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Economy of the Kazakh steppe populations during the construction of geoglyphs in Turgai region, Kazakhstan

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1. Introduction

1.1. State of the art

Monumental geometric structures extending up to 500 m in length, known as geoglyphs of Turgai, were discovered in 2007 in north Kazakhstan through the Google Earth imagery. Since the time of their discovery, around 69 geoglyphs were found and documented. The structures are spread around the territory of Turgai deflection in Kazakhstan steppe (fig. 1).

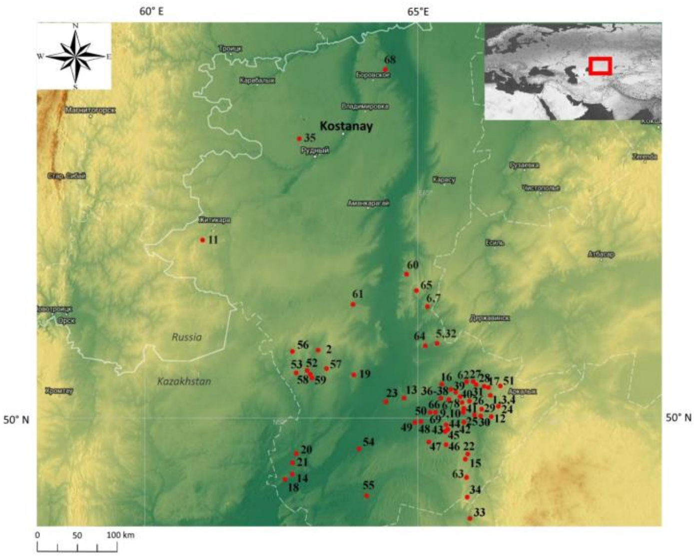


Figure 1: Locations and distribution of the geoglyphs in Turgai deflection. 1.Ashutasty line, 2.Ashibutak line, 3.Small Ashutasty cross, 4.Big Ashutasty cross, 5.Ushtogaiskyi square, 6.Aksai line, 7.Aksai ring, 8.Karatugai line, 9.Karatugai ring, 10.Karatugai cross, 11.Zhitikarin line, 12.Kayindy ring, 13.Suyindik ring, 14.Akshyganak cross, 15.Zharsai cross, 16.Mahat cross, 17.Arshaly lines, 18.Akshyganak line, 19.Andagul line, 20.Eginkol line, 21.Zhaltytobe line, 22.Zharsai line, 23.Zharyk line, 24.Zhasaly line, 25.Kayindy line, 26.Karabulak line, 27.Kyzylkan line, 28.Tasty line, 29.Tortkotai line, 30.Shilisai line, 31.Turgai ring, 32.Ushtogai line, 33.South Turgai cross, 34.South Turgai ring, 35.Rudnensk line, 36.Zhaldama line, 37.Zhaldama ring, 38.Kyzylkol line, 39.Zhaldama cross, 40.Tastemir line, 41. Shinsai lines, 42.Egindy cross, 43.Karabidayik line, 44.Uirek line, 45.Azerbai line, 46.Zholoba line, 47.Alasor line, 48.Alakol ring, 49.Alakol lines, 50.Koszhan lines, 51.Koktau lines, 52.Boget line, 53.Koktas line, 54.Kuat line, 55.Kyzyloba line, 56.Ashily line, 57.Mul’kolyan line, 58.Saikuduk line, 59.Tazhen line, 60.Shiily line, 61.Akbulak line, 62.Shoptikol line, 63.Uderbai line, 64.Sandyktau line, 65.Terisbutak ring, 66.Karaoba line, 67.Kagaly line, 68.Zhandra

swastika, 69.Ritual complex Upek (Turgai swastika). The map was modified after Logvin et al. (2018a)

"Geoglyphs of Turgai" is a popular name of the Kazakhstan structures used in press and public educational materials. However, the Turgai structures are often referred to as "geometric earthworks" or "ritual complexes". "Geoglyph" is a term used for describing the earthen geometric shapes made by creating a relief on the soil surface. In comparison to the world-known geoglyph structures such as the lines of Nazca valley, Turgai geoglyphs are made by a series of earthen mounds placed at equal spaces between each other. They were constructed out of the soil; no stone or other material was used. Before the construction, the surface of the top soil selected for a mound earth construction was cleaned and evened up (Logvin et al., 2018b). Then, individual mounds of the geometric earthworks were built using the loose soil and forming various geometric shapes.

The geoglyphs made of mounds that depict lines (n=52; size = 32-680 m.), crosses (n=9; size = 75-436 m.), rings (n=9; size = 30-170 m.), and a square (n=1; size = 287x287 m.), (fig. 1). Some geoglyphs were constructed in groups of two parallel lines, two unparalleled lines, a line, and a ring. Two swastika structures were also discovered in Turgai. However, these geometric earthworks were made out of a single rampart shaped as swastika (triskelion), instead of mounds (fig. 2). Therefore, they might represent a different episode of construction.

Geoglyphs of Turgai were first mentioned in I. A. Kastanye's book "Drevnosti Kirgizskoi Stepi I Orenburgskogo Kraya" (Kastanye, 1910). A structure discovered in Turgai oblast was described as "*a large number of kurgans, arranged in rows that follow the line order and make geometric shapes such as triangles and squares*". The information about the structure was provided by a researcher B. A. Skalov at a meeting of the Orenburg Scientific Archive Committee in 1909. Description of the site and its location given in the book suggested that B. A. Skalov was talking about Ushtogaiskyi square (fig. 2, D).

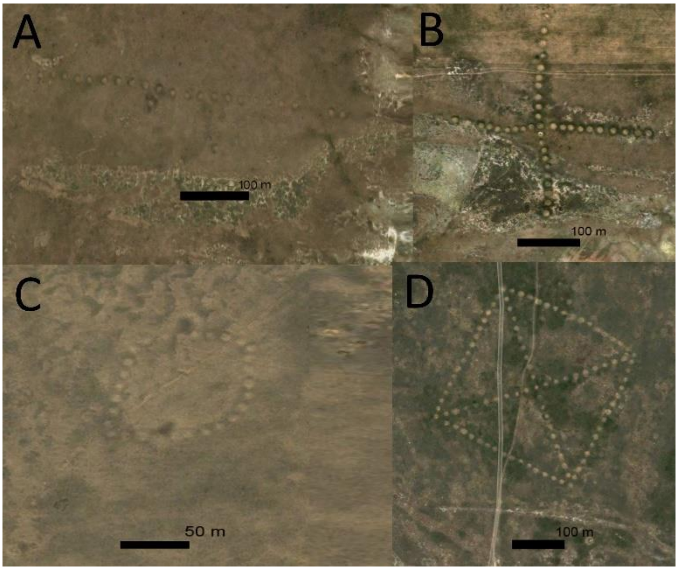


Figure 2: Examples of the different geoglyph structures of Turgai. A:Zhosaly line, B: Big Ashutasty cross, C: Suyindyk ring, D: Ushtogaiskyi square

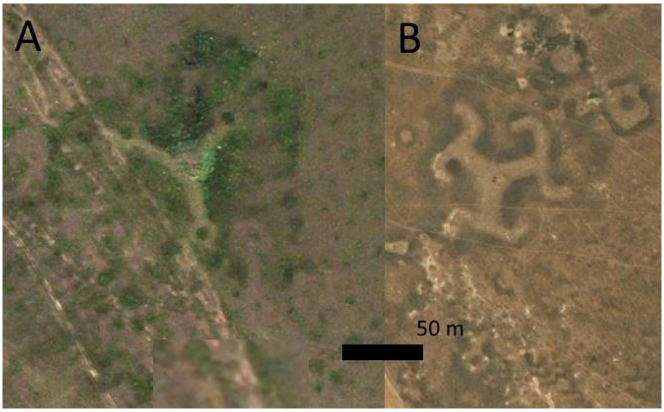


Figure 3: Swastika structures of Turgai. A: Zhandra swastika, B: Turgai swastika

In 2007, Ushtogaiskyi square was discovered for the second time by an amateur researcher Dmitryi Dei through the Google Earth imagery. Soon after this discovery, Dei identified another geometric structure currently known as Turgai swastika (fig. 3). Dei decided to contact a Kostanay State University archaeologist Andrei Logvin, with whom they traveled to Ushtogaiskyi square and Turgai swastika for the first time to carry out the preliminary investigations. One of the mounds of Ushtogaiskyi square was excavated (Logvin et al. 2011), but no artifacts or organic remains were discovered.

In 2013 a mound of Small Ashutasty cross was excavated. No artifacts or organic remains were discovered. One of the structures discovered next to Turgai swastika (fig. 3, right image) was also excavated but yielded no archaeological finds (Logvin et al., 2018a). A geophysical survey conducted around the excavated areas did not reveal any sub-surface constructions.

In 2015, Motuzaite Matuzeviciute et al. published two optically stimulated luminescence (OSL) dates from the Big Ashutasty Cross and the Ring of Turgai, which showed that the structures were constructed around 800-750 cal. BC. Additionally, a single caprine bone fragment discovered in the mound of the Ring of Turgai had shown a ^{14}C date of AD 42-85 cal.

By 2017 over 61 geometric earthwork sites in Turgai had been visited and studied in the field (Logvin et al., 2018b). In 2018, A. Logvin and his team published a monograph, where they described all known geometric earthworks and the research conducted since the time of their discovery.

Since the time of the geoglyphs discovery, a team of researchers, led by the original explorer of the Turgai geoglyphs - Dmitryi Dei, has been visiting and studying the sites and surrounding landscape. His major aim is to draw the attention of the publicity to the problem of preservation of the unique structures and ensure they can be protected and managed.

Every year, archaeologists and amateur researchers discover new geoglyphs through satellite imagery. Unfortunately, some of them are already partially destroyed by the time of their discovery by the modern human impact (fig. 4). The absence of any management of this valuable heritage puts the structures under risk of destruction in several years. However, in order to organize the protection measures, more information has to be acquired first. Due to the lack of information about the geoglyphs of Turgai, all sorts of speculations started to develop that aimed to “explain” the nature of the structures. Inside the archaeological science, the theories about the geoglyphs include “the landmark hypothesis” (Motuzaite Matuzeviciute et al., 2015b), “the sacred place theory”, and “the astronomical observation theory” (Logvin et al., 2018a). However, in the publically available World Wide Web resources, one can find a variety of pseudo-archaeological hypotheses, including non-human origins of the structures and the signs of pre-human civilizations. In the absence of the commonly accepted theory about the structures, the publicity often receives wrong information, which attracts people, who might want to destroy or “excavate” the geoglyphs illegally. An example of such behavior is coming from the Balkans, where pseudo-archaeological explanations for the natural stone formations, known as “Bosnian Pyramids” in the popular culture, possibly caused the destruction of the real archaeological heritage (Harding, 2006). Critical evaluation of the evidence, however, often aids in the destruction of the pseudo-archaeological hypotheses, which brings us back to the importance of studying the geoglyphs of Turgai.

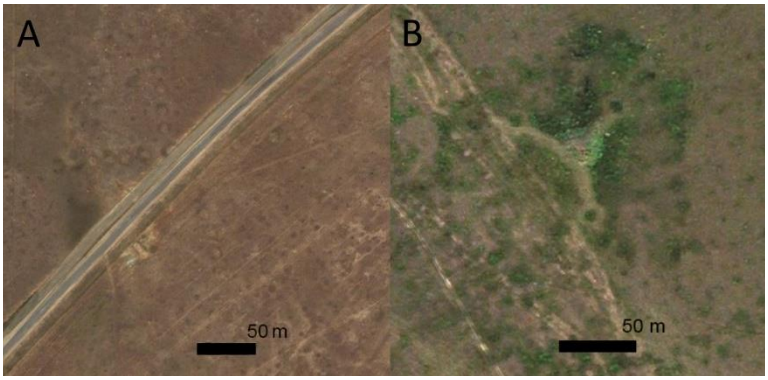


Figure 4: Examples of the geoglyphs destroyed by the human impact. Modern asphalt road going across the Mohat cross (left image), field roads next to the Zhandra swastika (right image)

Geoglyphs of Turgai are unique archaeological structures not present anywhere else in Central Asia in such concentration. They date to the beginning of the Iron Age in the Eurasian steppe, which was a time of important socio-economic changes that affected all aspects of the human lifestyle. The large size and number of the structures point to the enormous input of time and human power required for their construction. Moreover, the specific arrangement of the mounds within geometric earthworks points to the presence of consolidated power and human management, which was not observed in the earlier periods. Thus, these structures can directly be associated with the rise in social complexity and stratification. Archaeological research of the Turgai geoglyphs can, therefore, provide valuable information about the social and political organization of the Early Iron Age society inhabiting the steppes of Kazakhstan. Social and political aspects of the prehistoric societies are usually hard to access through the archaeological evidence. However, geoglyphs of Turgai present a piece of a socio-political puzzle of the Early Iron Age steppe community. Understanding the reasons and purpose of the geoglyphs construction could potentially help us to understand the processes of formation of more complex social units within the steppe that played the key mediators role between the western and eastern worlds. Despite the years of research carried out at the different geoglyph sites in Turgai, we still know very little about who constructed the structures and with what purpose. It has been previously demonstrated that traditional archaeological methods of research, such as excavation, yield no evidence that could hold clues in understanding the purpose of geoglyphs construction because the structures and surrounding territory do not contain any evidence of material culture. It is evident, however, that the construction of the geoglyphs required major economic investments of time and human resources.

Thus, geoglyphs of Turgai is an important phenomenon that reflects the social transformations of the transitional period from Bronze to Iron Ages. A study of the other aspects of the social and economic life of the community that constructed the geoglyphs might, therefore, provide important clues to the nature and purpose of the geoglyphs. Moreover, in order to create a bigger picture of what was happening in the transitional period and what was the role of the geoglyphs, it is important to study data from wider chronological frames and geographical regions. The archaeological evidence suggests that economic processes and transformations were happening on a larger scale of Central Asia. Thus, a review of the economic evidence from Central Asia might point to the wider processes that affected the Turgai region at different periods.

1.2. Research goals and objectives

The main goal of this research is to understand the economic background of the ancient Kazakhstan inhabitants before, during and after the geoglyph construction. A study of the economic settings across time and space might help to reveal the processes that fueled the geoglyphs phenomenon. There is little known about the socio-economic changes that happened in the transitional period from the Bronze to Iron Ages and what caused those changes. However, various archaeological evidence points to the transformations and appearance of the new social rules and economic behavior. Investigation of the economic changes might lead to better understanding of why and by whom the geoglyphs of Turgai were constructed and later abandoned. In order to achieve this goal, the key objectives of the thesis were selected:

1. To review the palaeoclimatic data

2. To review the published literature on archaeology of the Turgai region and surrounding territories on a wide chronological scale
3. To study all available information on the geoglyphs of Turgai
4. To review the previously published evidence for the past economy of the Turgai region and surrounding territories, including archaeobotanical, zooarchaeological, stable isotope, and metallurgy evidence
5. To carry out an excavation of Ashutasty settlement site located close to the geoglyphs
6. To analyze the human diet on a wide geographic and chronological scale by using stable isotope analysis on bone samples that were collected from the Western Kazakhstan Centre for History and Archaeology (Uralsk), Lisakovsk Museum of History and Culture of Upper Tobol (Lisakovsk), Archaeological Laboratory at Kostanay State Museum named after A. Baitursynova (Kostanay), National Museum of the Republic of Kazakhstan (Nur-Sultan), L. N. Gumilev Eurasian State University (Nur-Sultan), Nazarbayev University (Nur-Sultan), Saryarka Archaeological Institute of the Buketov Karaganda State University (Karagandy), Margulan Institute of Archaeology (Almaty), Kazakhstan State Museum (Almaty), and "Archaeological Expertise" LLC (Almaty), and during the excavations of the Ashutasty settlement.
7. To carry out zooarchaeological and collagen peptide fingerprinting (ZooMS) analyses on the samples collected during the excavation of Ashutasty settlement.
8. To conduct the compound-specific nitrogen analysis of amino acids on Bronze-Middle Age samples from three target zones in Kazakhstan: Southern Turgai, central Kazakhstan, south-east Kazakhstan (this analysis will be applied to Kazakhstan archaeological material for the first time)

2. Theoretical background

2.1. Importance of palaeoeconomic studies

The significance of palaeoeconomic studies in understanding other aspects of past human life was already recognized in the 20^{th}-century academic society (Clark, 1939; Forde, 1934). Higgs and Jarman (1975) further noted that palaeoeconomy (or economic archaeology) has to be investigated through the use of scientific methods. According to the Cambridge Encyclopedia of Archaeology (Dennel, 1980, p.38), one of the definitions of the economic archaeology is: "the study of the production, distribution, and consumption of all commodities used by early communities; its main concerns are prehistoric trade and exchange systems between communities, and the production and distribution of goods and resources within human groups".

