dr. Emily Schalk from Berlin, who carried out the translation work with great patience and expertise. Finally, we would like to thank the publishing house of Dr. Rudolf Habelt in Bonn and Dr. Susanne Biegert for their support and advice and for the speedy and reliable printing of the volume.

Frankfurt/Ekaterinburg, October 2021
Rüdiger Krause and Ludmila N. Koryakova

Foreword
of the German Consul General, Ekaterinburg

Scientific cooperation and academic mobility play an increasingly important role also in sustainable German foreign policy. Germany's science diplomacy actively shapes this network, promotes scientific exchange and advocates freedom of science and research worldwide. International university partnerships, double study courses, academic exchange programs – universities and scientific institutions around the world are increasingly networked. Therefore, global challenges such as peace, climate change and pandemics can only be solved together with international partners. Germany as location for innovation, science and research actively promotes this networking: Science diplomacy creates the framework for international cooperation and exchange and strengthens Germany as a location for innovation and excellence.

Since 2009, German and Russian scientists have been conducting joint archaeological research in the southern Ural region on settlement forms of the Middle Bronze Age. This project is the result of an extremely successful cooperation between the Goethe University Frankfurt/Main and the Ural Department of the Russian Academy of Sciences in Ekaterinburg under the direction of Prof. Dr. Rüdiger Krause and Prof. Dr. Ludmila N. Koryakova, who together with their teams have made lasting contributions to the cooperation between Germany and Russia. This project shows what is possible within the framework of a cooperation that is pursued with determination and perseverance.

Engaged in the Chelyabinsk region in the administrative district of the Consulate General, this project is a particularly successful example of German-Russian scientific cooperation. The annual excavations in July and August were carried out with Russian and German students. Undeterred by some of the political upheavals of the last few years, the scientific collaboration could be continued in a targeted manner and has found expression in numerous publications. As part of this scientific cooperation, the third anthology is now being published, which documents the fruits of the intensive research work since 2014. Last but not least, this volume once again exemplifies the enormous potential of scientific cooperation between the two countries.

The aim is to investigate developments in population structure and demographics over long periods of time. The project was carried out on an interdisciplinary basis and has provided insights into new forms of life, the spread of agricultural usage patterns and the adaptation of cultivated plants and livestock. Among other things, the question of the extent to which genetic influences from Europe or the Central Asian steppe go hand in hand with the cultural change was investigated. Thus, concerned here is nothing less than the reconstruction of a chapter in human history around 4,000 years ago in order to make it understandable and to make these roots of our common culture and civilization tangible for us today!

I wish this substantial work as many readers and the authors as possible a successful future in their important work.

Mathias Kruse
Consul General of the Federal Republic of Germany in Ekaterinburg, Russia

Foreword of the Director of the Institute of History and Archaeology, Ural Branch of the Russian Academy of Sciences

Dear Reader!

Presented here is a fundamental and comprehensive study of the Bronze Age structures and processes localized in the Karagaily-Ayat river valley in the Southern Trans-Urals.

The book is characterized by the multifaceted nature of the study, which covers a variety of aspects: from soil, vegetation, landscape to architecture, tools, various branches of economic activity, etc.

The research is of a pronounced interdisciplinary nature, involving a synthesis of approaches and methods applied in archaeology, archaeobotany and biology, archaeometallurgy and the spatial distribution of artifacts. It was thanks to interdisciplinary hybridization that it was possible to significantly deepen the goals of previous research, to pose new problems, and to expand the horizons of scientific knowledge in the perspective of understanding the economy and culture of the Bronze Age.

I would like to state with the pride that the book is the result of joint research, long-term international scientific cooperation of archaeologists of the Institute of History and Archeology of the Ural Branch of the Russian Academy of Sciences and the staff of the Institute of Archaeological Sciences on Prehistory and Early History of the Johann Wolfgang Goethe University in Frankfurt am Main. This cooperation has continued for more than 10 years, and is marked by new theories, discoveries and conclusions presented in this collective monograph.

With sincere wishes of joy in obtaining new knowledge,

Igor' V. Poberezhnikov
Doctor of Historical Sciences
Director of the Institute of History and Archeology of the Ural Branch of the Russian Academy of Sciences
Ekaterinburg, Russia

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Chapter 12
Bone remains from the Bronze Age fortified settlements of Kamennyi Ambar and Konoplyanka

Pavel A. Kosintsev, Alexey Ju. Rassadnikov and Olga P. Bachura

The fortified settlement of Kamennyi Ambar was studied from 2005 to 2013. The archaeological material could be assigned to three main groups according to the types of pottery: the Sintashta, the Petrovka, and the Srubnaya-Alakul' cultures (Koryakova et al. 2013, 113). Material of the Sintashta and Petrovka groups partially overlaps both stratigraphically and planographically; therefore, for the purposes of this study they are referred to together as the Sintashta-Petrovka complex. The fortified settlement of Konoplyanka, located at a distance of 14 km from Kamennyi Ambar, was excavated in 2012–2013. The ceramic assemblage is represented by sherds with attributes of the Sintashta-Petrovka complex (Sharapova et al. 2014). The major part of the archaeozoological assemblage from the Kamennyi Ambar settlement has been described in detail elsewhere (Rassadnikov et al. 2013). Since then the cultural and the chronological characterizations of some bone samples have been updated, and some new material has been obtained, including material from the Konoplyanka settlement.

In this regard, we would like to first highlight the following information. Our study was made on two asynchronous groups of samples from the same settlement. This excluded the possibility of the effect of spatial differences in the natural environment on characteristics of the economic pattern. It was thus possible to assess the impact of "pure" cultural and chronological differences on the economy. The purpose of this chapter is the characterization of the bone remains obtained during excavations at the fortified settlements Kamennyi Ambar and Konoplyanka.

One of the objectives of the study was a comparative analysis of the respective bone samples from the asynchronous settlements according to the following parameters: 1) species composition; 2) degree of fragmentation; 3) ratios of different species and groups of species remains in samples; 4) ratios of skeleton segments of different types of ungulates; 5) age composition of different types of ungulates; 6) composition of modified bones; 7) presence of pathological changes on domestic ungulates bones; 8) size of the different types of domestic ungulates bones; and 9) the role of the various domestic ungulates in the ancient population's diet.