At the time of its establishment as a discipline, economic archaeology was mainly limited to the study of human subsistence and involved investigation of animal bones and plant remains collected from excavations. Recently, it has been recognized that economic archaeology does not only involve the study of subsistence patterns (Outram and Bogaard, 2019). Technology, production, and exchange systems also belong to the field of economic archaeology. Moreover, human time and labour have been highly valued economic resources since ancient times. Thus, economic archaeology addresses very important subjects closely related to the growth of civilizations and social progress.

2.2. Methods selected for the study of the economy of Turgai

Turgai archaeology has been poorly studied due to the remoteness of the region. The number of investigated archaeological sites in the region is very small, and the available material does not provide enough information to create the image of the Early Iron Age Turgai population. Therefore, one of the major objectives of the project is to collect more data from the region and surrounding territories through fieldwork and excavation. In present times, we can utilize a wide range of interdisciplinary methodologies in the study of economic archaeology. Some of the most useful methods that provide more information and require fewer resources were selected for the current study.

Landscape survey and archaeological excavation of a settlement site located in close proximity to the geoglyphs were conducted to collect artefactual and organic data, which would allow studying the local economy on a full scale. A range of laboratory analyses were carried out, including ^{14}C dating carried out to understand if the settlement and the geoglyphs are contemporaneous; macro-botanical analysis, zooarchaeological investigations, and ZooMS (see below).

Analysis of zooarchaeological assemblages provided information about the pastoral aspect of the economy: use of different animals, butchery techniques, herd compositions, and role of secondary products (Ananyevskaya et al., 2020). A review of the previously published zooarchaeological data (see chapter 5) and comparison with the new results allowed for the understanding of the wider patterns of pastoralism and animal herding. A cutting-edge method known as collagen peptide fingerprinting (aka ZooMS) allowed for the animal species identification using small unidentifiable bone fragments, which greatly aided in zooarchaeological interpretations (Ananyevskaya et al., 2020).

Stable isotope methods, including bulk collagen isotopes as well as compound-specific amino-acid analysis of nitrogen, were used to reconstruct the changes in human and animal diet across a territory of Kazakhstan as well as to analyze the effect of animal herding strategies on human isotopic values (Ananyevskaya, 2018; 2019a; Ananyevskaya, 2019b; Ananyevskaya et al., in press; Ananyevskaya et al., 2018; Itahashi et al., 2020). The importance of various food resources, including C_3, C_4 crops, freshwater fish, and animal meat and milk were analyzed on a large geographic and chronological scale.

Review of the macrobotanical data from a wide territory of Central Asia allowed for the analysis of the appearance, spread, and increasing importance of such cultivars as wheat, barley, and millet (see chapter 5). Evidence for the agriculture presented as macro-botanical remains provide us with important information on the economy and human lifestyle as well as exchange systems and trade routes.

Palaeoclimatic research has also been reviewed during this research in order to understand the environmental changes that were happening in the prehistoric times and could potentially affect the socio-economic transformations (see chapter 3).

2.3. Contents of the research

This research addresses a wide range of problems related to the construction of the geoglyphs of Turgai. In order to draw conclusions from the results of fieldwork and laboratory analysis, a whole variety of topics from economic aspects to archaeological and palaeoecological evidence are reviewed in chapters three-five. The methodological bases of the research are addressed in chapter six. The results of the fieldwork and laboratory analysis are presented in chapter seven. Discussion on the contributions of this research to the current base of knowledge is provided in chapter eight. Conclusions of the research are outlined in chapter nine. Raw data, statistics, and calculations are contained in appendices one-eight.

3. Present and past environmental settings

Economic activities of the prehistoric populations were always dependent on the surrounding environment as well as climatic oscillations. The open-steppe landscape spread across a large territory of Kazakhstan, including southern Turgai and central Kazakhstan, provided opportunities for grazing of large herds of animals. Mountains in the south-east and east of Kazakhstan were used for vertical transhumance herding, which is a practice of seasonal movement of animals between lowland pastures and richly-vegetated highlands. Agricultural practices also depended on the landscape features (see chapters 7,8). Some natural features, such as elevation and melt-water, allowed for the use of irrigation channels. Complex irrigation systems were also built on wide rivers in some arid areas, such as Syr Darya and Amu Darya River basins. Climatic oscillations could be responsible for the major socio-economic changes that happened at the end of the Bronze Age – beginning of the Iron Age. Therefore, a review of the present and past environment of the region will provide a necessary background to critically analyze the economic situation in the prehistoric Kazakh steppe.

3.1. Geographical and environmental positioning of the research area

Geographically Turgai plateau spans from the West-Siberian plain in the north to the Turan plain in the south and from the Trans-Ural plateau in the west to the Ulutau Mountains and Kazakh Uplands in the east. Turgai deflection, which is 15-50 km wide, crosses the Turgai plateau from the south to the north (Boboyedova, 1971b); its height above sea level is about 200 m. Turgai oblast (fig. 5) that existed from 1868 to 1920 as part of the Russian Empire extended almost to the Aral Sea in the south. Now the borders of the Turgai plateau almost fully match the modern borders of Kostanay oblast. All discovered geoglyphs also lay within Kostanay oblast (see Chapter 4).

The landscape is changing from the forest-steppe in the north to the arid steppe in the central plateau and deserts in the south. Three major rivers: Tobol, Ubagan, and Turgai flow across the Turgai plateau. River Tobol starts in the Ural Mountains and flows across the northern Turgai plateau. River Ubagan enters Tobol from the east, while the Turgai River flows in the south of the plateau. The greatest concentration of geoglyphs is centered on Turgai river channels and confluences.

Figure 5: Turgai oblast on the map of Central Asia in 1910 (Kastanye, 1910)

Figure 6: Open steppe landscape of Turgai deflection

Turgai plateau has a large number of lakes (over 5000) (Kalieva and Logvin, 1997). There are patches of forests in the central steppe area, which are inhabited by game animals, such as moose and roe deer, while saiga antelopes (*Saiga tatarica)* inhabit steppe and semi-desert landscapes. Boars can be encountered in the swampy river and lake banks. Modern steppe vegetation includes plants of *Stipa*, *Festuca*, *Agropyron*, and *Artemisia* genera (Vilesov et al., 2009) (fig. 6).

The modern climate in the Turgai plateau is continental with winter temperatures dropping as low as -45° C and summer temperatures getting as high as +42° C (Boboyedova, 1971a). Annual precipitation rates are about 300-350 mm in the north and 150-200 mm in the south of the plateau (Zaharov and Udris, 1971).

3.2. Palaeoclimatic evidence

There have been multiple attempts to reconstruct the past climatic conditions in Central Asia. However, in many cases, the results of such studies do not agree with each other (see Tairov, 2007). First of all, there are no direct dates for the majority of the palaeoclimatic evidence. Second of all, the application of different methods, including studies of the water levels in lakes, pollen stratigraphy, and soil morphology, tend to show contradicting results even in the same region. Thirdly, the climate often changes on the local level, and therefore, the studies conducted on the Trans-Uralian material might show a different result to the research of the Balkhash lake (south-east Kazakhstan) water levels. Finally, there are no strict criteria at what is called “humid” and “arid”, “cold” and “warm”.

Tairov (2003) reviewed the climatic evidence from the steppe and forest-steppe landscapes of Central Asia. Based on the previously published palaeosoil evidence (Ivanov and Chernyanskyi, 1996; Ryskov and Demkin, 1997) from the Trans-Uralian steppe, he suggested that from around 2700 BC to 1600 BC the climate was more arid than modern, then from 1600 BC until the 1000 BC the humidity level was similar to modern, from 1000 BC to 500 BC, it was getting wetter and colder, and from 500 BC the climate was getting more arid. Zakh et al. (2010) studied pollen stratigraphy at archaeological sites located on the Tobol and Ishim Rivers and indicated that from around 1450 until the 1200 BC there was an increase in precipitation levels, and from 1200 BC until the 500 BC, the climate was continental with multiple fluctuations.

A recent analysis of stalagmite profiles from Kyrgyzstan cave showed that from 1500 until 1000 BC, the climate was wet and cold, but from 1000 until 500 BC the climate was arid and warm (Wolff et al., 2017). A study of paleosols buried under kurgans in the Volga-Ural steppe showed that the climate was arid from 1000 until 400 BC (Aleksandrovskyi, 2003). Another investigation of soils deposited under kurgans Kara-Oba and Obaly located in northern Kazakhstan indicated that the period from 1100 until 800 BC was most arid in the Sub-Boreal phase (Ivanov, 1989; Ivanov and Chernyanskyi, 1996).

On the other hand, Zdanovich (2003) suggested that the climate of the late Sub-Boreal stage (1800-500 BC) was generally colder and humid, but there were also multiple climatic oscillations. The most humid phase began at the end of the 2nd mil. BC – beginning of the 1st mil. BC and lasted until 800-600 BC (Zdanovich et al., 1984). Zdanovich (2003) suggests that the Final Bronze Age communities had to abandon their settlements due to continuous floodings. Evidence of floods was observed during the excavations of the Late-Final Bronze Age settlement sites Novonikol'skoye I, Petrovka II, Ilyinka I located in north Kazakhstan. Research of peat stratigraphy in the Kokshetau mountains of northern Kazakhstan similarly demonstrated an increase in precipitation from 900 until 200 BC (Zharkova, 1967). Vinogradov and Mamedov (1991) who studied the palaeogeography and archaeology of the Lower Amu Darya also argued towards a humid climate from 1000 until 500 BC. Pollen data from south-west Altai, in the same way, points to the wet climatic conditions during the first half of 1st mil. BC (Chernova et al., 1991; Mihailov et al., 1992).

Archaeological data indicates that settlements of the Iron Age are usually discovered in landscapes that are different from the typical locations of the Bronze Age settlements. Iron Age settlements tend to be situated in areas that are protected from the wind, and further away from the river and lake banks (Habdulina, 2003). The character of the Iron Age settlements in central and northern Kazakhstan generally points to the cold climatic conditions during this period (Beisenov, 2015). People were using a lot of stone for the dwellings that were clustered close to each other.

Despite the differences in the conclusions of the palaeoclimatic studies, many researchers suggest that at the end of the 2nd millennium BC, major climatic changes happened that affected the socio-economic structure of the steppe communities. Some researchers argue that the change of climatic conditions at the transitional period from the Bronze to Iron Ages forced the populations of Central Asia to adopt the pastoral nomadic economy (Bokovenko, 2004; Khazanov, 1994; Kuz'mina, 2004).

4. Archaeology of Turgai and northern Kazakhstan

“Who at least once had to travel through Turgai oblast,

They could not help but notice

In a multitude scattered through steppes

Almost regular dome-shaped cones –

These are ancient kurgans – burial grounds,

Sad, mute witnesses of the long-gone,

Long fallen into the eternity, perhaps, whole millennia,

And with them many tribes and nations,

Who have ended their earthen existence,

And have taken with them under those heavy, grim mounds,

So much of everything precious and interesting for the modern humanity”.

A. Anihovskyi, “Drevniye kurgany-mogil’niki v Kustanaiskom uyezde Turgaiskoi oblasti”, 1905[1]

In 2017, Smirnov and Sokolov made a review of the archaeological investigations and excavations carried out in the Turgai plateau until 1917. Their review showed that the Turgai region, which was known before 1917 as Turgai oblast, attracted many archaeologists. In fact, in 1910, Kastagne published his book, where Ushtogaiskyi square was mentioned for the first time in the literature. However, despite the significant amount of archaeological research carried out in the region since the XIX century, there is still very little known about the lifestyle and economy of Turgai inhabitants, especially its central and southern parts. Therefore, a greater geographic area and a wider chronological period have to be studied in order to understand the role of Turgai in various socio-economic processes happening in the steppe and mixed-steppe landscapes.

[1] Translation from the original text was made by the author

4.1. Neolithic-Eneolithic

During the Neolithic (~5000-3500 BC) period, Turgai plateau was already inhabited by egalitarian communities that produced ceramic vessels, bone tools, and stone tools as well as stone artifacts of yet unknown purpose, such as “irons” and ornamented disks (Kalieva and Logvin, 1997). Flint tool industry included the production of scrapers, one-side and double-sided blades, arrow and spear points, discs, etc. Neolithic sites in the region tend to be associated with Mahandzhar ceramic tradition, which was defined by cone-bottom vessels ornamented with “zig-zag”, “pitted” and “stroke” patterns (Kalieva and Logvin, 1997).

Eneolithic period (~3500-3000 BC) is marked by the beginning of horse husbandry in the north Kazakhstan steppes. The famous Botai site located near Kokchetav has provided the evidence for the earliest horse husbandry and milking (see chapter 5). The Botai culture has a sister culture Tersek, which is spread across Turgai. Recent technological and ornamentation study of Botai ceramic vessels indicated that Tersek and Botai pottery likely presented one ceramic complex, which allowed suggesting that the broad territory of the north Kazakhstan steppe was populated by a unified community, groups of which inhabited different settlements but maintained contact likely through marriages and exchange of ideas (Rahimzhanova et al., in press).

The two cultures also share an extreme focus on horse exploitation. Around 99% of the Botai faunal assemblage is represented by horse remains (Olsen, 2003; Olsen, 2006). Zooarchaeology analysis of Kozhai I (fig. 7) Eneolithic assemblage demonstrated that over 65% of all skeletal remains belonged to horse. Gaiduchenko (1998) suggests that the Kozhai I horses were husbanded and some of them were even ridden based on the bit wear evidence. A large number of wild animal skeletal remains discovered at the site also points to the importance of hunting with over 15000 animal bones identified as *Saiga tatarica* (Gaiduchenko, 1998).

Archaeological research carried out at other Tersek sites in the region demonstrated that the material culture included stone tools made mainly out of quartzite, ceramic vessels, ornamented stone disks and “irons”, as well as ornamented horse phalanges (Logvin and Shevnina, 2015).

Investigations at Kozhai I settlement demonstrated that the site was likely used only during warm seasons (Kalieva, 1998), unlike Botai, that was occupied all year round. Spectral analysis of a copper item discovered at the site pointed to the southern provenance, most likely Syr Darya River region. Overall, the evidence from Kozhai I suggests that the community that occupied the site during warm seasons travelled there from the south, where they had a winter encampment (Kalieva, 1998). There is little evidence for the seasonality or nomadism during the Eneolithic period. The size and character of the Botai settlement, with over 240 houses identified through the landscape (V. Zaibert, personal communication, July 2020) and geophysical surveys (Gaunitz et al., 2018), suggests that the site was occupied permanently. The hypothesis about the seasonality of the Kozhai I settlement proposed by Kalieva (1998) is likely based on the idea that the Tersek population practiced hunting-gathering form of economy and, therefore, could not stay in one area permanently. The Tersek sites, however, are located on the seasonal migration routes of *Saiga tatarica*, which maintains a stable food supply in springs and autumns. The evidence for the horse husbandry in the north Kazakhstan Eneolithic community further suggests that Tersek people could support themselves while living in permanent settlements.

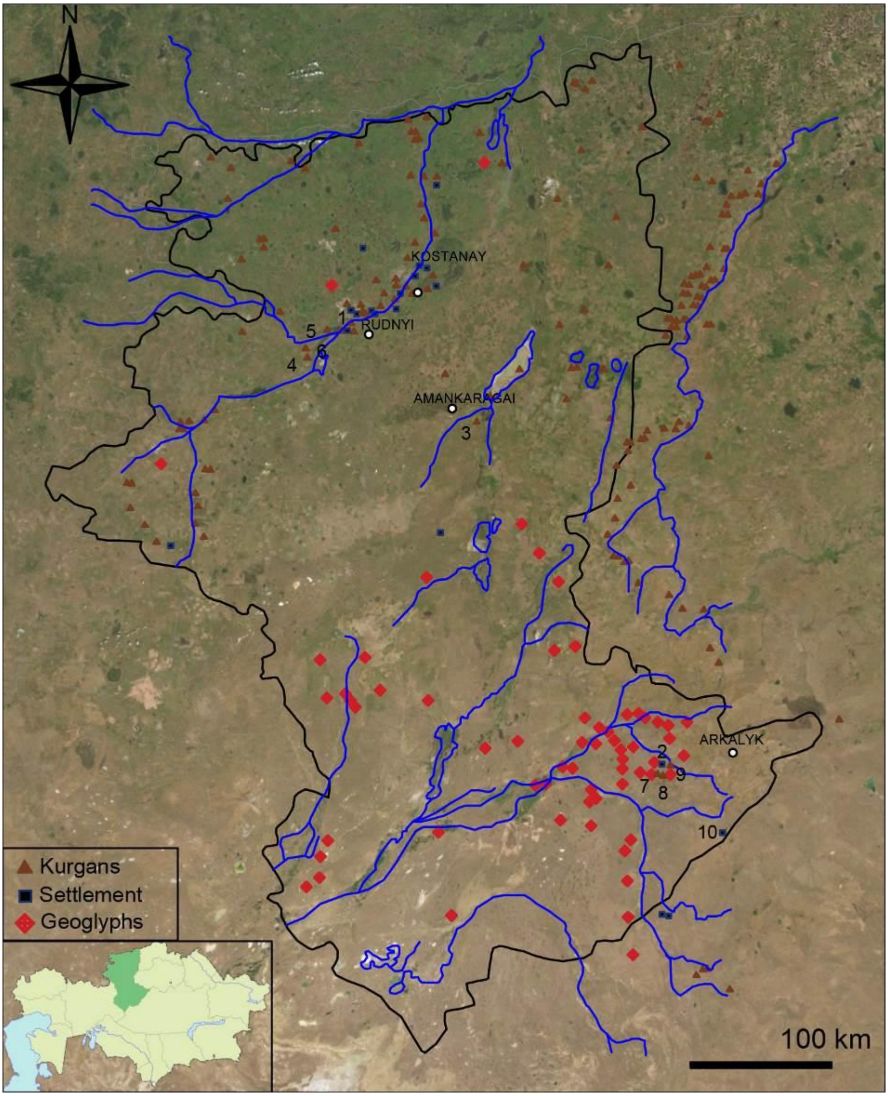


Figure 7: Map of archaeological sites in Kostanay oblast and nearby (majorly fits the natural borders of Turgai plateau) with geoglyphs and archaeological sites marked. Blue lines outline the present day rivers and channels. The locations of archaeological sites were taken from Ageeva et al. (1960a; 1960b), Bazarbayeva and Dzhumabekova (2017), Dzhumabekova and Bazarbayeva (2017), Kalieva (1998), Krivtsova-Grakova (1948) Logvin et al. (2018a) Seitov (2011a), Shevnina et al. (2014), Usmanova (2005; 2012; 2018a). The map was generated with use of AutoCAD 2018 software. Basemap imagery was taken from BingMaps DigitalGlobe 2020. Major sites discussed in the chapter are numbered: 1. Alekseevskoye complex, 2. Ashutasty site, 3. Bestamak cemetery, 4. Lisakovsk an Novoil'inoskyi cemeteries, 5. Karatomar and Halvai cemeteries, 6. Tobolskyi kurgan, 7. Ashutasty 1 cemetery, 8. Ashutasty 2 cemetery, 9. Ashutasty-30 kurgan, 10. Kozhai-1

4.2. Bronze Age

The transition from the Eneolithic to the Bronze Age period is marked by the appearance of Yamnaya culture (~3200-2600 BC), which is known in the world archaeology as the community that brought Indo-European languages, wheeled transport, horse-centered symbolism and kurgan tradition to Europe during the process of massive migrations from the steppe (Anthony, 1991; 2010; Gimbutas, 1997). Originally, it was defined that Yamnaya culture spreads from the Black Sea steppes in the west to the Urals in the east (Merpert, 1974). A lot more Yamnaya kurgans were investigated in the western part (Ukrainian steppe and Western Urals) of the culture spread than in its eastern part (Eastern Urals) (Koryakova and Epimakhov, 2014). Recent aDNA studies showed that the Yamnaya people and the Afanasyevo population of Altai are genetically identical (Allentoft et al., 2015). Ancient DNA evidence also points to the backward migrations of Yamnaya people to northern Kazakhstan, Trans-Urals, and western Siberia.

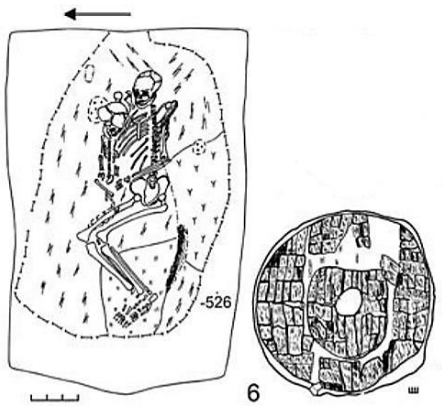


Figure 8: Burial 2 of Shumayevo II burial complex (wheel on the right side was discovered within the burial) (Morgunova, 2014)

Yamnaya kurgans tend to include ceramic vessels, ochre, bedding made of bark or grass, bone and stone artifacts, and sometimes objects made of copper (Koryakova and Epimakhov, 2014). Some burials had wooden roofs. Remains of wagons, usually wheels and imprints of wheels, are occasionally found within Yamnaya burials (Morgunova, 1992; 2014; Morgunova et al., 2003) (fig. 8).

Merpert (1974) suggested that the Yamnaya community had a nomadic pastoral economy focused on sheep herding, which implied that the people of the Yamnaya culture did not have permanent settlements. Other scholars also argued that the Yamnaya people were exploiting open-steppe landscapes and made seasonal movements (Bogdanov, 2000; Morgunova, 2000). Currently, there is little evidence for the Yamnaya settlements. However, the presence of settlements associated with the preceding and succeeding archaeological cultures suggests that the Yamnaya community likely had similar socio-economic management. Furthermore, the absence of horse remains in the burials allows some scholars to argue that the Yamnaya people did not have domestic horses, and could not manage migrations (Koryakova and Epimakhov, 2014). The number of discovered wagons in the burials is quite small therefore the exploitation of cattle for transportation of people and their belonging during migrations is also disregarded (Ivanova, 2001). It is possible to suggest that the Yamnaya culture settlements have not been discovered or possibly were completely destroyed by water erosion, if, for example, the settlements were positioned close to the river banks and were small in size. However, there is also a possibility that the Yamnaya burials might have been poorly dated through precise methods, and possibly coexisted with other archaeological communities.

Another Early Bronze Age culture appearing in the region of Turgai is Sintashta (~2200-1800 BC). Ancient DNA studies demonstrated that the Sintashta community migrated into Asia from the west (Allentoft et al., 2015). The main area of the culture spread is the Trans-Ural region, which includes fortified settlements such as Arkaim and Andreevskoye (fig. 9) as well as kurgan cemeteries and individual burials.

Settlements of Sintashta culture are often fortified and have a circular or rectangular shape (fig. 9). Some scholars argue that the early settlements had a circular shape, while the later settlements were rectangular and could be associated with the succeeding Petrovka culture (Koryakova and Epimakhov, 2014; Zdanovich and Batanina, 2002). The fortifications included ramparts and ditches, and walls made of soil and wood. Dwellings and other constructions inside a settlement were commonly arranged in continuous rows with entrances facing the central square. The settlements varied in size from 6000 to 35000 m^2 (Koryakova and Epimakhov, 2014).

Sintashta settlements were commonly constructed on flat landscapes and did not take advantage of the natural fortifications. The inhabitants of Sintashta settlements produced metal objects in their dwellings. Remains of furnaces, metal objects, and slag were discovered in the buildings of Arkaim settlement (Zdanovich, 1997). The settlement material also includes animal bones, ceramic vessels, bone, and stone tools.

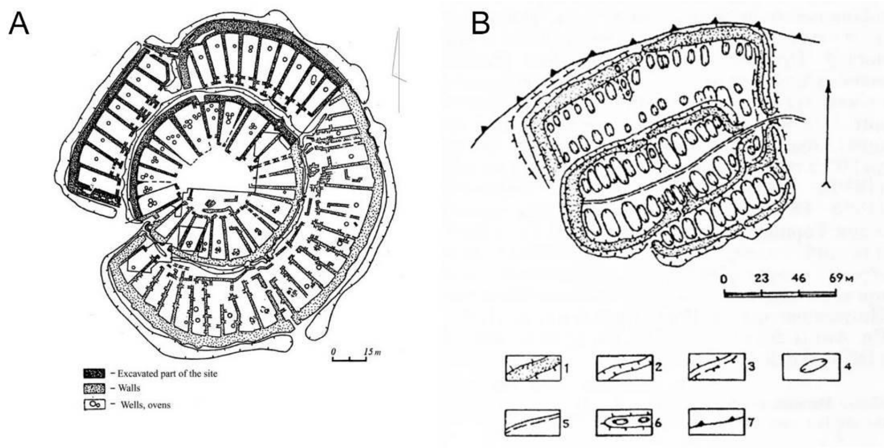


Figure 9: Plans of Sintashta settlements. A: Arkaim settlement (Zdanovich, 1997); B: Adreevskoye settlement (Zdanovich and Batanina, 2002)

Burial complexes of Sintashta culture tend to have above ground kurgan constructions with an exception of Sintashta burial ground, where no above-ground constructions were observed (Koryakova and Epimakhov, 2014). Wood and soil were commonly used for the burial chamber constructions (Shevnina and Logvin, 2015), while stone was used very rarely. Animal sacrifices become more common in the Sintashta burial ritual. Zdanovich and Gaiduchenko (2002) analyzed the composition of the zooarchaeological assemblage from Bolshekaraganskyi kurgan 25 and demonstrated that 115 animal individuals were sacrificed for the burial of 24 people. Often, several different animals were deposited together with the deceased. The burial inventory of Sintashta cemeteries also included ceramic vessels, various metal objects, jewelry, bone items, and stone items. However, there were no special or unique objects in the burials. Overall, the burial ritual could differ by the type of sacrificial food or animals depending on the age and sex of the deceased, for example, children burials were often accompanied by a sheep or goat sacrifice, while horses were put inside adult male burials (Zdanovich and Gaiduchenko, 2002). The differences in particular types of tools and objects put in the burials were also caused by the age and sex of the individual, for example, weapons were included as part of a male burial inventory, while jewelry and spinning whorls were often put inside female burials (Koryakova and Epimakhov, 2014). Some burials also included remains of chariots and horse harnessing. This tradition was inherited from the Yamnaya culture. However, there seemed to be no particular social stratification, which can be observed in the burials of the later periods starting from the Late – Final Bronze Age.

The evidence for Sintashta culture in Turgai includes only kurgan cemeteries and individual burials. No settlements of Sintashta culture have been discovered in Turgai yet. Burial sites of Turgai deflection associated with Sintashta culture include kurgan 3 and 5 of Halvai and some burials of Karatomar burial site and Bestamak cemetery complex. The burial goods discovered at a Sintashta culture Karatomar cemetery (fig. 7) included turquoise and chalcedony beads, bronze pendants, ceramic vessels, wooden spear, wooden dish, birch bark dish, bronze vessel, and bronze adzes (Logvin and Shevnina, 2018). Burial of a child from the pit 9 of Halvai 3 (fig. 7) had bronze arrow points, remains of wooden arrows, ceramic vessels, birch bark, bronze knives, bronze axe, stone arrow and spear points, and whetstone (Shevnina and Logvin, 2015). Typically Sintashta burials located in Turgai deflection and surrounding areas contain bronze knives, axes, spears, flat axes, jewelry, ceramic vessels (Havanskyi, 2015).

Petrovka cultural formation (~1800-1600 BC) follows on after the Sintashta culture. Petrovka culture is represented by settlements and cemeteries and geographically distributed from the Trans-Urals to northern and central Kazakhstan. Many Sintashta settlements were later used by the Petrovka population (Koryakova and Epimakhov, 2014). Generally, Petrovka settlements have many similarities with Sintashta sites, but there is a tendency towards simpler and lighter constructions in Petrovka settlements. Petrovka burial complexes tend to have multiple burials within a kurgan, with a main burial in the center and other graves scattered around the central one. The inventory is similar to Sintashta burials, but, sometimes, even richer.

Judging from the archaeological material, the socio-economic reality of the Sintashta-Petrovka community was dependent on metal production as well as pastoralism with the focus on cattle and horses (Koryakova and Epimakhov, 2014; Kosintsev, 2000). Some scholars argue that there was an exchange system that included metals and cattle (Shishlina et al., 2020), which implies that there was a metalworking community based in the Urals and a pastoralist community of the Kazakh steppes, hence, the two groups traded their produce with each other.

During the Late Bronze Age (~1600-1200 BC), Andronovo cultural horizon, involving such cultures as Alakul and Fedorovo, appears in the Urals and Turgai plateau. Research of the human genomes demonstrated that Andronovo populations are direct descendants of the Sintashta people (Allentoft et al., 2015). The material of the Andronovo cultures is distributed from Ukraine to western Siberia and central Kazakhstan (Koryakova and Epimakhov, 2014). Alakul settlements are commonly located on the river terraces (Koryakova and Epimakhov, 2014). The houses are rectangular and arranged in one or two lines. The choice of building materials depended on the landscape: in Uralian forest-steppe, wood was frequently used, whereas in the Kazakh steppes stone was used more often due to the lack of wood. The archaeological materials (Koryakova and Epimakhov, 2014) discovered at Alakul settlements include metal objects, ceramic vessels, metalworking tools, bone tools and, animal bones.

Fedorovo culture is represented by the differences in the burial ritual; although, Fedorovo material appears to be absent in the settlement sites. Therefore, scholars argue that Alakul and Fedorovo material culture might be shared by the same community (Koryakova and Epimakhov, 2014). Fedorovo kurgans tend to include fence, wooden burial construction, single burials, and, often, cremations. However, usually, they do not have a stone moat, stone burial constructions, multiple burials, individual sacrificial pits (Usmanova, 2018a). On the other hand, Alakul burial sites have stone moat, fence, kurgan construction, wood and stone used for the burial construction, multiple burials, individual sacrificial pits, ritual objects, and often inhumations (fig. 10, 11). Food offerings in the form of full animal bodies and their parts were conducted in both Alakul and Fedorovo burial ritual (Koryakova and Epimakhov, 2014). Grave goods usually include ceramic vessels, amulets, jewelry, beads, and other items. Burials of children often include only ceramic vessels (fig. 11, B). Based on the burial material, we know that Alakul community had very elaborate female hair decorations (nakosniki) usually made of metal, precious stones, and bone (Usmanova, 1997).

Figure 10: A - An Alakul kurgan excavation at Novoil'inovskyi burial site carried out in 2017; B - Archaeologist E. Usmanova studying the burial construction of Novoil'inovskyi kurgan

Lisakovsk and Novoilinovskyi cemetery complexes of the north Turgai plateau include multiple kurgan cemeteries. The sites have been investigated for over 20 years and provided a large amount of archaeological material. Individual kurgans and even burials inside a kurgan are associated with Alakul or Fedorovo cultural traditions (Usmanova, 2018a).

Based on the research of the Lisakovsk and Novoil'inovskyi burial ritual, E. Usmanova (2018b) suggested that during the Late Bronze Age, female and male roles were clearly defined. There were certain professions and social statuses associated with the women that reached a particular age or became a mother. Moreover, "Ritual intrusion" was a common practice in the burial ritual of the Bronze Age in Central Asia (Koryakova and Epimakhov, 2014). Intrusion into a burial was often done soon (several weeks or months) after the burial was complete. The character of some graves indicates that the intrusion could be done before the burial pit was covered by soil. Usmanova (2013) suggests that during this ritual, the intruders were often displacing skulls and taking precious items, except for some objects that were under a taboo. The robbers knew the layout of a kurgan because the intrusion was done exactly in the central burial pit, while some other burials (e.g. children burials that did not have valuable items) were left intact. This ritual had greatly influenced the preservation of anthropological and artefactual material. Upon excavation of a kurgan, human remains are often discovered in a non-anatomical order (fig. 11, A), many bones are broken and some skeletal elements are never recovered (Aigozina, 2012). Moreover, as the robbers were often taking precious items, such as jewelry and metal objects, it is very difficult to analyze the burial ritual and social stratification.

Figure 11: A - Central burial of the Novoil'inovskyi kurgan (note: the burial was robbed in antiquity) B -Burial of a child inside the Novoil'inovskyi kurgan of the Alakul culture

Cultures of the Late Bronze Age have gradually transformed into Sargary-Alekseevo (~1400-1000 BC) cultures of the Final Bronze Age. The settlement sites of this period are often large in size (e.g. Kent, Alekseevskoye), however, some small settlements, which were characterized as potential seasonal camps, are also present (Koryakova and Epimakhov, 2014). Settlement materials usually include ceramic vessels, metal objects, and animal bones. Pottery ornamentation is very simple, a large number of discovered vessels do not have any decorations (Koryakova and Epimakhov, 2014).

Alekseevskoye (fig. 7) is a large archaeological complex excavated back in the 1930s and dated to the Late Bronze Age (Krivtsova-Grakova, 1948). It is located in the north Turgai, within the modern borders of the town Rudnyi. Alekseevskoye complex includes a settlement, cemetery, and sacrificial hill. During the archaeological investigations of ritual pits situated on top of the sacrificial pit, the researchers discovered wheat grains, which remain the only evidence for the agriculture in prehistoric northern Kazakhstan (see chapter 5). Alekseevskoye cemetery was partially excavated. Discovered burial inventory was limited to pottery with Andronovo ornaments and beads. Inhumated individuals often had their legs tight judging by the position of the skeletons. Alekseevskoye cemetery, however, did not reveal any signs of kurgan constructions, which are common in the Late Bronze Age.