Material and methodology

In the process of excavations at the Kamennyi Ambar and Konoplyanka settlements the same methodological approach was used for the collection of bones. The exact location coordinates for each bone within the level were obtained with the use of a tacheometer. The following parameters have been recorded for all identifiable bones: skeletal element; whole bone or fragment; in case of a fragment, the specific part of the bone; adherent or non-adherent epiphyses; in the case of jaws – presence and/or number of erupted teeth.

The bones indeterminable in species (Mammalia indet.) have been grouped into three categories according to size: "large ungulate", "small ungulate", "indeterminable". The category of "large ungulate" includes the bone fragments of the animals that match in size with bovine cattle and horses. The category of "small ungulate" includes the bone fragments of animals matching in size with sheep, goats and pigs. The "indeterminable" category includes the small bone fragments by which it was not possible to determine the size of the animal.

For the purposes of the study on ratios of skeleton segments of domestic ungulates, the skeletal segments were arranged in several groups. The "head" group includes fragments of skull, mandible and sublingual bones. The "tooth" group includes isolated teeth. The "body" group includes the breastbone, vertebra and rib as well as their fragments. The "proximal limbs segments" group includes the shoulder blade, the humerus, the radius, the haunch bone, the talus and the cannon. The "distal limbs segments" group includes the carpal and tarsal bones, the metapodia, the phalanges and the sesamoid bones.

The age composition of bovine cattle and small ruminants was determined by tooth eruption (Silver 1969). The age of horses was determined by tooth attrition. Four different age groups of the horse have been established: young (up to 2 years), semi-adult (2–5 years), adult (from 5 to approximately 15 years), and old (over 15 years of age). All primary teeth are included in the "young" group.

The cultural layer of the Kamennyi Ambar settlement had a complex structure that had formed as a result of construction and economic activities of the ancient population throughout at least two chronological periods: the Sintashta-Petrovka and the Srubnaya-Alakul' cultures (Koryakova et al. 2013; Epimakhov/Krause 2013). The analysis of the stratigraphic and the planographic distribution within the level of different cultural and chronological pottery types demonstrated that there were certain layers, which contained mostly ceramics of only one of the groups: the Sintashta-Petrovka or the Srubnaya-Alakul' culture (Koryakova et al. 2013, 113; Panteleeva 2013, 171–186). Other horizons contained a significant amount of either both groups or ceramics displaying a mixed appearance. We proceeded from the assumption that the bones were deposited in the same chronological sequence as the pottery. The comparison of the coordinates of the ceramics sherds and the bones resulted in the formation of three groups: the predominantly Sintashta-Petrovka, the predominantly Srubnaya-Alakul', and the mixed group (Table 1). Hereafter, only the samples of the Sintashta-Petrovka cultural group and of the Srubnaya-Alakul' cultural group will be analysed. The bone samples from the Konoplyanka settlement belong to the Sintashta-Petrovka period (Sharapova et al. 2014).

Certain differences in the composition of bone samples from the Kamennyi Ambar and Konoplyanka settlements should be noted. The Kamennyi Ambar samples were formed by means of bringing together the bones from different sections of the cultural layer in the settlement. In this case the local specifics of the bones distribution in the level could be counterbalanced, and the characteristics would apply to the whole sample in general. The Konoplyanka sample, by contrast, was obtained from a single small excavated area (see Chapter 7). Therefore, it might reflect the local specifics of the bones in a particular excavation area.

Each of the three samples consisted of over 600 identifiable bones, i.e. all of the skeleton segments are representative.

The bone measurements follow the common methodology (von den Driesch 1976). The anterior length of phalanx I and phalanx II of bovine cattle, sheep and goats was measured in the same way as that of horses (Eisenmann et al. 1988). In addition, the medial line length (the length of the sagittal) of the astragalus was measured. The data analysis was performed with the use of Statistica 6.0 software.

Results and discussion

Taxonomical composition

Comparison of the species composition in the Sintashta-Petrovka and the Srubnaya-Alakul' bone samples from the Kamennyi Ambar and Konoplyanka settlements demonstrate their significant similarity (Table 1). The explanation for differences in the sample of wild species might be their very small number and, hence, the random nature of their inclusion in the samples. The analysis of the ratio of remains of the different species and groups as follows: all three samples had practically identical shares of the remains of dogs – 0.9 %, 1.0 % and 2.6 %, and wild species – 1.2 %; 1.1 % and 0.5 % (Table 2). The ratios of remains of domesticated ungulates in the Kamennyi Ambar and Konoplyanka samples were quite close – 74.2 %, 79.1 % and 76.9 % (Table 2). These

data may be interpreted as evidence for the similar role that hunting and animal husbandry played in the economy of both settlements during the periods under study.

Species	Kamennyi Ambar		Konoplyanka	
	Samples			
	Sintashta-Petrovka	Srubnaya-Alakul'	Mixed	Sintashta-Petrovka
Cattle – *Bos taurus*	4727	978	1489	392
Sheep – *Ovis aries*	570	132	150	20
Goat – *Capra hircus*	65	19	20	0
Small cattle (ruminants) – *Capra et Ovis*	3156	829	873	137
Horse – *Equus caballus*	521	96	286	46
Pig – S*us scrofa domestica*	54	13	17	5
Dog – *Canis familiaris*	112	27	38	20
Elk – *Alces alces*	2	0	0	0
Roe deer – *Capreolus pygargus*	2	0	1	1
Wild ox – *Bos primigenius*	1	0	0	0
Saiga – *Saiga tatarica*	2	0	0	0
Wolf – *Canis lupus*	12	4	2	0
Bear – *Ursus arctos*	4	0	0	0
Fox – *Vulpes vulpes*	32	4	6	1
Beaver – *Castor fiber*	10	0	3	1
Hare – *Lepus timidus*	3	0	1	
Marmot – *Marmota bobak*	75	16	52	1
Large ungulate – *Mammalia indet.*	2604	388	522	115
Small ungulate – *Mammalia indet.*	195	55	86	27
Mammals – *Mammalia indet.*	109	47	86	14
Birds – *Aves indet.*	5	0	0	0
Fish – *Pisces indet.*	2	6	3	0
Total, NISP	12263	2614	3635	780

Table 1. The species composition of archaeozoological assemblages from the Bronze Age settlements Kamennyi Ambar and Konoplyanka in the Karagaily-Ayat river valley (pcs).

Species and groups of species	Kamennyi Ambar		Konoplyanka
	Sintashta-Petrovka sample	Srubnaya-Alakul' period sample	Sintashta-Petrovka sample
Dog – *Canis familiaris*	0.9	1.0	2.6
Domesticated ungulates	74.2	79.1	76.9
Wild species	1.2	1.1	0.5
Indeterminable – Mammalia indet.	23.7	18.8	20.0
Total, NISP	12263	2614	780

Table 2. Ratio of dog bones and different species groups in %.

Let us consider the ratio of domestic ungulates remains (Table 3). The greatest variations between the asynchronous samples from the Kamennyi Ambar settlement were observed in the proportion of the remains of small ruminant; the deviation reached 5.8 %. The variations between other species were not as pronounced. This led to the conclusion about the lack of a noticeable difference in ratios between samples of domestic ungulates from the Sintashta-Petrovka period and the Srubnaya-Alakul' period. The ratios of domestic ungulates remains differed significantly in the Sintashta-Petrovka samples from those of the Kamennyi Ambar and Konoplyanka settlements (Table 3). In the Konoplyanka sample there was a significantly smaller proportion of small ruminants bones (26.2 %) than in the synchronous Kamennyi Ambar sample (41.7 %). Within the same sample the proportion of bovine cattle bones at Konoplyanka (65.3 %) was larger than at Kamennyi Ambar (51.6 %). The proportions of horses and pigs were roughly the same and variations did not exceed 3.1 %. In both settlements, the dominant species in the small ruminants group was sheep – about 95 %. The goat remains represented not more than 5 %. The similarity of the asynchronous samples from Kamennyi Ambar and their difference from the Konoplyanka sample became apparent in the cluster analysis (Fig. 1).

Type of animals	Kamennyi Ambar		Konoplyanka
	Sintashta-Petrovka sample	Srubnaya-Alakul' sample	Sintashta-Petrovka sample
Cattle – *Bos taurus*	52.0	47.4	65.3
Small ruminants – *Capra et Ovis*	41.7	47.4	26.2
Horse – *Equus caballus*	5.7	4.6	7.7
Pig – *Sus scrofa domestica*	0.6	0.6	0.8
Total bones, pcs.	9093	2067	600

Table 3. Ratio of domestic ungulates bones in %.

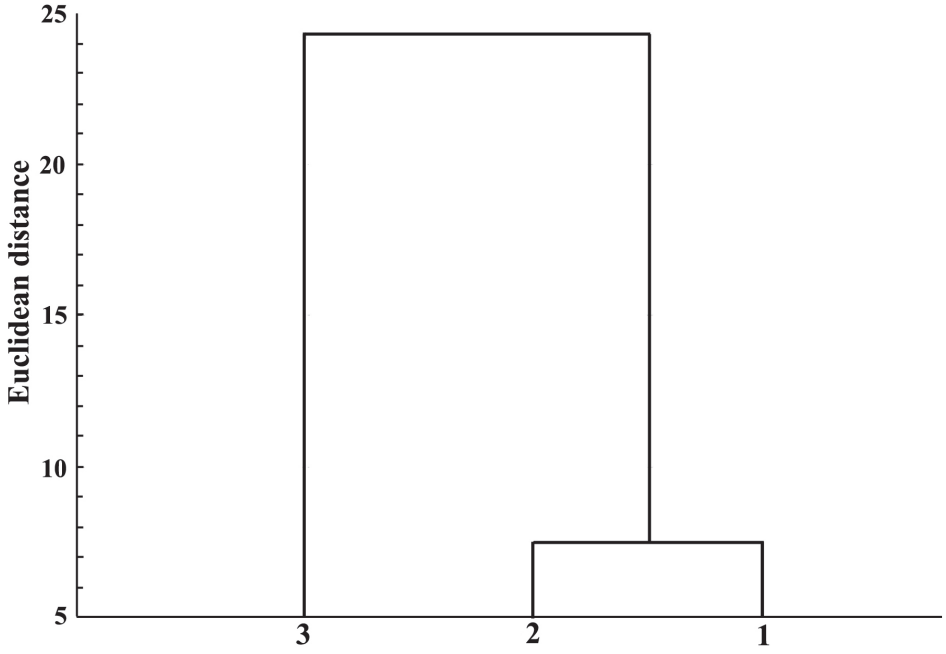

Fig. 1. The Sintashta-Petrovka (1) and the Srubnaya-Alakul' (2) samples from the Kamennyi Ambar settlement and the sample from the Sintashta-Petrovka period in Konoplyanka (3) in a similarity dendrogram with regard to the ratio of remains from domestic ungulates.

Bone fragmentation

The index of bone fragmentation was calculated by the proportion of indeterminable bones (Mammalia indet.) and the ratio of size groups within the category (Tables 2, 4). In the Sintashta-Petrovka and the Srubnaya-Alakul' samples from the Kamennyi Ambar and Konoplyanka settlements, the proportions of indeterminable fragments were 23.7 %, 18.7 % and 20 % respectively (Table 2). The variation between the samples was less than 5 %. Thus, we may assume a significant similarity of the samples in this parameter. However, the ratio of size groups within the indeterminable category of bone fragments demonstrates a different picture. The variation of "large ungulates" remains in both samples from the Kamennyi Ambar settlement was 10.3 %; the proportion of "small ungulates" remains differed almost by half (6.7 % and 11.2 %), whereas in the "indeterminable" category the proportion differed almost three times as much (3.8 % and 9.6 %) (Table 4). This difference is significant. At the same time the proportions of determinable large ungulates remains (bovine cattle, horse) in these samples were 57.7 % and 52.0 %, and the determinable small ungulates remains (small ruminants, pigs) were 42.3 % and 48.0 % respectively (Table 3). This variation is insignificant. Thus, the identified variation in the proportions of indeterminable remains, such as "large ungulates", "small ungulates" and the "indeterminable" could not be related to a different number of large and small ungulates in the samples. The aforementioned variations in the ratios attest that during the Sintashta-Petrovka period the large ungulates bones (bovine cattle, horses) were subject to more significant fragmentation, while the small ungulates bones (small ruminants, pigs) were less fragmented than during the Srubnaya-Alakul' period.

A significant variation in the ratios of size groups was observed between samples of the Sintashta-Petrovka cultural sample in the Kamennyi Ambar and Konoplyanka settlements (Table 4). The proportions of "large ungulates" in both sites differed by 16.2 %, while the variation in proportions of "small ungulates" was 10.6 % and of "indeterminable" 5.2 %. During the Sintashta-Petrovka period in Konoplyanka the large ungulates bones were fragmented to a lesser degree, whereas the small ungulates bones were subject to higher fragmentation than in Kamennyi Ambar.