During the Final Bronze Age, the monuments of Begazy-Dandybayevo culture (~1300-900 BC) also appear in central Kazakhstan. The sites of this culture include large mausoleums with elaborate ceramic vessels, but no settlements. The absence of settlements associated with Begazy-Dandybayevo suggests that the culture likely co-existed with Sargary-Alekseevo and belonged to the same community of people. The mausoleums of the Begazy-Dandybayevo present unique and complex constructions (fig. 12), which required massive input of time and effort to build (Varfolomeev et al., 2017). This suggests that the mausoleums were constructed for high status individuals. Therefore, in the Final Bronze Age, the first clear evidence for the existence of the elite appears in the Kazakh steppes.

Metal production and pastoralism remain the major parts of the economy in the Final Bronze Age. The number of horses in the herds increases (see Chapter 5), which might point to the increase in mobility (Taylor et al., 2020; Ventresca Miller and Makarewicz, 2019). During the Final Bronze Age, the population of central Kazakhstan starts to grow crops (Ananyevskaya, 2018; 2019a; Ananyevskaya et al., in press; Ananyevskaya et al., 2018; Lightfoot et al., 2015). Finds of charred grains and impressions on pottery generally appear in the Urals and northern Kazakhstan in the Late-Final Bronze Age (see Chapter 5). Therefore, by the end of the Bronze Age, major socio-economic transformations start to happen. Social stratification becomes more visible through the presence of Begazy-Dandybayevo funerary monuments, while mobility and long-distance exchange are evident through the distribution of cultivated crops and an increase in the number of horses.

Figure 12: Karazhartas mausoleum of the Begazy-Dandybayevo culture: A – After the excavations (Kukushkin and Dmitriev, 2016); B – modern reconstruction (source: Wikipedia.com)

4.3. Transition from Bronze to Iron Ages –nomadism vs. social complexity

4.3.1. The “nomadism” theory

Throughout the 20th century and the beginning of the 21st century, the beginning of the Early Iron Age in the Kazakh steppes was considered a time of the rise of nomadism (Koryakova and Epimakhov, 2014). Many scholars believed that the steppe communities practiced nomadic pastoralism, and did not have any permanent settlements (Akbulatov, 1999; Akishev, 1972; Khazanov, 1975; Khazanov, 1994; Tairov, 1993). The classical idea of the barbaric steppe nomads with a military lifestyle associated with equestrianism also implied that the Early Iron Age communities had very primitive technologies, economy, and limited material culture. Essentially, nomadism is based on the movement of the animal herds between pastures. It also implies that no permanent settlements were constructed, all structures were lightweight and transportable, like modern Kazakh yurts, and no agriculture was practiced.

The hypothesis for the appearance of the Early Iron Age nomads was greatly based on the knowledge about the ethnographic nomads of the Eurasian steppes. The lack of discovered Iron Age settlements and the great number of known Iron Age kurgans also strengthened the argument towards nomadism. Some scholars argued that nomadism could be influenced by the popularity of hunting as a form of the economy (Masanov, 1995; Vainshtein, 1980). Thus, nomadic communities were travelling along with the migratory animals and also moving their herds.

In the 20th century literature on the subject, it was hypothesized that the origins of the nomadism were influenced by the growing number of livestock and the lack of pastures. Thus, groups that relied on animal husbandry had to develop a strategy of regular movements across pastures (Gryaznov, 1955; 1957; Gumilev, 1966). Several other hypotheses about the beginnings of the nomadism included environmental changes (see Chapter 3), the arrival of the new population, and a change towards a seemingly more advanced economic structure influenced by the accumulated knowledge about technologies and pastoral strategies.

Some archaeologists argued that the "elements of settled lifestyle and agriculture accompany nomadic pastoral economy" (Tolstov, 1934). Based on the ethnographic research, Tolybekov (1971) suggested that a semi-nomadic form of the economy could include the production of fodder, cultivation of crops, and permanent houses, while the population that practiced such economic strategy had to spend about half-a-year at one place. However, according to many scholars animal herding and management of pastures was the main focus of the Early Iron Age nomadism. Based on the ethnographic evidence (Vostrov, 1962), it has also been suggested that the steppe nomads had clearly defined winter and summer pastures, for example, lower Syr Darya River and upper Tobol River (Koryakova and Epimakhov, 2014).

4.3.2. Increase in social complexity

Until recent time, no investigations of the Iron Age settlements had been conducted in Kazakhstan due to the popularity of the "nomadic pastoralism" theory (Habdulina, 2003). Complex research and investigations of the Iron Age settlements began in 80s-90s. A Kazakh-AmeIVrican research project was carried out in south-east Kazakhstan in the late 90s to investigate the origins of the ancient towns. During this project, over 40 Iron Age settlements were discovered (Baipakov and Chang, 1997).

One of the major problems with the discovery of the Iron Age settlements in the 20th century was the lack of prior information about the preferable landscape exploited by the Iron Age communities. Based on the knowledge about the Bronze Age settlement sites, the researchers were searching for an

Iron Age settlement along the river and lake banks. However, recent investigations demonstrated that the Iron Age communities built settlements in shallow canyons, which were well protected from the wind (Beisenov, 2015; Habdulina, 2003).

South-east Kazakhstan

Archaeological research of the past decades demonstrated that Iron Age communities inhabiting mountain-steppe region of south-east Kazakhstan had complex agro-pastoral economies. Faunal and macro-botanical assemblages collected from the Iron Age layers of Tuzusai, Tseganka 8, Taldy Bulak 2, Begash and Mukri point to the presence of both pastoral and agricultural components in the economy (Benecke, 2003; Chang et al., 2003; Frachetti and Benecke, 2009; Haruda, 2007; Spengler et al., 2017). Isotopic data points to the importance of millet in the subsistence of Late Bronze Age and Early Iron Age populations (Ananyevskaya, 2019a; Ananyevskaya et al., in press; Ananyevskaya et al., 2018; Motuzaite Matuzeviciute, 2016; Motuzaite Matuzeviciute et al., 2015a) (see Chapters 4,6,7). Evidence from Tuzusai points to the use of irrigational channels for the facilitation of agricultural activities (Chang et al., 2003; Rosen et al., 2000). Zooarchaeological analysis of Taldy Bulak 2 data indicated that sheep were likely used for wool production (Benecke, 2003). Spinning whorls and textile ceramic vessels discovered at other closely located sites also point to the focused wool production industry (Chang, 2017). Similar data pointing to the specialized wool production economy in the Final Bronze Age is coming from Kyrgyz Tian Shan (Ananyevskaya et al., 2020). Recent isotopic evidence from a site located in the Kazakh Tian Shan demonstrated a seasonal movement of animal herds (vertical transhumance), which suggests that a part of the population practiced semi-nomadic lifestyle (Ventresca Miller et al., 2020). However, semi-nomadism here was a part of the essential economic management.

Investigations conducted during the past several decades in central Kazakhstan revealed a high number of settlement sites (Beisenov, 2009; 2016b; Beisenov et al., 2019; Beisenov et al., 2018; Beisenov and Loman, 2009; Beisenov, 2013). Standard archaeological excavation techniques applied to the study of central Kazakhstan settlements yielded faunal, ceramic, and stone material. An application of flotation methods for archaeobotanical investigations demonstrated that cultivated crops were also available to the local Iron Age community (Beisenov et al., 2019).

North Kazakhstan

Close to the geoglyphs' landscape, in northern Kazakhstan, several Iron Age settlements were discovered, including the large settlement of Kenotkel-10 excavated by Habdulina (2003). One fortified settlement Aktau dated to the ~500-200 BC and located near modern town Petropavlovsk was also investigated. However, the number of discovered settlement sites in northern Kazakhstan is much smaller in comparison to central and south-eastern Kazakhstan. Moreover, evidence for the agriculture in northern Kazakhstan during the Iron Age is very scarce and mostly limited to the isotopic data (Ventresca Miller and Makarewicz, 2019).

Syr Darya

During the ~400-100 BC, fortified settlements and fortresses start to appear in the lower Syr Darya River basin. This culture was called "Chirikrabat" after the largest discovered fortress – Chirik Rabat that takes the territory of over 40 ha (Utubaev and Bolelov, 2016; Utubayev, 2018). Archaeological research suggests that the community of the Chirikrabat culture practiced agro-pastoral economies, which involved the use of irrigation channels (Utubayev, 2018).

Turkmenistan

Soviet-time research in Turkmenistan also pointed towards the cultural degradation and deurbanization in the Late Bronze Age (Kohl, 1987). Multiple theories including climatic changes and human impact on the environment, barbarian invasions, changes in trade networks, and migrations were proposed (Dales, 1977; Dolukhanov, 1981; Sarianidi, 1981). However, later it was recognized that the observed changes were likely caused by economic and cultural transformations. Moreover, archaeological evidence from the later period points to more sophisticated settlement structures, advanced metal production technology, and new burial practices (Kohl, 1987).

Based on the collation of data from the overview of archaeological sources, it can be suggested that economic strategies practiced by the Iron Age populations in Kazakhstan and surrounding territories varied depending on many factors, including environment, social structure, and complexity, cultural traditions, etc. Thus, archaeological evidence suggests that communities inhabiting rich landscapes of the mountain foothills in central, south-eastern and eastern Kazakhstan had agro-pastoral economies with settled or semi-nomadic lifestyle since Bronze-Iron Ages (Akishev, 1972; Bernshtam, 1957; Chang, 2008; 2015; Chang et al., 2003; Margulan, 1947; Rosen et al., 2000; Spengler et al., 2017). On the other hand, social developments in the Early Iron Age Khorezm likely influenced the development of fortified towns and settlements in the lower Syr Darya. However, the open steppe landscapes of northern and central Kazakhstan remain enigmatic from the economic point of view.

4.4. Early Iron Age

At the beginning of the Iron Age, Tasmola culture (~900-400 cal. BC) spreads across the Kazakh steppe, Altai, and the near-Aral lands. Tasmola belongs to the early Saka-Scythian tradition. The appearance of this community is associated with the rise of nomadism. Based on the differences between the Late Bronze Age and Iron Age material, Itina and Yablonskyi (2001) suggested that the Tasmola community migrated into the steppe from the East and replaced the local population. Recent aDNA evidence, however, points to the three distinct groups of Saka-Scythians existing in Central Asia in the Iron Age: Southern Siberian group, central steppe group (Tasmola culture), and the Tian Shan group (de Barros Damgaard et al., 2018).

Tasmola burial sites spread across Kazakhstan and Altai can be very rich and include golden items and complex burial constructions (e.g. Taldy, Akbeit), (fig. 13). The artifacts discovered in Tasmola kurgans tend to have a distinctive animal style of the Saka-Scythian tradition (fig. 13,14).

Some kurgans of the Iron Age that yielded a great amount of luxury items or complex burial constructions are called princely burials or “golden” kurgans. Inside the famous mound Issyk (south-east Kazakhstan), a burial of a human in rich clothing with golden ornaments was discovered (Akishev, 1978) (fig. 15, left image). The individual has been referred to as “golden man”, and was believed to have a high military status. Recent investigations of the Taksai burial complex located in west Kazakhstan revealed a rich burial of a woman (Lukpanova, 2015) (fig. 15, right image). Amongst the grave goods, there were an elaborate wooden comb, golden mirror and jewelry, and other luxury items (Altynbekov, 2013; Beisenov et al., 2017).

Figure 13: Tasmola burial goods. A: cemetery Akbeit, kurgan 7, child's burial (Beisenov, 2017); B: Bone pin from cemetery Karashoky, kurgan 1 (Beisenov et al., 2017)

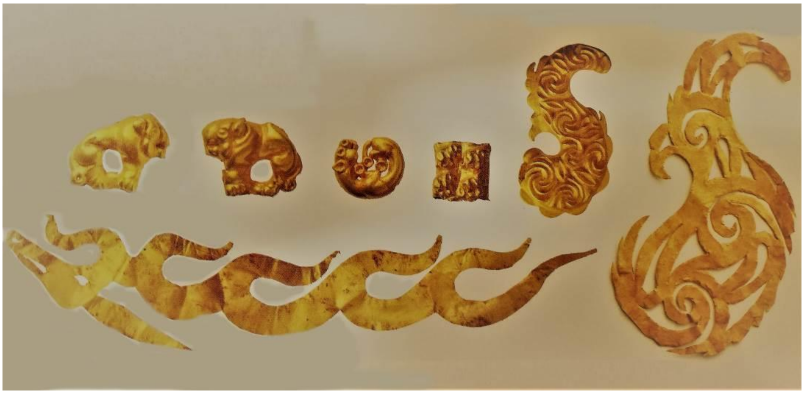


Figure 14: Animal style ornaments from Taldy 2 burial site of Tasmola culture (Altynbekov, 2014)

Figure 15: A: “Golden Man” from Issyk kurgan and B: “priestess” of Taksai (both reconstructions by K. Altynbekov).

Burial constructions of the Iron Age period are often very complex and distinctive. On the territory of Kazakhstan, there are examples of very large kurgans, such as kurgan Issyk that had a 60 m. diameter and 6 m. height (Akishev, 1978). Tasmola burial chambers often have extensive stone covers (fig 16, A), some Tasmola kurgans also have “dromos”, which is a stone corridor that leads from the entrance of the kurgan to the burial chamber (Beisenov et al., 2016). Some Iron Age kurgans have two lines of stones coming out of the kurgan, which tend to be called “moustache” (Beisenov et al., 2017; Beisenov, 2016c). Small sacrificial constructions were often positioned on the ends of the stone lines. There are also examples of complex inner chambers at Iron Age sites in Kazakhstan. For example, kurgan 11 at the cemetery Berel (eastern Kazakhstan) included a wooden sarcophagus with the deceased, which was put inside a wooden chamber filled with grave goods, and the chamber was positioned inside the burial pit, which also had 13 sacrificed horses in golden attire (fig. 16, B). Finally, in

Altai, a massive kurgan Arzhan was excavated and yielded a very sophisticated wooden construction that presents circular wooden corridors with multiple chambers that contained various burial goods, animal sacrifices, and human burials (fig. 16, C).

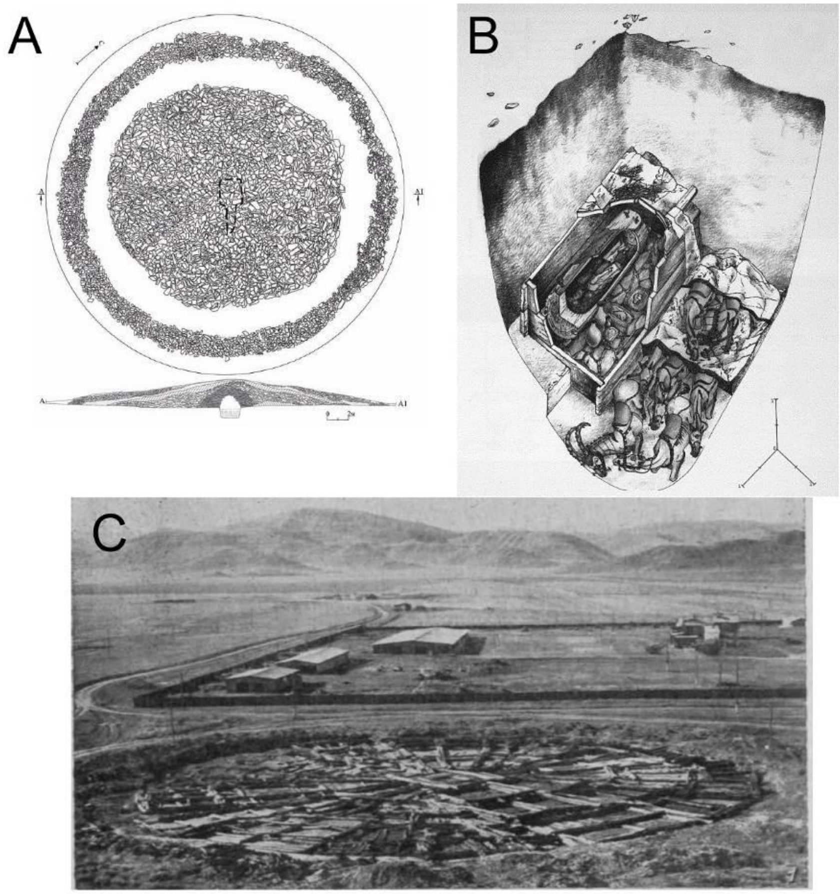


Figure 16: Examples of the Iron Age burial constructions from Central Asia. A: Karashoky, kurgan 1 – plan and cross-section of the kurgan (Beisenov et al., 2017); B: Berel, kurgan 11 – reconstruction of the burial chamber (Samashev, 2011); C: Photo of kurgan Arzhan after the top soil was removed (Gryaznov, 1980).