Size group	Kamennyi Ambar		Konoplyanka
	Sintashta-Petrovka sample	Srubnaya-Alakul' period sample	Sintashta-Petrovka sample
"Large ungulates"	89.5	79.2	73.7
"Small ungulates"	6.7	11.2	17.3
"Indeterminable"	3.8	9.6	9.0
Total, NISP	2908	490	156

Table 4. The ratio of size groups within the category of indeterminable remains (Mammalia indet).

Composition of skeletal segments

We carried out a comparison between the proportions of various skeleton segments of bovine cattle, small ruminants, and horses. The ratios of skeleton segments of bovine cattle in samples of the Sintashta-Petrovka and the Srubnaya-Alakul' period in the Kamennyi Ambar settlement varied insignificantly (Table 5). There were small variations in the proportion of teeth – about 6 %. The ratio of skeleton segments in the Konoplyanka sample differed significantly from the ratio in the Sintashta-Petrovka sample from Kamennyi Ambar. This is reflected in the uneven distribution of body bones (23.7 % and 13.0 % respectively) and distal limbs bones (26.2 % and 39.4 % respectively). The ratios of skeleton segments in samples from small ruminants of the Sintashta-Petrovka and the Srubnaya-Alakul' period in the Kamennyi Ambar settlement were similar (Table 6). The ratio of skeleton segments in the Sintashta-Petrovka sample from the Konoplyanka settlement again differed from the Kamennyi Ambar sample. These differences were particularly evident in the uneven distribution of teeth (24.2 % and 13.5 % respectively) and distal limb bones (16.7 % and 25.9 % respectively). The ratios of horse skeleton

segments demonstrate significant variations (Table 7). However, the sample sizes of the Srubnaya-Alakul' period from the Kamennyi Ambar and Konoplyanka settlements were rather small. Given the small size of the samples, the effect of random factors increases, and in this case could be the reason for the aforementioned variations. A common characteristic of all samples of horse remains is the presence of bones from all skeleton segments.

The analysis has demonstrated that in all samples the bones from all skeleton segments of all groups of species were represented. The very presence of each segment of all species is important. This indicates that butchering and meat consumption occurred mostly in the settlements. The variations between the ratios of skeleton segments of bovine cattle and small ruminants in the asynchronous samples from the Kamennyi Ambar settlement were insignificant. Thus, we may assume that the Kamennyi Ambar population followed the same butchering and meat consumption patterns during the Sintashta-Petrovka and the Srubnaya-Alakul' periods. On the other hand, ratios of

Skeleton segment	**Settlements**		
	Kamennyi Ambar		**Konoplyanka**
	Sintashta-Petrovka sample	**Srubnaya-Alakul' sample**	**Sintashta-Petrovka sample**
Head	12.6	14.4	14.2
Teeth	13.2	19.2	11.2
Body	13.0	11.0	23.7
Proximal limbs bones	21.5	16.6	24.4
Distal limbs bones	39.4	38.5	26.2
Total bones, NISP	4727	978	392

Table 5. Ratio of cattle skeleton segments in samples from Kamennyi Ambar and Konoplyanka.

Skeleton segment	**Settlements**		
	Kamennyi Ambar		**Konoplyanka**
	Sintashta-Petrovka sample	**Srubnaya-Alakul' sample**	**Sintashta-Petrovka sample**
Head	13.6	12.2	19.7
Teeth	13.5	14.2	24.2
Body	15.2	19.2	12.7
Proximal limbs bones	31.6	27.5	26.7
Distal limbs bones	25.9	26.6	16.5
Total bones, NISP	3791	980	157

Table 6. Ratio of skeleton segments of small ruminants in samples from Kamennyi Ambar and Konoplyanka.

Skeleton segment	**Settlements**		
	Kamennyi Ambar		**Konoplyanka**
	Sintashta-Petrovka sample	**Srubnaya-Alakul' sample**	**Sintashta-Petrovka sample**
Head	5.9	6.1	6.9
Teeth	9.8	20.4	16.2
Body	9.4	19.3	18.6
Proximal limbs bones	24.0	17.3	37.2
Distal limbs bones	50.6	36.7	20.9
Total bones, NISP	521	96	46

Table 7. Ratio of skeleton segments of horse in Kamennyi Ambar and Konoplyanka samples, %.

skeleton segments of the same types of animals in the synchronous samples from the Kamennyi Ambar and Konoplyanka settlements differed significantly. Hence, the question is - why? Is this a reflection of different butchering techniques and different patterns in the consumption of the meat of these animals, or were there other reasons? As mentioned above, the bone samples from the two settlements were formed differently, which could explain the differences. So far, there is no straightforward answer to the question about the reasons for these differences.

Age composition of domestic ungulates

Cattle

The analysis of the slaughter age of bovine cattle demonstrates that in the Sintashta-Petrovka sample more than one-half of the animals belonged to the group of juveniles and subadult (Table 8). Most cows of that age did not yet calve and produce milk or were only beginning to do so. The slaughtering of a significant number of young animals indicates that meat was as important as milk in the food ration. We already determined the slaughter age for a small group of animals (Bachura 2013). In the Sintashta-Petrovka sample, we determined the age of 23 animals in the bovine cattle group. No animals were older than 7–8 years in that sample. In the Srubnaya-Alakul' sample, we determined the age of 6 animals in the bovine cattle group, all of which were not older than 5–6 years. In both Kamennyi Ambar samples there were several pieces of bovine cattle jaw bones with signs of severe tooth attrition. This is evidence that only very few animals lived to an old age. The Srubnaya-Alakul' sample from Kamennyi Ambar and the sample from the Konoplyanka settlement were quite small; their size was insufficient for a sound interpretation. It may be assumed with a high degree of probability that during the Srubnaya-Alakul' period in Kamennyi Ambar mostly adult animals in the bovine cattle group were slaughtered.

Teeth condition	Age, month	Kamennyi Ambar		Konoplyanka
		Sintashta-Petrovka sample	Srubnaya-Alakul' sample	Sintashta-Petrovka
M3 present	Over 30	47.5	58.8	61,1
M2 present, no M3	18–30	26.8	23.5	27,7
M1 present, no M2	6–18	21.9	5.8	0
no M1	Below 6	3.6	11.6	11,1
Total bones, pcs.		164	17	18

Table 8. Slaughter age of cattle in Kamennyi Ambar and Konoplyanka samples, %.

Small ruminants

The sample sizes from Konoplyanka and the Srubnaya-Alakul' complex from Kamennyi Ambar are rather small. The age composition of juvenile to adult small ruminants in the Sintashta-Petrovka sample from the Kamennyi Ambar and Konoplyanka settlements was quite similar. More than one-half of the slaughtered animals were juvenile and subadult (Table 9). In the Srubnaya-Alakul' sample these groups amounted to less than one-half, adult animals were predominant. This gave reason to assume that in the Sintashta-Petrovka period small ruminants were kept for meat rather than for wool production. In the Srubnaya-Alakul' period the emphasis shifted towards wool production. We already determined the slaughter age for a small group of animals (Bachura 2013). In the Sintashta-Petrovka sample, we determined the age of 13 animals in the group of small ruminants. No animals were older than 5–6 years in that sample. In the Srubnaya-Alakul' sample, we determined the age of

Teeth condition	Age, month	Kamennyi Ambar		Konoplyanka
		Sintashta-Petrovka sample	Srubnaya-Alakul' sample	Sintashta-Petrovka
M3 present	Over 24	48.6	56.5	41,1
M2 present, no M3	12–24	42.9	38.4	47,2
M1 present, no M2	6–12	7.6	5.1	11,7
no M1	Below 6	0.9	0	0
Total bones, pcs.		210	39	39

Table 9. Slaughter age of small ruminants in Kamennyi Ambar and Konoplyanka samples, %.

5 animals in the group of small ruminants, all of which were not older than 6–7 years of age. In both Kamennyi Ambar samples there were several pieces of jaw bones with signs of severe tooth attrition. This is evidence that only very few animals lived to an old age. Apparently, the settlement inhabitants preferred to eat the meat from young animals.

Horses

The age composition of slaughtered horses can only be interpreted for the Sintashta-Petrovka period, because the sample for the Srubnaya-Alakul' period was rather small (Table 10). The largest group was that of adult animals. The proportions of animals slaughtered at young, semi-adult, and old age were approximately the same. This age composition gave reason to assume that the inhabitants of Kamennyi Ambar used horses for various purposes during the Sintashta-Petrovka period. The young and semi-adult horses were normally not used for riding or as draught animals; they were slaughtered for meat. The significant proportion of animals in these groups (47.8 %) suggests the "meat" specialization in horse breeding by the Kamennyi Ambar population during that period. At the same time the significant proportion of adult and old animals might be evidence that the horses were also used as draught animals in situations where agility and stamina were required, as well as for other economic purposes.

The results of the study on epiphyses adherence confirmed the above conclusions. The settlement inhabitants slaughtered approximately equal numbers of young and adult animals in the groups of bovine cattle and small ruminants. Almost half of the horses were slaughtered at a young and semi-adult age (up to 5 years). According to data on slaughter-season determination in Kamennyi Ambar (Bachura 2013), both bovine cattle as well as

Age	Kamennyi Ambar	
	Sintashta-Petrovka sample	Srubnaya-Alakul' sample
Young	24.0	0
Semi-adult	24.0	7.6
Adult	34.7	61.5
Old	17.3	30.7
Total bones, pcs.	46	13

Table 10. Slaughter age of horses in the Kamennyi Ambar sample, %.

small ruminants were slaughtered during the time from autumn to spring. We found no evidence for slaughtering in the summer months.

Bone sizes of domestic ungulates

The study of bone sizes of domestic ungulates pursued two goals: 1) reconstruction of the animal size, and 2) assessment of the degree of uniformity in bone size (i.e. whether the bones belonged to animals of one size or of different size groups). For this purpose we compared the sizes of the talus bones, phalanx I and phalanx II of bovine cattle, and the talus bones and phalanx I of sheep in the Sintashta-Petrovka and the Srubnaya-Alakul' samples. The reason for choosing these bones was their sample representativeness. Samples of horse and pig bones from Kamennyi Ambar and all samples from Konoplyanka were not representative; therefore, they were excluded from the analysis. We measured only phalanges with adherent epiphyses. In the talus group, the measurements were taken on the bones with completely formed bone tissue. In the bovine-cattle group, these were the animals of more than 1.5–2 years of age, and in the sheep group of more than 1 year of age.

Cattle

The sizes of talus and phalanx II bones of bovine cattle in both samples were statistically identical (Tables 11, 12). However, phalanx I in the Srubnaya-Alakul' sample was larger than in the Sintashta-Petrovka sample (Table 12). Variations in the anterior length between them by t-criterion were true at a 5 % confidence level. We calculated the height of bovine cattle at the shoulder, according to the greatest length of the lateral half of the talus (Tsalkin 1970, 162). In the Sintashta-Petrovka sample, this varied from 114 cm to 139 cm; in the Srubnaya-Alakul' sample the height varied from 114 cm to 137 cm; i.e. the average height of the cattle is very similar. We consider the bovine cattle in the Sintashta-Petrovka and the Srubnaya-Alakul' periods to have been of the same size.

We performed a multidimensional analysis of talus-bone size in both samples using the principal component analysis method (PCA). Thereby we considered the position of bones only on the first two principal components axes (PC1 and PC2) since they covered 96.8 % of the dispersion (Table 13). They completely overlapped (Fig. 1). This reflects a significant similarity of bone sizes in both samples. The analysis of bone distribution along the axes demonstrates that each sample along the PC1 axis formed two groups: a small group on the left side and a larger group on the right side. The boundary between the groups runs between PC1 values -0.5 to -0.2 (Fig. 1). The group on the left side was formed by bones with the largest sizes, the group on the right side – by smaller bones. We

Attribute	n	Lim	M±m	σ
Sintashta-Petrovka sample				
Greatest length of the lateral half	33	61.2 – 74.7	66.8±0.7	4.1
Greatest length of the medial half	34	56.6 – 68.8	61.8±0.6	3.6
Length of the sagittal	35	46.3 – 58.8	52.3±0.5	3.1
Greatest breadth of the distal end	33	38.4 – 52.2	44.3±0.7	4.3
Greatest depth of the lateral half	32	33.7 – 43.3	37.8±0.5	2.7
Srubnaya-Alakul' sample				
Greatest length of the lateral half	16	61.3 – 73.5	66.6±0.8	3.4
Greatest length of the medial half	16	57.1 – 67.5	61.7±0.7	2.9
Length of the sagittal	17	47.5 – 57.5	52.0±0.6	2.6
Greatest breadth of the distal end	13	38.4 – 49.1	43.3±0.9	3.4
Greatest depth of the lateral half	14	33.8 – 42.0	37.5±0.6	2.3

Table 11. Sizes of talus bones of cattle (*Bos taurus*) from Kamennyi Ambar.