4.4.1. Turgai during the Early Iron Age

Perhaps, due to the remoteness of the region, sites of the Early Iron Age in Turgai deflection have not been systematically studied yet (Bazarbayeva, 2015; Seitov, 2011a). Therefore, there is not much information about the people that inhabited the region during the time of geoglyphs construction.

We know very little about their lifestyle, economy, cultural, and ideological views.

Only a small number of individual burials from the Early Iron Age are known in Turgai deflection. Early Iron Age burials that were investigated (n=9) are located at cemetery complexes, such as Bestamak, Halvai 3, Kenysh 3, Lisakovsk, Karatomar, as well as kurgans of Nadezhdinka 4, Naurzum. Burial goods discovered inside these burials include iron swords (6 cases), bronze and iron arrow points (5 cases), quiver (2 cases), iron knife (6 cases), iron plates (1 case), bone badges (1 case), ceramic and wooden vessels (5 cases), iron and bronze buckles (2 cases), ceramic beads (2 cases), bronze mirror in birch bark box (1 case), ceramic spinning whorl (2 cases) (Bazarbayeva and Podzyuban, 1997; Logvin and Shevnina, 2011; Logvin et al., 2008; Logvin et al., 2019; Logvin, 1993; Seitov, 2011a; Usmanova and Suslov, 2000).

Archaeological research was conducted at two Tasmola culture cemeteries located near the modern village Ashutasty, geoglyphs Big Ashustasty cross, Small Ashutasty cross, and Ashutasty line. The cemeteries are known as Ashutasty-1 and Ashutasty-2 (fig. 7). Kurgan 10 of the Ashutasty-1 was excavated. After removing the top soil, the archaeologists discovered a circular area densely covered with stones, which were laid out on top of the burial as a part of the ritual (Dzhumabekova and Bazarbayeva, 2017). The burial chamber was 1.8 m. in depth and included scattered human remains. The character of the discovered burial suggested that it was robbed in ancient times. The burial goods included animal-style ornaments made of gold foil and a bronze arrow point.

During the archaeological research at Ashutasty-2 burial site, an anthropomorphic stone sculpture dated to the Early Iron Age was discovered (Bazarbayeva and Dzhumabekova, 2017). Such anthropomorphic sculptures are spread across Central Asia and commonly dated to the Early Iron Age – Medieval period. Beisenov (2016a) suggests that this tradition followed into the Early Iron Age from the stellae of the Final Bronze Age Begazy-Dandybayevo culture. It has been suggested that the anthropomorphic sculptures were put on top of some kurgans to mark the connection of a tribe with their warrior-ancestor (Gutcalov and Tairov, 2000). It is believed that such sculptures were based on the appearances of real people, possibly warriors that were famous for their heroic actions.

Another kurgan excavated near Ashutasty village in 2014 by a group of archaeologists from Kostanay State University and known as Ashutasty-30 (fig. 7) contained the remains of a 1.5-year-old child (Shevnina, 2014). The kurgan had a circular area filled with stones in a similar way as Ashutasty-1. The burial pit did not have any artifacts, however, anthropomorphic stone sculpture was discovered next to stone accumulation.

Famous Kaindy hoard was discovered on the banks of Aidarbulak Lake in Turgai, and originally included 80 objects of the Early Iron Age material culture. Now 76 objects are stored in the Arkalyk museum. The hoard included elements of bronze bridles, zoomorphic decorations, badges, pendants (Seitov, 2011b; 2015). The objects of Kaindy hoard have analogies at other sites of the Early Iron Age located in eastern, central, south-eastern Kazakhstan, and Altai. The artifacts were dated to ~1000-600 BC by cultural affiliation.

A case of an Early Iron Age kurgan containing only animal skeletal remains is also known in Turgai. A large kurgan (d=26 m.) dedicated to a horse and not including human remains was discovered and excavated in the northern part of Turgai deflection (Usmanova, 2012). The kurgan, known as Tobolskyi (fig. 7), included the burials of two horses, four constructions, and a sacrificial complex. Burial goods included only ceramic vessels. The kurgan was dated to the Early Iron Age by cultural affiliation (E. Usmanova, personal communication, March 2018).

4.5. Geoglyphs of Turgai

Geoglyphs of Turgai were dated by the OSL method to the Early Iron Age period (Motuzaite Matuzeviciute et al., 2015b). They are scattered around the Kostanay oblast and concentrated mainly in the Turgai River basin (fig. 7). Around 70 of the geoglyphs have been discovered to date. The most recent discovery was done on the 25th of May, 2020 by a Kostanay State University archaeologist Irina Shevnina and publically shared on Facebook social network (fig. 17).

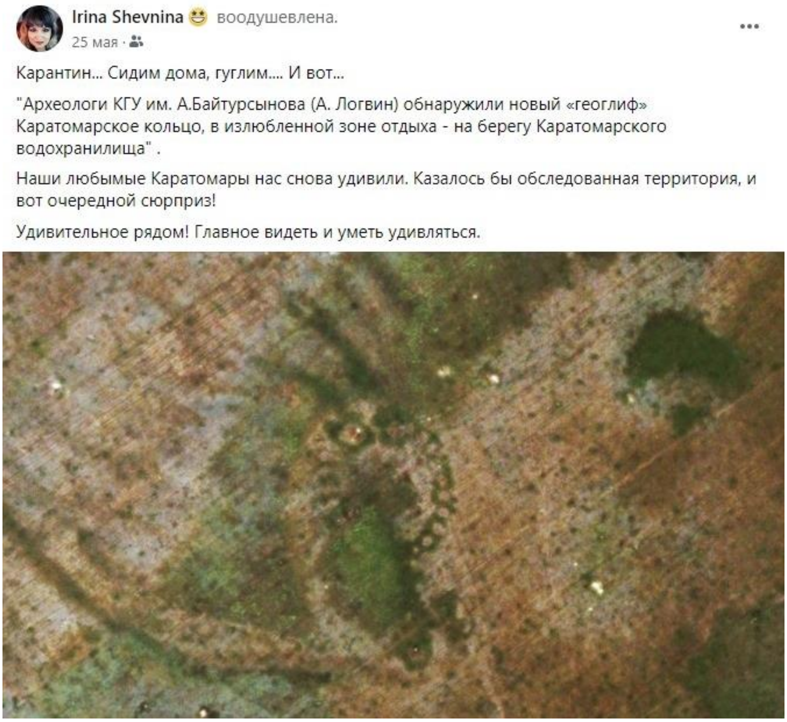


Figure 17: Discovery of a new “Karatomar ring” geoglyph as published on the social network Facebook.

4.5.1. Types of structures

The majority of the discovered geoglyphs present lines of mounds (table 1) ranging from 32 m. (Arshaly line) to 680 m. (Zhitikarin line) in length and made out of 5 (e.g. Ashutasty, Arshaly lines, etc.) to 23 (Zhitikarin, Zhosaly (fig. 18, right) lines) mounds. Some line structures present two parallel lines, such as Arshaly (fig. 18, left), Shinsai, and Alakol lines, while one discovered structure (Koszhan lines) presents two unparalleled lines. Logvin et al. (2018a) analyzed the frequency of different mound numbers in the line structures. They have shown that the most frequent number of the mounds in “lines” is 7 (13 structures), 9 line structures consisted of 11 mounds, 5 and 9 mound-“lines” were encountered 8 times each, 7 discovered “lines” are made out of 15 mounds, 4 “lines” have 13 mounds each, 2 “lines” are made out of 23 mounds each, and only one “line” includes 21 mounds.

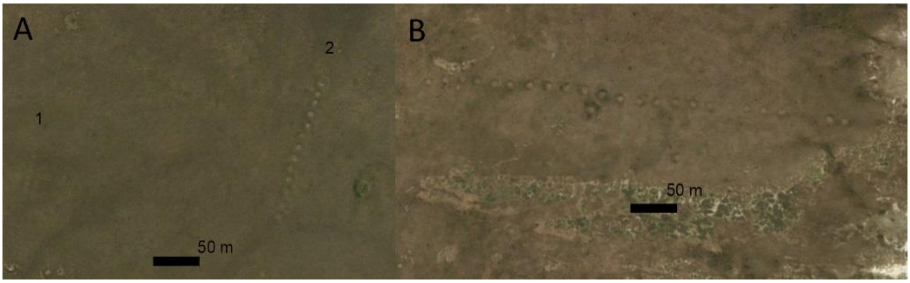


Figure 18: Arshaly lines (right image) and Zhosaly line (left image). Both images were taken from Bing Maps 2020 (DigitalGlobe, Maxar, Tom Tom, HERE).

The cross structures (table 1) are made out of perpendicular lines with a central mound. The rays of the crosses almost always have an even number of mounds and consist of 4 (n=1), 5 (n=4), 6 (n=2), or 10 (n=1) mounds with another mound located in the center of a cross. Only one discovered structure – Zhaldama cross (fig. 19 - left image) is made out of rays with uneven numbers of mounds – two rays have 3 mounds each and two other rays have 4 mounds. It is possible that the structure was not finished, and perhaps the original plan was to construct rays with 4 or 5 mounds in each. A structure Mohat cross (fig. 19 - right image) was partially destroyed by a modern road, and currently has two rays with 6 mounds in each and two rays with 4 mounds. However, from the arrangement of the structure, it is visible that there were 6 mounds in each ray. Therefore, 4 mounds and the central mound were destroyed by the modern constructions.

The rings (n=9) also contain different numbers of mounds (table 1). One discovered structure includes 29 mounds (Suyindyk ring, fig. 20 – left image), two structures are made out of 25 mounds, one structure has 23 mounds, two structures include 15 mounds, two structures have 9 mounds, and only one discovered “ring” is made out of 7 mounds (Zhaldama ring, fig. 20 – right image).

A single known Turgai earthwork structure – Ushtogaiskyi square (fig. 21), present a square with even sides and lines of mounds going through the diagonals of the square. Therefore, this structure combines a square and a cross. This structure is made out of 101 mounds (table 1), which is the biggest number of mounds in all discovered geometric earthworks of Turgai. It is unknown whether the Ushtogaiskyi square had a special meaning or purpose which was different from other structures.

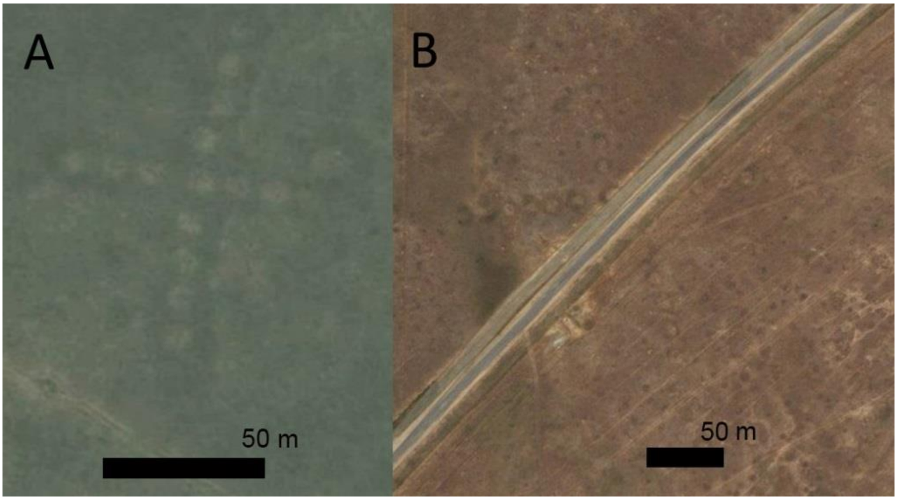


Figure 19: A: Zhaldama cross and B:Mahat cross. The image of Zhaldama cross was taken from Logvin et al. (2018a), the image of Mahat cross was taken from Bing Maps 2020 (DigitalGlobe)

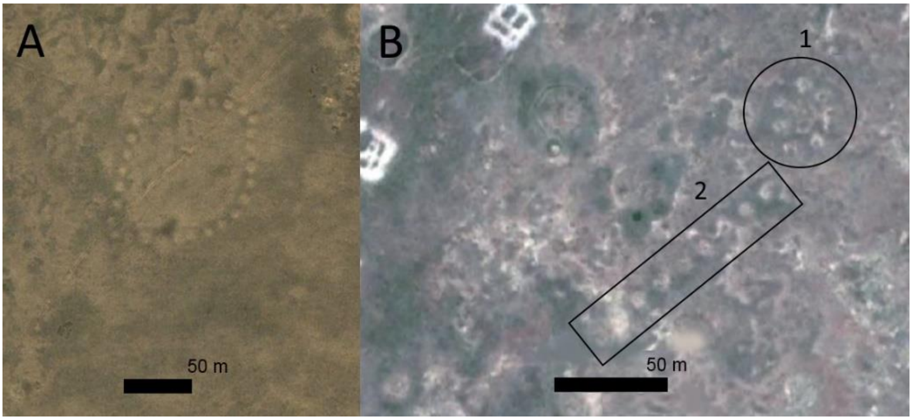


Figure 20: A:Suindyk ring and B: Zhaldama ring (1) with Zhaldama line (2). Both images were taken from BingMaps 2020 (Maxar, TomTom, HERE)

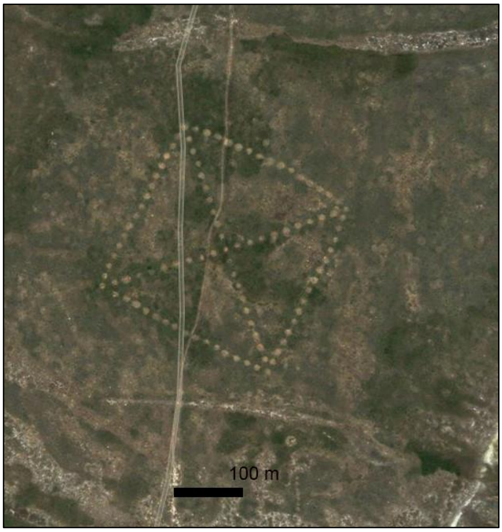


Figure 21: Ushtogaiskyi Square. The image was taken from BingMaps 2020 (DigitalGlobe)

The swastikas present structures which are different from other types of geoglyphs. These structures are made of a single swastika-shaped mound (triskelion). Moreover, the shape itself is more complex and not geometric. Some scholars have argued that the two discovered swastika structures (Turgai (fig. 22 - left image) and Zhandra (fig. 22 - right image) swastikas) cannot be included amongst the other geometric earthworks of Turgai (table 1), as they were possibly constructed by a different group of people at a different chronological period, and likely had other purposes (I. Shevnina, personal communication, August 2017).

The geometric earthworks were often constructed on elevated areas (Logvin et al., 2018a). The excavations of the individual mounds of the Ushtogaiskyi Square and the Small Ashustasty Cross have shown that before the mounds were constructed, the surface was cleared and evened up. The individual mounds were erected on the even surface using the loose soil (Logvin et al., 2018b).

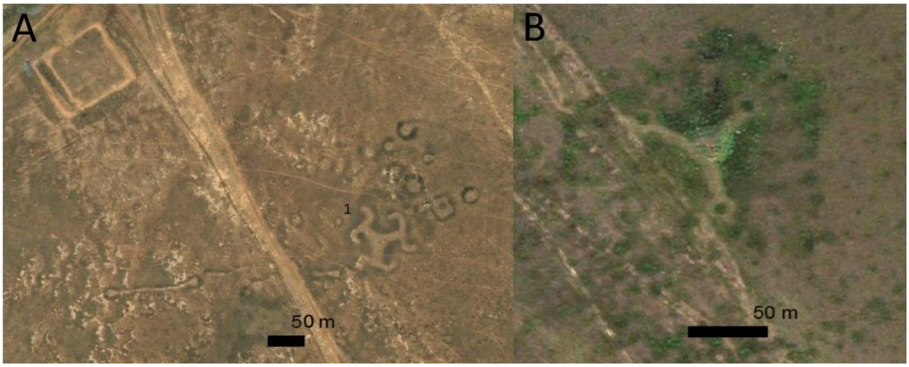


Figure 22: A: Turgai swastika (1) and surrounding archaeological objects. The image was taken from BingMaps 2020 (Maxar, TomTom, HERE). B:Zhandra swastika (right image). The image was taken from Logvin et al. (2018a)

Table 1: Summary information on the Turgai geometric earthworks (information collected from Logvin et al. (Logvin et al., 2018a).