Attribute	n	Lim	M±m	σ
Phalanx I				
Sintashta-Petrovka sample				
Anterior length	107	42.1 – 67.7	53.6±0.5	4.7
Breadth of the proximal end	106	22.2 – 43.4	30.0±0.3	3.5
Smallest breadth of the diaphysis	109	21.2 – 35.5	26.4±0.3	3.3
Breadth of the distal end	96	23.5 – 39.2	29.2±0.3	3.4
Srubnaya-Alakul' sample				
Anterior length	21	51.0 – 67.8	56.4±1.0	4.5
Breadth of the proximal end	21	26.6 – 35.7	31.8±0.6	2.9
Smallest breadth of the diaphysis	21	21.6 – 33.1	27.3±0.7	3.1
Breadth of the distal end	19	25.4 – 37.3	31.3±0.7	3.2
Phalanx II				
Sintashta-Petrovka complex				
Greatest length	31	33.2 – 44.4	38.4±0.4	2.7
Anterior length	32	32.4 – 40.8	36.2±0.5	2.4
Breadth of the proximal end	31	26.1 – 36.7	30.3±0.5	2.7
Smallest breadth of the diaphysis	35	20.1 – 31.8	22.4±0.5	2.7
Breadth of the distal end	28	21.3 – 32.6	24.8±0.5	2.7
Srubnaya-Alakul' complex				
Greatest length	4	35.2 – 43.8	38.2±1.9	3.8
Anterior length	4	32.9 – 40.9	35.8±1.8	3.5
Breadth of the proximal end	4	27.7 – 34.2	29.8±1.5	3.0
Smallest breadth of the diaphysis	4	21.6 – 27.2	23.6±1.2	2.5
Breadth of the distal end	4	22.6 – 27.5	24.8±1.0	2.0

Table 12. Sizes of phalanx I and phalanx II of cattle (*Bos taurus*) from Kamennyi Ambar.

Attributes	PC1	PC2
Greatest length of the lateral half	-0.98	-0.15
Greatest length of the medial half	-0.97	-0.18
Length of the sagittal	-0.98	-0.05
Greatest breadth of the distal end	-0.91	0.41
Greatest depth of the lateral half	-0.96	-0.01
Dispersion, %	92.3	4.5

Table 13. Cattle talus from the Kamennyi Ambar settlement; attribute contribution to the factor analysis of principal components.

believe that this distribution reflects the gender dimorphism of bovine cattle, which was well-marked in that group. The left-side group was formed by bull bones, and the right side – by cows. Accordingly, in the Sintashta-Petrovka sample, there were 7 bull bones and 24 cow bones; i.e. the ratio was approximately 1:3. In the Srubnaya-Alakul' sample, there were 3 bull bones and 9 cow bones; i.e. the ratio was approximately 1:3, too. At birth the cattle gender ratio approached 1:1. In order to reach the ratio of approximately 1:3, approximately two-thirds of the bulls must have been slaughtered during the first 1.5 to 2 years of life. The remaining bulls were slaughtered at older ages. This demonstrates that the structure of slaughtering bovine cattle during the Sintashta-Petrovka and the Srubnaya-Alakul' periods was very similar and rational. Bulls were mostly used for meat production. Meat increment in the semi-adult and adult age is quite small and does not justify the costs of their feeding. Therefore, it was not

economically viable to keep all the bulls born until they reached maturity; hence, most of them were slaughtered at a younger age. In all probability, the settlement inhabitants tried to save all cows for milk production.

It should be noted that one bone in the Sintashta-Petrovka sample was located separately in the diagram, in the lower left corner (Fig. 1). It was the largest bone. Its isolated position demonstrates that it probably belonged to another sample. One of the animals that existed in the territory of the southern Trans-Ural at that time was the wild ox (*Bos primigenius*) — the wild ancestor of domestic cattle (Kosintsev/Bachura 2013). The size of wild ox bones, particularly of the bulls, was much larger than the bone size of domestic cattle of the Late Bronze Age (Tsalkin 1970, 64–65).

Sheep

The sizes of talus bones in the Sintashta-Petrovka sample were larger than those in the Srubnaya-Alakul' sample (Table 14). Variations were observed not only in the average attributes values, but also in their variation limits (Min–Max). In the Sintashta-Petrovka sample, the minimum and the maximum bone sizes were larger than in the Srubnaya-Alakul' sample (Table 14). The greatest length of the lateral half and the greatest depth of the lateral half variations by t-criterion were true at a 5 % confidence level. There were no variations in the samples of the phalanx I size. We calculated the sheep height at the shoulder by the greatest length of the lateral half of the talus (Teichert 1975). In the Sintashta-Petrovka phase, it varied from 65 cm to 85 cm, i.e. 75 cm on average. In the Srubnaya-Alakul' period, this value varied from 64 cm to 80 cm, i.e. 72 cm on average. It seems that sheep were larger in size during the earlier phase.

Attribute	n	Lim	M±m	σ
Talus				
Sintashta-Petrovka sample				
Greatest length of the lateral half	45	28.8 – 37.8	33.2±0.3	1.7
Greatest length of the medial half	43	27.3 – 35.8	31.9±0.3	1.9
Length of the sagittal	47	22.6 – 29.9	26.6±0.2	1.5
Greatest breadth of the distal end	40	18.1 – 24.1	21.5±0.2	1.3
Greatest depth of the lateral half	45	15.2 – 20.4	18.5±0.2	1.2
Srubnaya-Alakul' sample				
Greatest length of the lateral half	33	28.4 – 35.5	32.1±0.3	2.0
Greatest length of the medial half	32	26.9 – 34.5	30.8±0.4	2.2
Length of the sagittal	34	22.7 – 29.0	25.8±0.3	1.6
Greatest breadth of the distal end	32	17.8 – 24.4	20.8±0.3	1.5
Greatest depth of the lateral half	34	15.0 – 20.0	17.8±0.2	1.3
Phalanx I				
Sintashta-Petrovka sample				
Anterior length	27	34.6 – 42.5	38.2±0.5	2.5
Breadth of the proximal end	29	12.8 – 15.5	14.1±0.2	0.8
Smallest breadth of the diaphysis	30	9.8 – 13.7	11.7±0.2	1.0
Breadth of the distal end	27	10.5 – 15.9	13.3±0.3	1.3
Srubnaya-Alakul' sample				
Anterior length	11	34.1 – 41.0	38.0±0.7	2.2
Breadth of the proximal end	11	13.0 – 15.6	14.3±0.3	0.8
Smallest breadth of the diaphysis	11	10.8 – 12.9	11.7±0.2	0.8
Breadth of the distal end	11	12.0 – 14.2	13.0±0.2	0.7

Table 14. Sizes of talus and phalanx I of sheep (*Ovis aries*) from the Kamennyi Ambar settlement.

We performed a multidimensional analysis of the talus size in both samples using the principal component analysis method (PCA). Thereby, we considered the position of the bones only in the first two principal components axes (PC1 and PC2), since they covered 95.1 % of the dispersion (Table 15). The samples almost completely overlapped (Fig. 2). However, the Sintashta-Petrovka sample slightly shifted left along the axis PC1 with regard to the Srubnaya-Alakul' sample. This reflects the larger sheep-bone sizes of that time. The analysis of the bones' distribution along the axes demonstrates that each sample formed two groups along the PC1 axis – a small group on the right side and a larger group on the left side. The boundary between them ran between PC1 values 1.0 to 1.3 (Fig. 3). The right-side group was formed by the smaller bones, while the left-side group consisted of large bones. The analysis revealed the existence of two groups of different-sized animals in the sheep herd: a significant number of the large ones and a few small ones. The male sheep were larger than female sheep; therefore, this distribution apparently reflects the gender dimorphism. The left-side group was formed by ram bones, and the right-side group by sheep bones. Thus, in the Sintashta-Petrovka sample there were 33 ram bones and 4 sheep bones; i.e. the ratio was approximately 1:8. In the Srubnaya-Alakul' sample there were 23 ram bones and 7 sheep bones; i.e. the ratio was approximately 1:3. These ram and sheep ratios were observed for animals of more than 1 year of age. At birth, the gender ratio was close to 1:1. In order to result in the ratios of 1:8 and 1:3, it was necessary to slaughter a large number of sheep during the first year of life. In the Sintashta-Petrovka period, approximately 90 % of sheep were slaughtered at that age, and in the Srubnaya-Alakul' period – about 70 %. This demonstrates that the sheep-slaughtering structure during the Sintashta-Petrovka and the Srubnaya-Alakul' periods was different. If the above

Attributes	PC1	PC2
Greatest length of the lateral half	-0.98	0.10
Greatest length of the medial half	-0.97	0.17
Length of the sagittal	-0.96	0.16
Greatest breadth of the distal end	-0.93	-0.34
Greatest depth of the lateral half	-0.95	-0.11
Dispersion, %	91.4	3.7

Table 15. The contribution of sheep talus from Kamennyi Ambar attributes to the factor analysis principal components.

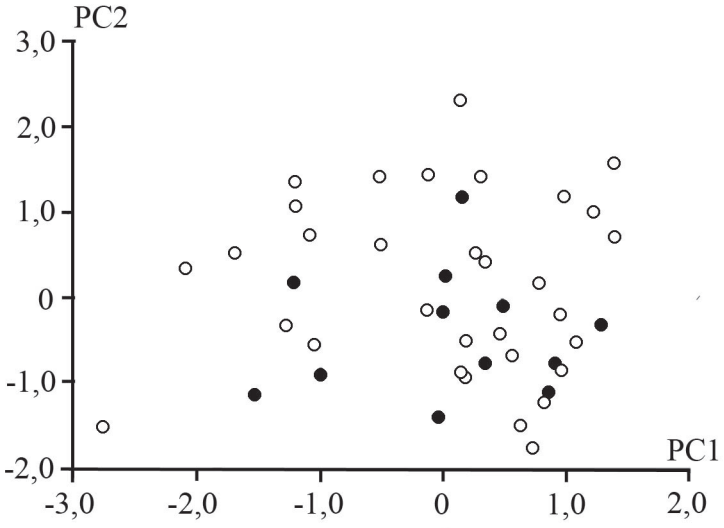

Fig. 2. PCA plot showing the distribution of cattle (*Bos taurus*) talus bones from Kamennyi Ambar (empty circles: Sintashta-Petrovka sample; filled circles: Srubnaya-Alakul' sample).

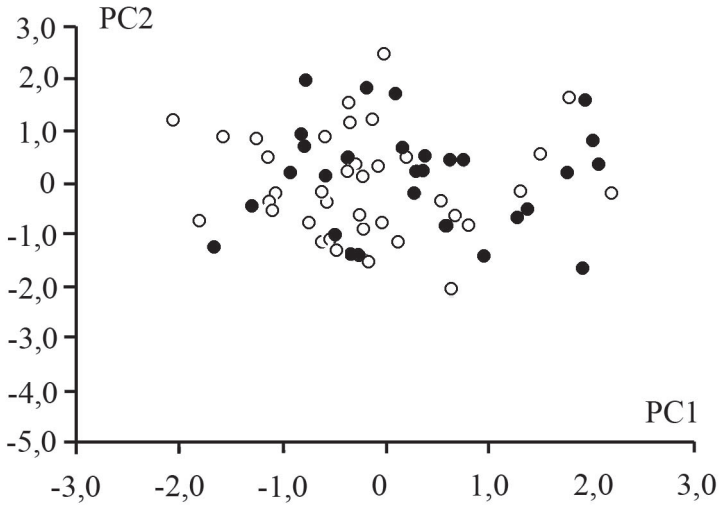

Fig. 3. PCA plot of the distribution of sheep (*Ovis aries*) talus bones from Kamennyi Ambar (empty circles: Sintashta-Petrovka sample; filled circles: Srubnaya-Alakul' sample).

interpretation of the multidimensional analysis is true, the herds in both periods consisted mostly of rams. The reasons are not quite clear, since in addition to meat and wool sheep could also produce some milk. We assume that the ancient sheep produced very little milk, and that it was economically more profitable to have more rams which produced more meat and wool.