Type of structure	Number	Size, m.	Number of mounds, m.	Diameter of mounds, m.	Height of mounds, m.
lines	52	32-680	5-23	5-12	0.1-0.7
crosses	9	75-436	15-41	6-13	0.05-1
rings	9	30-170	7-29	5-12	0.05-1
squares	1	287x287	101	10-12	0.8-1

It is also important to mention that all discovered structures have odd numbers of the mounds, which might have a symbolic meaning. Moreover, almost all geometric earthworks have other archaeological constructions near them, such as kurgans, ditched structures, etc. Some geoglyphs have many archaeological structures around them, for example Koktas, line is situated next to 8 differently shaped kurgans (fig. 23, left image). In some situations, it is possible to suggest that a geometric earthwork structure was constructed later than the accompanying archaeological structures (Logvin et al., 2018a). For example, one of the rays of the South-Turgai Cross goes around a large kurgan (fig. 23, right image). In some cases, different types of geometric earthworks are encountered together in a complex, such as Zhaldama line fig. 20, right image)

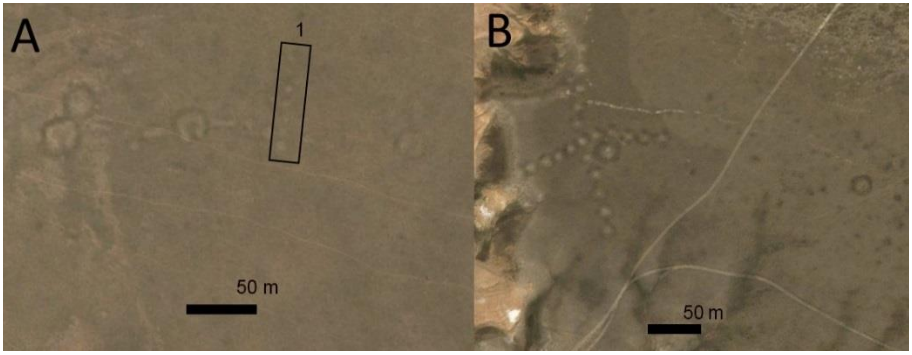


Figure 23: Koktas line (1) and surrounding archaeological structures (left image). South-Turgai cross with individual kurgans (right image). Both images were taken from BingMaps 2020 (Maxar, TomTom, HERE)

4.5.2. Comparison with other archaeological structures of Central Asia

Geometric earthworks of Turgai can be compared to a number of other archaeological structures scattered across Central Asia. A series of structures similar to the geometric earthworks of Turgai were discovered at Chash-Tepe funerary site in North-Western Chorezm (Uzbekistan). The burial complex consists of an accumulation of different constructions shaped as circles, squares and lines (Rapoport and Trudnovskaya, 1979). Some of the structures consist of individual mounds in the same way as Turgai structures. A swastika structure was also discovered at Chash Tepe (fig. 24, left image). The construction is similar to the Turgai swastika (fig. 18, left image). Many excavated kurgans and constructions of Chash-Tepe did not contain any organic remains or artifacts. However, a few structures yielded ceramic fragments and artifacts that were dated to AD IV-V by cultural affiliation. Rappoport and Trudnovskaya (1979) suggested that the Chash-Tepe swastikas had ritual meaning, but did not have any utilitarian purpose.

Swastika is an ancient symbol that was used by the Bronze Age Andronovo community during the process of pottery decoration. The symbol can be found in different variations on ceramic vessels across the Bronze Age sites of Central Asia (fig. 24, right image). Three-rayed swastikas were also used on coins from Chorezm (fig. 25) that are dated to the AD II-III. The symbols depicted on Choresmian coins were interpreted as “tamgas” – a symbol of a particular family or a clan (Tolstov, 1948).

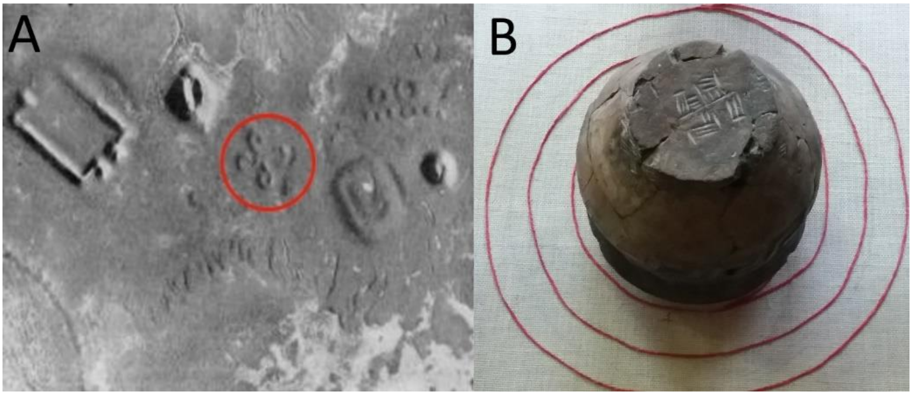


Figure 24: Chash-Tepe swastika (left image). The image was taken from Rappoport and Trudnovskaya (Rapoport and Trudnovskaya, 1979); Bronze Age pottery of the Andronovo cultural horizon (bottom of the vessel) from the museum of Lisakovsk (right image).

Figure 25: Coins from Toprak-Kala (Chorezm), Tolstov (1948)

Logvin et al. (2018a) compare geoglyphs to the “kurgans with moustache” that are spread across Kazakhstan and dated to the Iron Age. Long stone lines coming out of the main kurgan and shaped as “moustache” were often constructed as a part of the burial monument (Beisenov, 2016c; Kadyrbayev, 1959). The assosiation between the geoglyphs and the “moustache” of a kurgan is caused by the common presence of other archaeological constructions next to the geoglyphs. Geoglyphs could serve a similar purpose as the “moustache” and could be constructed as part of a funerary complex. Logvin et al. (2018a) also report a burial site Kairan, located in Kostanay oblast, which contains two “kurgans with moustache” and a line of 5 mounds.

Famous ritual structures - khirigsuurs spread across Altai, Baikal, and Mongolia also have common features with the Turgai geoglyphs (fig. 26). Khirigsuurs present geometrically shaped mound constructions made of stones and soil and commonly dated to the Late Bronze Age – Early Iron Age (~1400-700 cal. BC) (Honeychurch, 2015). The main khirigsuur structure often has several satellite mounds and circles. It has been debated that these monuments were used not only for burial ceremonies, but also for other rituals, celebrations, and meetings (Honeychurch, 2015; Houle, 2010). The complexity and large size of some khirigssur structures point to the enormous input of time, human labour and consolidated work required for the construction of the monuments (Honeychurch et al., 2009). Similarly to geoglyphs, some excavated khirigsuurs did not yield any human remains. Some scholars argue that the appearance of massive structures, such as khirigsuurs, in Central Asia might be related to the rise of the elite and an increase in social stratification (Allard and Erdenebaatar, 2005; Houle, 2009).

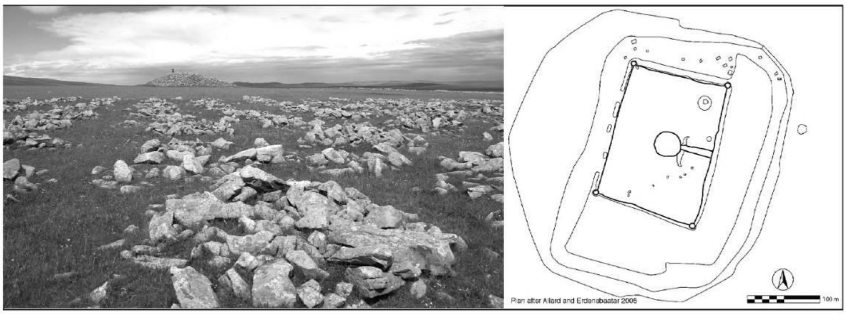


Figure 26: Khirigsuur of Urt Bulagyn (Mongolia), Wright (2014)

The “arrow-shaped” hunting installations of plateau Ustyurt (Yagodin, 1991) also bear some similarities to the geoglyphs of Turgai. The structures are large in size and visible from the satellite imagery. Over 100 of them were identified only in the north-east Ustyrt. Most of them are dated from the ~400 BC to 800 AD (Amirov et al., 2015). These structures also required large input of time and energy, and most likely were not built at once. A number of the hunting installations are present next to the Duana burial complex associated with nomadic groups (fig. 27), which suggests that the

Ustyurt plateau could be used by nomads as a winter encampment (Yagodin et al., 2007). The local landscape does not have a thick snow cover, which allows for some migratory animals, such as saiga and roe deer, to spend their winters in the plateau. Therefore, nomadic groups could exploit the local hunting grounds during the winters.

Figure 27: The "arrow-shaped" hunting installations of the Duana 1 complex (Bing Maps 2020; DigitalGlobe imagery)

4.5.3. Hypotheses related to the geoglyphs of Turgai

4.5.3.1. Territorial markers

It has been suggested that geometric earthworks of Turgai could be used for marking territories occupied or used by a certain community (Logvin et al., 2018a; Motuzaite Matuzeviciute et al., 2015b). Considering the time and human labour it took to construct the geometric earthworks, the "territorial marker" hypothesis implies that Turgai plateau had some kind of a valuable resource, for example, metal sources, rich pastures or hunting grounds. Economic-defensibility model states that a defensive territorial behavior happens when the value of defending a resource is less than the cost of the resource itself (Dyson-Hudson and Smith, 1978). Following this statement, the constructors of the geoglyphs invested their time and labour into the territorial markers, which possibly worked as defense systems.

This theory also implies that the geometric earthworks were not only visible from the surface level, but also recognizable. At the present times, the tallest mounds of the earthwork structures reach 1 m., while some of them are only as high as 0.05 m (table 1). Natural forces, such as water and wind erosion as well as human impact might have influenced the destruction of the top levels of the mounds. It is possible to suggest that the mounds were taller at the time of their construction. However, at the present moment, there is no possibility to explain the use of different shapes during the construction of geoglyphs. The use of crosses, lines, and rings might be associated with three different tribes or communities. However, in some cases (e.g. Zhaldama line and ring), the structures of different types are encountered together. It is also possible that various geoglyph shapes carried different messages in a manner of Early Muslim writings (tamga). Therefore, if the geometric earthworks were used as territorial markers, they were likely used by the community that constructed the structures or new the meaning of the different geoglyphs.

4.5.3.2. Astronomical observations

Another theory proposed and promoted by the original discoverer of the geometric earthworks Dmitryi Dei (personal communication, September 2019) points to the use of the structures as horizontal observatories (Logvin et al. 2018a). Taking Peruvian Chankillo observatory as an example, Dei suggests that from at a certain point nearby a geometric earthwork structure, the ancient people could see how the sun is setting down between the mounds, and the location of the sun would tell them what time of a season it is (fig. 28). Knowledge of a certain time in a season could help in hunting down migrating saiga or starting agricultural activities at a right time.

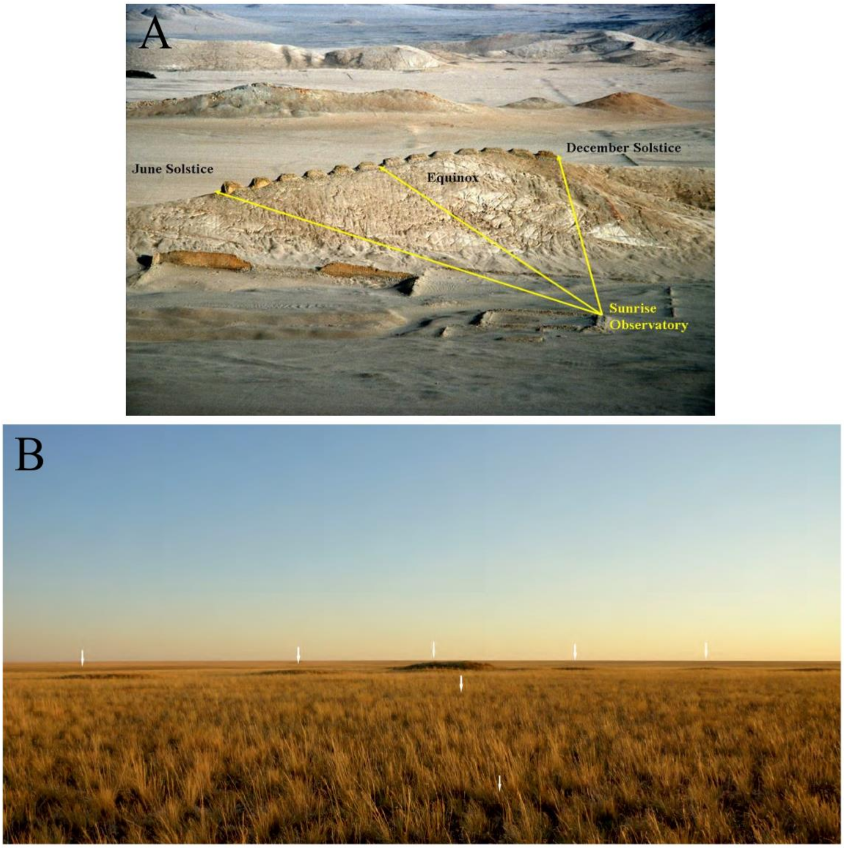


Figure 28: A: Chankillo observatory in Peru (the photo was taken from http://monkeybuddha.blogspot.com), B: South-Turgai Cross (the photo by Logvin et al. (2018a)).

However, the structures are oriented differently in meridional and geographic ways. Therefore, it does not appear that they could be used for astronomical observations. Moreover, some geometric earthworks are clustered together in large groups, which appears unreasonable if they were all used for the same purpose. Dei suggests that the structures were built in different periods, which would explain why they are oriented in different ways. Perhaps, the orientation of the structures had to match the magnetic or true north, which changed its position several times in the past.

4.5.3.3. Sacred-ritual meaning of the structures

The third hypothesis is based on the symbolic meaning of the mounds (kurgans) for the prehistoric people of Central Asia. In Central Asia, kurgans were erected since the Eneolithic period (Logvin et al., 2018a). There could be a burial of a single person, multiple people, animals or a cenotaph inside of a kurgan. Sometimes, kurgans were specifically constructed for animals, especially horses (Usmanova, 2012), and did not include any human remains.

During the archaeological landscape studies in Central Kazakhstan carried out in the first half of the XX century, the researchers discovered groups of mounds that were referred to as “sun” kurgans (Margulan, 1948). They present circular groups of mounds with a bigger mound in the middle. Several central mounds were excavated but did not yield any burials. It was suggested that such kurgans could be created to commemorate a festive dinner (Margulan, 1948). They could also present memorials erected after some kind of terrible disaster, for example death of the community from plague or an enemy attack.

In parallel to the phenomenon of khirigsuurs and as it has been suggested earlier by Logvin et al. (2018a), Turgai geoglyphs could be part of the ritual-burial complexes either accompanying a previously erected burial or another sacred construction. Archaeological and satellite data indicates that over 80% of geoglyphs structures have accompanying archaeological constructions next to them. Furthermore, in the case of Ushtogaiskyi square and Big Ashutasty cross, the complexes of accompanying archaeological structures are almost alike (fig. 29). Both geoglyphs have a complex of three ring-like mounds that are located on the northern side with the middle mound being parallel to one of the axes of the geometric earthwork. Ushtogaiskyi square and Big Ashutasty cross present the biggest geometric earthworks discovered so far, therefore the construction of these two monuments required even more time and human labour than the construction of other identified geoglyphs. It might be suggested, therefore, that the complexes of mounds situated to the north from these two geoglyphs contain burial of the higher status people or present sacred monuments of greater importance.

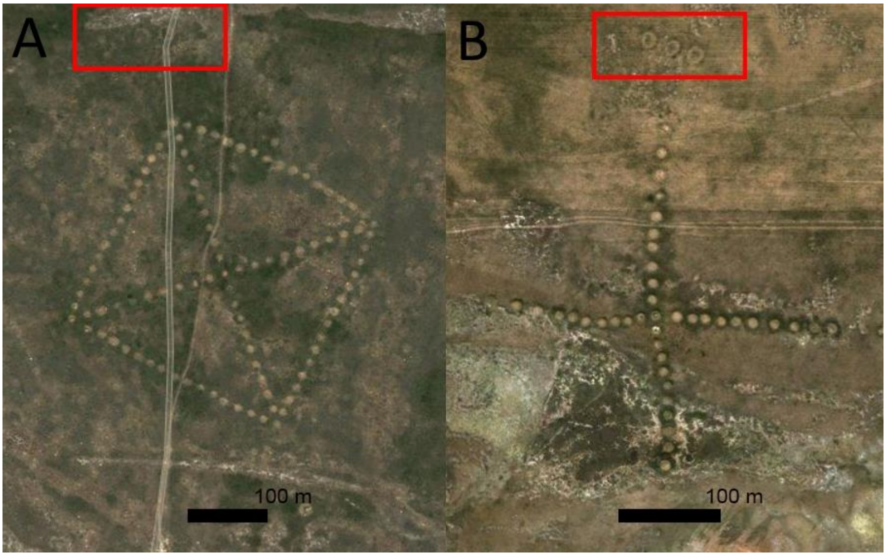


Figure 29: Ushtogaiskyi square with accompanying structures marked and B:Big Ashutasty cross with accompanying structures marked. Both images were taken from BingMaps2020 (DigitalGlobe).