Meat diet system

For the reconstruction of the meat diet system, we applied the methodology developed by the Science Research Methods Laboratory of the Institute of Archeology RAS (Antipina 2013). The calculation of the volume of meat products demonstrates that in both settlements beef was the dominant product in meat diet during all periods of their occupation (Table 16). Mutton and horse meat constituted an insignificant part of the meat ration of the two settlements' population in approximately equal proportions (Table 16). Neither pork nor game made any significant contribution to the food ration.

Prior to summing up our characterization of bone remains from the Kamennyi Ambar and Konoplyanka settlements let us briefly discuss two problems.

The first problem is whether the studied bone samples matched the cultural and chronological periods during the occupation of the Kamennyi Ambar settlement. We assumed that the Sintashta-Petrovka and the Srubnaya-Alakul' period bone samples formed parallel to the respective types of pottery. At the same time, it was assumed that the bones were distributed in the cultural level in the same way as the ceramics. However, that assumption could have been wrong. If the bones distribution was different from that of the ceramics, we would have obtained a random sample of mechanically mixed bones from different periods. As a result, the characteristics of those samples would have been averaged, and there would be no differences between them.

Settlements	Beef	Mutton	Horse meat
Kamennyi Ambar (the Sintashta-Petrovka period)	81.0	10.8	8.1
Kamennyi Ambar (the Srubnaya-Alakul' period)	79.6	13.3	7.0
Konoplyanka	85.1	5.6	9.1

Table 16. Meat consumption ratios in the Kamennyi Ambar and Konoplyanka settlements, %.

The bone samples analyses shown above could be used as a test of whether our assumption was correct. It demonstrates that in a number of characteristics the samples under study were different. In the Sintashta-Petrovka period the large ungulates bones (bovine cattle, horses) were subject to a more significant fragmentation, whereas the small ungulates bones (small ruminants, pigs) were less fragmented than during the Srubnaya-Alakul' period. The Sintashta-Petrovka and the Srubnaya-Alakul' samples also differed significantly in the number of modified bones (see Chapter 13). The sizes of cattle and sheep bones in both samples differed significantly, too. In addition, the inhabitants of the Sintashta-Petrovka and the Srubnaya-Alakul' periods followed distinct sheep-slaughtering strategies. The characteristics by which the samples were compared were independent of each other. This indicates that the samples under study from the Sintashta-Petrovka and the Srubnaya-Alakul' periods had their own specific characteristics and were independent. That is, the samples were formed mostly from the bones belonging to different populations matching different cultural and chronological periods in the occupation of the Kamennyi Ambar settlement. They might be used for characterising the animal husbandry practiced by the inhabitants of the Kamennyi Ambar settlement during the Sintashta-Petrovka and the Srubnaya-Alakul' periods.

The second problem is whether the sample from Konoplyanka is characteristic for animal husbandry practices in that settlement. Comparison of the Sintashta-Petrovka samples from the settlements of Kamennyi Ambar and Konoplyanka demonstrates significant differences between them in the ratios of domestic ungulates remains and the ratios of skeleton segments of bovine cattle and small ruminants. In the Konoplyanka sample bones of domestic ungulates were more fragmented. This could reflect significant differences in animal husbandry and utilization practiced by the populations of these settlements. From that followed the question about the reason for these differences. Did they reflect the existence of actual differences in animal husbandry, or could they be related to some other factors? The data on the methodology used in the formation of the samples could provide an answer to this question. As mentioned before, the Kamennyi Ambar sample was formed by bones originating from different sections of the settlement and provided the averaged characteristics of bones from the Sintashta-Petrovka period. The Konoplyanka sample was obtained from one cultural layer section and produced the characteristics of the local bone group. These characteristics could differ significantly from the averaged ones, which could have been obtained by samples taken from different sections of the settlement. Therefore, at this stage we do not have a simple answer to the question about the reason for the revealed differences between the bone samples from these settlements. In view of a larger size of the Sintashta-Petrovka sample from the Kamennyi Ambar settlement, we would assume that it characterises the animal husbandry practices of the population in the Karagaily-Ayat river basin during the early period.

In the group of domestic ungulates the dominant species were bovine cattle and sheep bones. There were few remains of horses or, particularly, pigs. The use of cattle and small ruminants as well as horses during the Sintashta-Petrovka period was not specialized. These animals were used as a source of various products. Bovine cattle was a source of meat and milk; small ruminants – of meat and wool; horses were used both for meat and in situations requiring agility and stamina (military actions), as well as draught animals (for hauling heavy loads).

We do not have sufficient data for the reconstruction of the use of domestic ungulates during the Srubnaya-Alakul' period in the Konoplyanka settlement. We may only state that the use of small ruminants during the Srubnaya-Alakul' phase in the Kamennyi Ambar settlement did not change significantly. Variations between ratios in skeleton segments of bovine cattle and small ruminants in the asynchronous samples from the Kamennyi Ambar settlement were insignificant. However, there were significant differences in the degree of bone fracturing. This allows the assumption that the population of the Kamennyi Ambar settlement during the Sintashta-Petrovka and the Srubnaya-Alakul' periods used the same butchering practices. However, patterns in meat consumption display certain differences. These differences, apparently, were manifested at the stage of cooking and eating meat. During the Sintashta-Petrovka period bovine cattle and horse bones were more fractured, while the small ruminants' bones were less fractured. The reasons for these differences are not yet clear.

The results of the study on bone remains from Kamennyi Ambar and Konoplyanka demonstrate that the dominant species in all samples were domestic ungulates. Animal husbandry was the basis for the life support system of the excavated settlements in all stages of their occupation. This conclusion is also supported by the archaeobotanic data, which did not reveal any traces of agriculture (Stobbe 2013; Rühl et al. 2015; Stobbe et al. 2016). Apparently, the principal type of domestic animal in the economy and life support system of the Middle and Late Bronze Age population in the Karagaily-Ayat valley was bovine cattle. It was the main source of meat

and milk for the people. During all periods very little milk was obtained from small ruminants. The goat population was small, and sheep herds consisted mostly of rams. The role played by small ruminants and horses was significantly less than that of bovine cattle. Pigs contributed very little to the economy of the Kamennyi Ambar and Konoplyanka settlements. The role of hunting was also insignificant. Some scholars suggested earlier that fish could have been an important component in the Kamennyi Ambar population's diet (Stobbe et al. 2013). However, there are some arguments against this hypothesis (Sharapov/Korliakov 2016; Hanks et al. 2018).

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