Overall, the available data suggests that the structures could be built as part of funerary complexes of the Iron Age. Evidence about the diverse burial rituals of the Iron Age carried out in various territories of Central Asia indicates that the construction of monumental burial complexes that reflected the elite status of the deceased was quite common. Such evidence is available in the steppes of Kazakhstan (Taksai kurgan, Issyk kurgan, Tasmola kurgans with dromos), Altai (Pazyryk, Berel, Arzhan), Mongolia (khirigsuurs). The archaeological excavations of several mounds at some Turgai geoglyphs yielded no human remains. However, the presence of accompanying archaeological structures next to the majority of the geoglyphs suggests that the geometric earthworks could be constructed after those accompanying structures as part of the burial complexes.

5. Economy and subsistence in Central Asia

Due to the lack of archaeological investigations in Turgai, there is little known about the economy of its prehistoric populations. However, the archaeological evidence suggests that economic processes and transformations were happening on a larger scale of Central Asia, which stretched from the south-west Russia in the north to Afganistan and Iran in the south and from the Caspian Sea in the west to China in the east.

The role of Central Asia in the early economic developments and exchange has been actively discussed in the past decades. Frachetti (2012) have argued about the existence of Inner Asian Mountain Corridor (IAMC) of Central Asia, through which pastoralists of the 3rd mil. BC exchanged goods and technologies.The current evidence for the spread of early cultivars suggests two independent transmission pathways, which crossed Kazakh steppes from the West and the East (see below). Recent research also points to the movement of domestic animals across the mountains of Central Asia. Isotopic evidence suggests that the dietary changes affected many regions of Central Asia during the Late-Final Bronze Age. Spread and development of metalworking technologies was a continuous process observed at a large territory of north Central Asia.

Pastoral communities had to be highly mobile in order to provide their animal herds with sufficient amount of food. Evidence for the exchange of goods and technologies also points to a high degree of mobility across steppe and mixed-steppe regions of Central Asia. Thus, a review of the economic evidence from Central Asia might point to the wider processes that affected the Turgai region at different periods.

5.1. Transition from hunting to horse herding in the Kazakh steppes

Neolithic communities of the north Kazakhstan steppe known as Makhandzhar and Atbasar cultures relied on hunting and gathering for subsistence (Outram and Bogaard, 2019). The development of Eneolithic cultures, such as Botai (Zaibert, 2009) and Tersek (Kalieva and Logvin, 1997) around the 3800-3500 cal. BC coincided with the change of economy and lifestyle, settlement sites became more visible in the archaeological context. Archaeological research at the Eneolithic site of Botai (fig. 30) yielded extremely high concentration of horse skeletal remains with over 99% of all animal remains belonging to horses (Olsen, 2003). This became the first point in the argument towards the Botai horses being domestic. Years of research on Botai horses produced strong evidence towards husbandry of some horses (Outram et al., 2009), while a large number of horses was likely hunted as suggested by the traces of hunting damage on the skeletal remains (Olsen, 2003).

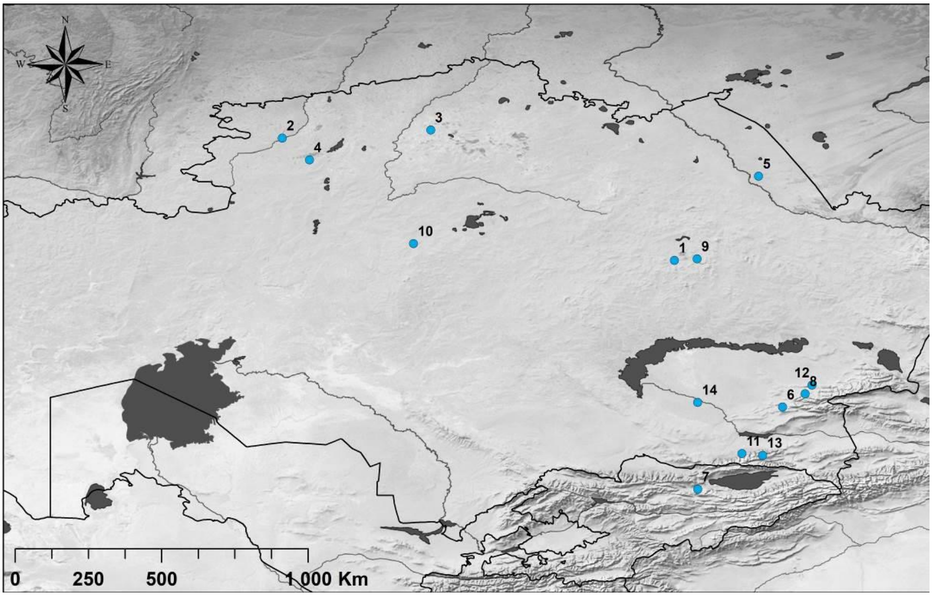


Figure 30: Map with the major sites disussed in sections 4.1-4.4; 1.Abylai, 2.Alekseevskoye, 3.Botai, 4.Belkaragai, 5.Borly-4, 6.Begash, 7.Chap I, 8.Dali, 9.Kent, 10.Kozhai-I, 11.Taldy Bulak-2, 12.Tasbas, 13.Turgen, 14.Serektas. The map was created in ESRI ArcMap 10.4.1. with the use of Natural Earth free data.

Zooarchaeological research at Belkaragai 1 (fig. 30), which is associated with the Eneolithic Tersek culture demonstrated a major focus on horse exploitation (Kosintsev, 2015). Archaeozoologist Pavel Kosintsev (2015) argues that the horse remains from Belkaragai 1 belonged to the wild horse (*Equus Ferus)*. However, osteometric comparison of the skeletal remains of horses from Belkaragai 1 and Botai showed that the horses from the two sites belonged to the same type (Kuz'mina, 1993), which argues towards the husbandry of horses in the Tersek culture. Evidence from another Tersek culture site – Kozhai I (fig. 30) also points to the horse husbandry and even riding (Gaiduchenko, 1998).

Archaeological investigations from the Eneolithic site Borly 4 (fig. 30) located in the Irtysh River valley in the eastern Kazakhstan demonstrated that the local economies were potentially based on horse and cattle herding (Gaiduchenko and Mertz, 2012). Although, the presence of domestic cattle in the Eneolithic contexts appears to be doubtful, recent genomic data indicated that the Borly horses are genetically very similar to the horses of Botai (Gaunitz et al., 2018), which suggests that the horses of Borly could also be husbanded.

Based on the evidence for horse husbandry coming from many Eneolithic sites of northern Kazakhstan, it is possible to suggest that during the 4th mil. BC, a large community of horse herders existed in the north Kazakhstan steppe (fig. 31) and forest-steppe and controlled the territory of 300 000 km^2 geographically spanning from Turgai River in Kostanay region to Irtysh River in eastern Kazakhstan.

Figure 31: A horse herd in the steppe of north Kazakhstan

Eneolithic sites of the north Kazakh steppes mainly concentrated on three large rivers – Irtysh, Ishim and Tobol. Finds of fish bones and isotopic evidence suggests that fishing also contributed to the diet of the Eneolithic communities (Gaiduchenko, 1998; Svyatko et al., 2015).

5.2. Animal herding in the Bronze and Iron Ages

Mixed pastoralism – a widespread form of the economy across Central Asia has developed in the Bronze Age, and was based on herding sheep (*Ovis aries*), goat (*Capra hircus*), cattle (*Bos taurus*) and horse (*Equus caballus*). Domestic sheep and goats, which were introduced into the Kazakh steppes only around 2500 BC (Frachetti, 2008; Motuzaite Matuzeviciute et al., 2016; Outram et al., 2011), eventually became economically important animals. The final Eneolithic layer at Botai dated by AMS to ~2800 cal. BC contains skeletal remains of sheep, however, there is no certainty that the bones came from the same context (Outram and Bogaard, 2019).

Full-scale zooarchaeological analysis has not been carried out at many sites in Central Asia. In many cases, it was limited to species identification, presentation of skeletal abundances, and the minimal number of individuals (MNI) of different species. Reconstruction of proportions of different species at the sites of Central Asia based on zooarchaeological research indicates the prevalence of cattle at northern Kazakhstan and Trans-Uralian sites in the Middle and Late Bronze Age (fig. 32), while the percentage of horses in the region increase by the Final Bronze Age and Iron Age (fig. 33). Archaeological sites of central and south-eastern Kazakhstan have higher percentages of sheep and goats in the Middle – Late Bronze Age as well as in the Final Bronze Age – Iron Age (fig. 32, 33). However, the percentage of horses at central Kazakhstan sites increase by the Final Bronze Age – Iron Age, whereas in south-eastern Kazakhstan, the percentage of horses does not change with the exception of Serektas (fig. 33).

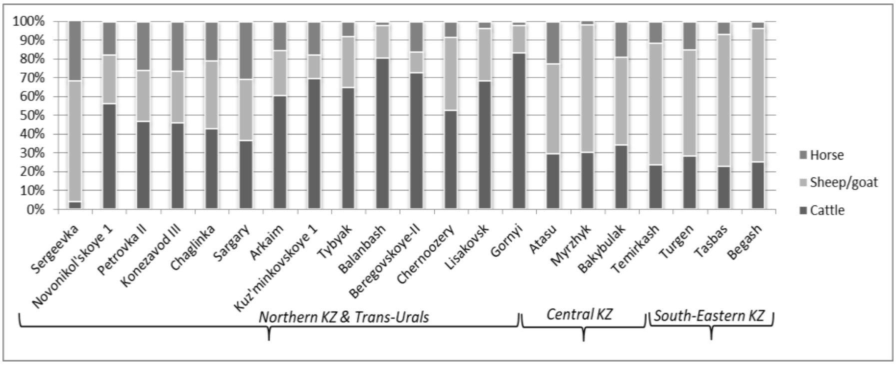


Figure 32: Proportions of main domestic taxa in the Middle - Late Bronze Age archaeological contexts across sites of Central Asia. Information about NISP (number of identified specimens) counts was collected from published sources (Ahinzhanov et al., 1992; Beisenov and Loman, 2009; Doumani et al., 2015; Frachetti and Benecke, 2009; Haruda, 2018; Kasparov, 2013; Kosintsev 2001; Kosintsev, 2000; Makarova, 1970; 1976; Makarova, 1980; Outram et al., 2012)

More detailed zooarchaeological studies conducted at few sites across Central Asian steppe gave an insight into the animal herding strategies. At central Kazakhstan Final Bronze Age site Kent (fig. 30), the majority of caprines were killed after they reached 2,5-3 years of age, which indicates that they were mainly kept for meat production (Haruda, 2018). Horses and cattle survived longer, which suggests that they were exploited for secondary products and transportation. Other data from Kent point to the potential use of sheep for wool production (Outram et al., 2012).

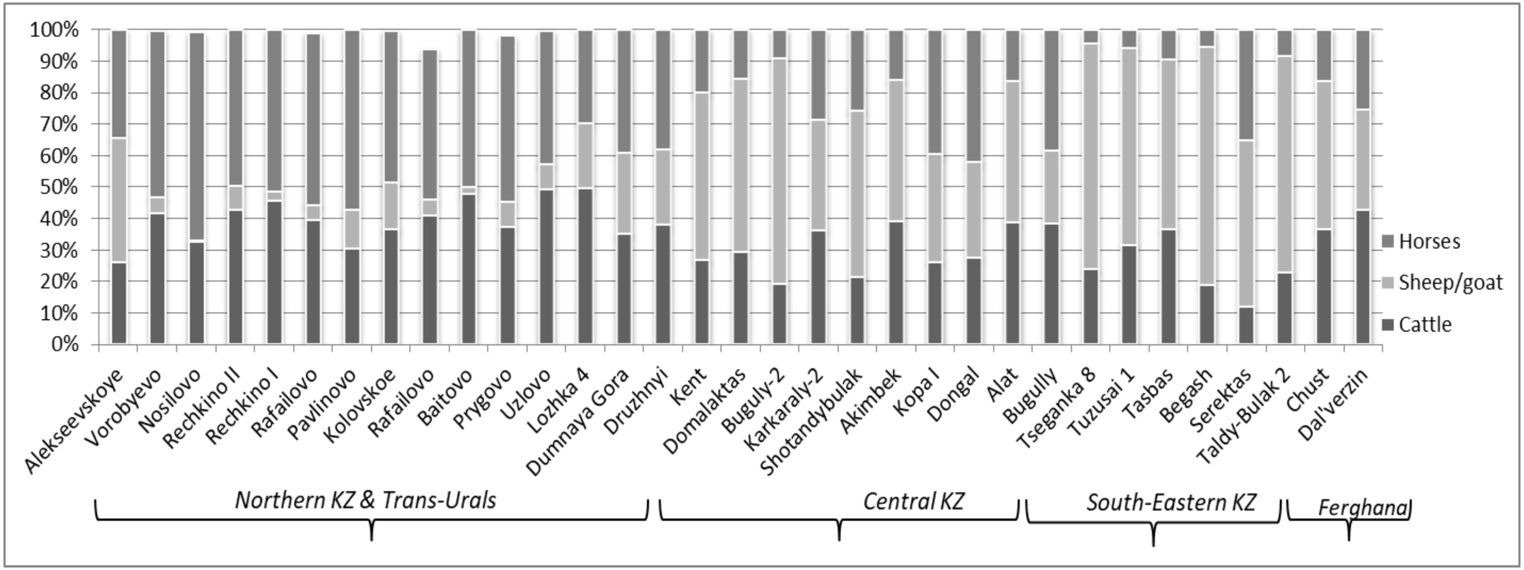


Figure 33: Proportions of main domestic taxa in the Final Bronze Age – Iron Age archaeological contexts across sites of Central Asia. Information about NISP (number of identified specimens) counts was collected from published sources (Beisenov and Varfolomeev, 2008; Chang et al., 2003; Doumani et al., 2015; Frachetti et al., 2010; Gaiduchenko, 2015b; Haruda, 2007; Haruda, 2018; Koryakova and Hanks, 2006; Krivtsova-Grakova, 1948; Lhuillier and Mashkour, 2017; Outram et al., 2012; Varfolomeev, 1991)

Data from a highland site Turgen (fig. 30) located in south-eastern Kazakhstan and dated to the Final Bronze Age pointed to a similar exploitation pattern with the majority of caprines killed before reaching 3 years of age, and cattle and horses kept longer for the exploitation of secondary products (Haruda, 2018). Recent isotopic research of Turgen caprines, however, not only includes data on the older individuals, which were likely exploited for the secondary products but also suggest that the animals were seasonally moved between altitudes (vertical transhumance) (Ventresca Miller et al., 2020).

Evidence from Serektas (fig. 30) – a site located in south-eastern Kazakhstan points to the higher survival rates. Sheep, goats, cattle and horses were all left at ~60-70% survival rate after 1,5-3 years of age (Haruda, 2018). There was a significant amount of hunting involved at the site of Serektas, therefore hunted animals, such as *E. hemionus kulan* contributed a lot to the subsistence of the inhabitants.

Data from a south-east Kazakhstan Iron Age site Taldy Bulak 2 (fig. 30) similarly point to the focus on sheep/goat exploitation (Haruda, 2007). Based on the mortality profiles, it was debated that sheep were kept for the production of wool as well as meat (Benecke, 2003). Other data from the region, such as spinning whorls and textile pottery also suggest that sheep were exploited for wool production (Chang, 2017). Recent data from Kyrgyz Tian Shan highland site Chap I (fig. 30) dated to the Final Bronze Age also suggests exploitation of sheep for wool (Ananyevskaya et al., 2020).

Recent research from Mongolia based on ZooMS and aDNA analysis of animal bones from archaeological sites demonstrated that intensive horse exploitation for food and transportation started there in the Late Bronze Age (~1200 BC) and caused an increase in mobility (Taylor et al., 2020). ZooMS data from the Early Bronze Age Kyrgyzstan additionally suggest that horses were introduced into the Kyrgyz Tian Shan in the later periods (Taylor et al., 2018). Although the sample size of the study is very small, which might explain the absence of the *Equus* genus amongst the identified species.

It had been debated that the proportions of various domestic animals at archaeological sites vary depending on the environmental factors, such as the annual precipitation and extreme temperatures (Bendrey, 2011, Benecke and von den Driesch, 2003). This suggests that sheep and goats as animals suffering less from lack of water would be more common in arid environments, while cattle should be more widespread in regions with high precipitation (Kay, 1997). However, a comparative study conducted by Haruda (Haruda, 2018) demonstrated that exploitation of caprines is almost equal in rate in central and south-eastern Kazakhstan, and cattle were not kept in higher numbers at a high-altitude south-eastern Kazakhstan site, where precipitation is the highest of all studied regions. The preference towards cattle in the north and sheep/goat in the south should, therefore, be explained by other factors, such as cultural traditions or economic needs.

5.3. Early use of domestic crops in Central Asia

Archaeological evidence suggests that wheat and barley came to the Kazakh steppes from the Near East and Europe around the mid-third millennium BC, while the domestic millet originated in China and came from the East (Jones et al., 2011; Spengler et al., 2016). Recent evidence from Altai, however, indicated that barley and wheat were used by the local population since the 3200 BC, and the broomcorn millet was introduced at around 2100 cal. BC (Zhou et al., 2020). This data changes the view towards the trans-Eurasian exchange and suggest that wheat and barley could be introduced to Kazakhstan from the East.

The earliest crops discovered in Kazakhstan come from the south-east region. First known wheat grains were discovered at Tasbas (2840-2500 cal. BC) (fig. 30) and the first broomcorn millet was found in Begash (2450-2100 cal. BC) (Doumani et al., 2015; Frachetti et al., 2010) (fig. 30). However, the grains of millet were discovered in cremation cists together with charred human remains and were believed to be associated with a ritual rather than subsistence. Millet dated to the early second millennium BC was also found in the ritual contexts of Gonur settlement site situated in the Murghab delta (Bakkels, 2003).

Recent isotopic evidence from teeth of domestic herbivores discovered at sites of Dali and Begash located in south-eastern Kazakhstan and dated to the Early Bronze Age (~2500-2000 BC) demonstrated that cattle and caprines were foddered by millet during the cold season (Hermes et al., 2019). Findings at Dali and Begash have also shown that broomcorn millet likely arrived there after pastoralism has spread into western China.

Overall, the evidence about the early use of cultivars in Kazakhstan suggests that crops, especially broomcorn millet, could be used as part of animal management strategy and in ritual activities. However, at this point, we lack the evidence for the presence of crops in the diet of Kazakhstan population before the Late Bronze Age.

5.4. Cultivated crops as part of the human diet

As mentioned above, wheat and barley appeared in Kazakhstan and surrounding territories before broomcorn millet. Macro-botanical data from the regions located on the west from Kazakhstan suggest that wheat and barley grains are dated to as early as 4500-4000 BC (sites Anau North and Sarazm, fig. 34, 35). In Kazakhstan and Kyrgyzstan, earliest wheat and barley are dated to the Early Bronze Age (~2800-2000 BC). However, the grains tend to be discovered in ritual contexts. Macro-botanical research conducted at a Bronze Age site Kamennyi Ambar located in Trans-Urals yielded no cultivated crops (Rühl et al., 2015). Starting from the Late – Final Bronze Age, wheat and barley appear simultaneously in different regions of Central Asia (fig. 34, 35). Apart from multiple macro-botanical evidence discovered in south-east Kazakhstan and Kyrgyzstan, wheat grains were found at Late Bronze Age site Cherkassy and Iron Age sites Novy Kumak and Alekseevskoye (fig. 30) located in north Kazakhstan and Trans-Urals (fig. 34). Macro-botanical remains of barley were discovered in south-west Siberia Iron Age site Serebryakovsky and Altai sites Maima-1 and Ushlep-5 as well as in central Kazakhstan at Abylai settlement (fig. 30).

The evidence is not limited to macro-botanical finds. There were reports of barley and wheat grain imprints on pottery from the Late Bronze Age settlement Olkhovka and an Iron Age settlement Kolovskoye located in the Trans-Urals (Matveyev et al., 1998; Matveyeva et al., 2003). Similarly, wheat and millet grain impressions on ceramic vessels were reported from the site of Milovanovo-3 located in the south-west Siberia region (Sidorov, 1986).

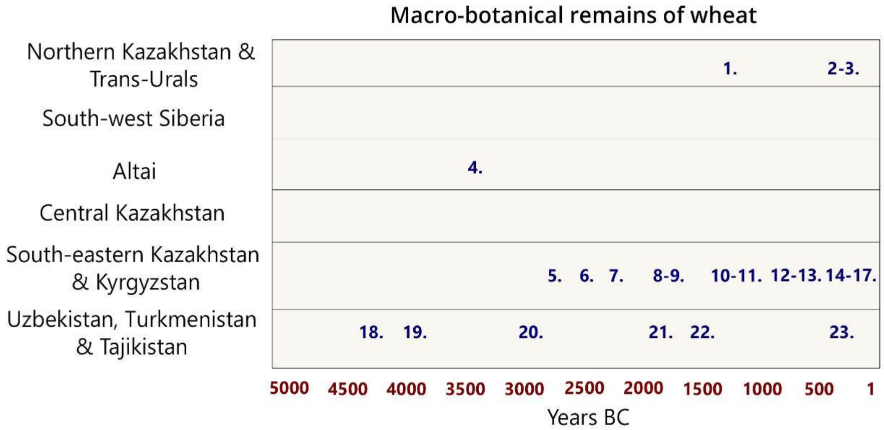


Figure 34: Finds of macro-botanical remains of wheat across North Central Asia in relation to the chronology (x-axis) and geography (y-axis). Numbers stand for the archaeological sites: 1 – Cherkassy (Lebedeva, 2005), 2 – Novy-Kumak-2 (Akbulatov, 1999), 3 – Alekseevskoye (Shishlina et al., 2018), 4 – Tongtian Cave (Zhou et al., 2020), 5 – Tasbas (Doumani et al., 2015), 6 – Chap II (Motuzaite Matuzeviciute et al., 2020a), 7 – Begash (Frachetti et al., 2010), 8 – Aigyrzhal-2 (Motuzaite Matuzeviciute et al., 2018), 9 – Uch-Kurbu (Motuzaite Matuzeviciute et al., 2018), 10 – Tasbas (Doumani et al., 2015), 11 – Mol Bulak-1 (Motuzaite Matuzeviciute et al., 2018), 12 – Chap I (Motuzaite Matuzeviciute et al., 2020b), 13 – Mukri (Spengler et al., 2014a; Spengler et al., 2017), 14 – Taldy Bulak 2 (Spengler et al., 2017), 15 – Tuzusai (Spengler et al., 2017), 16 – Tseganka 8 (Spengler et al., 2017), 17 – Begash (Spengler et al., 2017), 18 – Anau North (Miller, 1999), 19 – Sarazm (Spengler and Willcox, 2013), 20 – Anau South (Miller, 1999), 21 – Jarkutan (Miller, 1999), 22 – Ojakly & 1211/19 (Spengler et al., 2014a), 23 – Koy-Krilgan-Kala (Andrianov, 1969; Tolstov and Vaynberg, 1967)

Broomcorn millet at the time of its introduction in Kazakhstan was used as an animal fodder (Hermes et al., 2019). However, by the Late Bronze Age, the crop becomes an important dietary source as evident through the isotopic data. Akbulatov (1999) suggested that broomcorn millet is a very suitable crop for semi-nomadic communities inhabiting steppe and arid steppe regions of Eurasia. Broomcorn millet has a fast reproduction cycle and can grow in arid environments, which makes it a better option for agricultural developments in Central Asia than wheat and barley (Akbulatov, 1999).

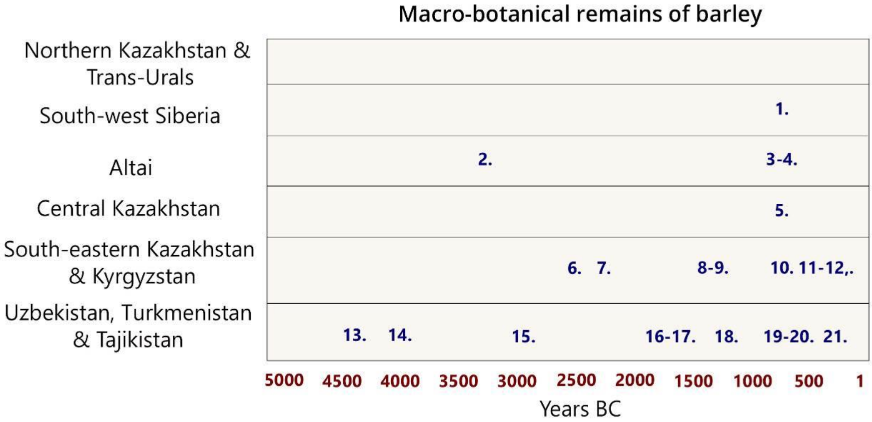


Figure 35: Finds of macro-botanical remains of barley across North Central Asia in relation to the chronology (x-axis) and geography (y-axis). Numbers stand for the archaeological sites: 1 – Serebryakovsky (Martynov, 1979), 2 – Tongtian cave (Zhou et al., 2020), 3- Maima-1 (Abdulganeyev, 1997), 4 – Ushlep-5 (Abdulganeyev, 1997), 5 – Abylai (Beisenov et al., 2019), 6- Chap II (Motuzaite Matuzeviciute et al., 2020a), 7 – Begash (Frachetti et al., 2010), 8 – Uch-Kurbu (Motuzaite Matuzeviciute et al., 2018), 9 – Tasbas (Doumani et al., 2015), 10 – Chap I (Motuzaite Matuzeviciute et al., 2020b), 11 – Tuzusai (Spengler et al., 2017), 12 – Tseganka 8 (Spengler et al., 2017), 13 – Anau North (Miller, 1999), 14 – Sarazm (Spengler and Willcox, 2013), 15 – Anau South (Miller, 1999), 16 – Jarkutan (Miller, 1999), 17 – Ojakly & 1211/19 (Spengler et al., 2014a), 18 – Dam Dam Cheshme (Harris, 2011), 19 – Tahirbaj Tepe (Nesbitt, 1994), 20 – Kyzyltepa (Spengler et al., 2017), 21 – Dingild'zhe (Vorobyeva, 1973)

Macro-botanical data from Kazakhstan and neighbouring regions suggest that millet became widespread in the Ealy Iron Age. Evidence for millet grains comes from a number of Iron Age sites located in all studied regions (fig. 36). Charred millet grains have not been discovered in northern Kazakhstan. However, data from a Trans-Uralian site Novy Kumak points to the presence of millet in the Iron Age context (Akbulatov, 1999).

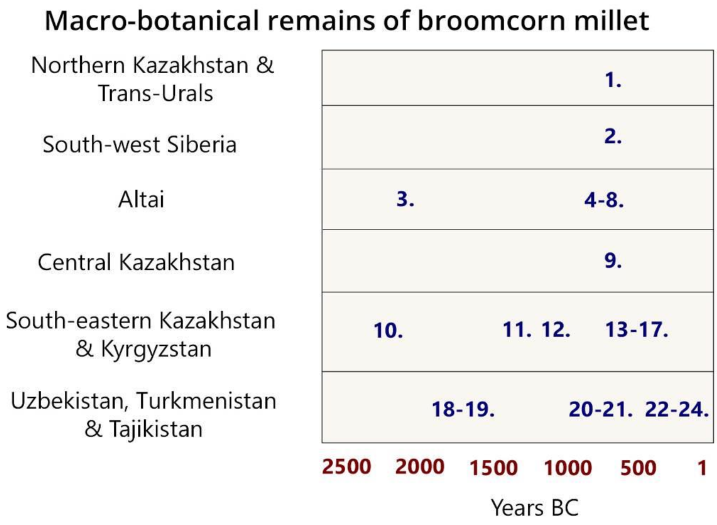


Figure 36: Finds of macro-botanical remains of broomcorn millet across North Central Asia in relation to the chronology (x-axis) and geography (y-axis). Numbers stand for the archaeological sites: 1 – Novy Kumak-2 (Akbulatov, 1999), 2 – Serebryakovsky (Martynov, 1979), 3 – Tongtian Cave (Zhou et al., 2020), 4 – Maima-1 (Abdulganeyev, 1997), 5 – Ushlep-5 (Abdulganeyev, 1997), 6 – Kokel (Vainshtein, 1980), 7 – Kazylgan (Vainshtein, 1980), 8 – Arzhan (Neef, 2010), 9 – Abylai (Beisenov et al., 2019), 10 – Begash (Frachetti et al., 2010), 11 – Uch Kurbu (Motuzaite Matuzeviciute et al., 2018), 12 – Chap I (Motuzaite Matuzeviciute et al., 2020b), 13 – Mukri (Spengler et al., 2017) 14 – Tuzusai (Spengler et al., 2013; Spengler et al., 2017), 15 - Taldy Bulak 2 (Spengler et al., 2017), 16 – Tseganka 8 (Spengler et al., 2017), 17 – Begash (Spengler et al., 2017), 18 – Gonur (Bakkels, 2003), 19 – Ojakly & 1211/19 (Spengler et al., 2014a), 20 – Tahirbaj Tepe (Nesbitt, 1994), 21 – Kyzyltepa (Wu et al., 2015), 22 – Dingild'zhe (Vorobyeva, 1973), 23 – Farmstead 641, Djanbas Kala (Vorobyeva and Gertman, 1991), 24 – Koy-Krilgan-Kala (Andrianov, 1969; Tolstov and Vaynberg, 1967).

5.5. Stable isotope data on diet in prehistoric Central Asia

Stable isotope analysis of animal and human bone collagen became a very important tool for the study of prehistoric diet. The majority of archaeologists doing field research in Kazakhstan do not carry out sieving and flotation, which results in potential loss of macro-botanical data. Therefore, stable isotope analysis can provide additional information on the consumption of plant food and freshwater resources by ancient humans.

Privat (2004) conducted a large stable isotope study of Trans-Uralian and south-west Siberian prehistoric populations. Her research indicated that there was no consumption of millet in those regions from the Bronze to Iron Ages.

However, the inhabitants of a Late Bronze Age Chicha site located in south-west Siberia relied on fish as part of their subsistence. This is strengthened by finds of fish bones in the archaeological contexts at Chicha. Stable isotopic research of the Bronze Age Kamennyi Ambar site located in Trans-Urals pointed to the absence of broomcorn millet in the diet and reliance on animal meat and milk products (Hanks et al., 2018).

Isotopic data from north Kazakhstan Middle Bronze Age site Bestamak and Late Bronze Age site Lisakovsk pointed to the absence of broomcorn millet in the diet and consumption of animal and fish products (Ventresca Miller et al., 2014). Analysis of correlation between human and herbivore isotopic data from the Trans-Uralian region indicated that consumption of fish was on a large scale during the Middle Bronze Age, but decreased by the Late Bronze Age (Ventresca Miller and Makarewicz, 2019). Recent isotopic data also points to the absence of millet in the diet of north Kazakhstan inhabitants from Bronze to Middle Ages (Ananyevskaya et al., in press).

Early Bronze Age data from eastern Kazakhstan points to the reliance on fish resources and the consumption of animal proteins (Svyatko et al., 2015). A comparison study between Neolithic/Eneolithic and Bronze Age human isotopic data from Altai showed the decrease in δ^{15}N values, which is likely related to the development of animal pastoralism (Motuzaite Matuzeviciute et al., 2016). However, high δ^{15}N values were observed in both periods, which was interpreted as fish consumption. Late Bronze Age and Early Iron Age isotopic evidence from the Minusinsk basin and Altai point to the large-scale consumption of millet (Murphy et al., 2013; Svyatko et al., 2013). It has also been suggested that freshwater fish could contribute significantly to the diet of Bronze Age humans from Minusinsk basin and Altai (Ventresca Miller and Makarewicz, 2019).

Isotopic data from the Middle–Late Bronze Age central Kazakhstan sites demonstrated an absence of millet in the diet (Lightfoot et al., 2015). An appearance of a C_4 food source becomes isotopically visible in the Final Bronze Age – Early Iron Age (Ananyevskaya, 2018; 2019a; Ananyevskaya et al., in press; Ananyevskaya et al., 2018; Lightfoot et al., 2015; Svyatko and Beisenov, 2017; Ventresca Miller and Makarewicz, 2019). However, the majority of the human isotopic data from the region still point to the reliance on animal products.

Isotopic evidence from south-east Kazakhstan suggested that millet became an important component in the human subsistence from the Late Bronze Age

(Motuzaite Matuzeviciute, 2016; Motuzaite Matuzeviciute et al., 2015a); the reliance on C_4 resource increased by the Iron Age (Ananyevskaya et al., in press; Ananyevskaya et al., 2018).

5.6. Consumption of fish across Central Asia

Stable isotopic research conducted across various sites of Central Asia demonstrated generally high δ^{15}N values, which was usually interpreted as fish consumption (O'Connell et al., 2003). The question of fish consumption in Bronze and Iron Age Central Asia has been widely debated, and there is no clear answer to it yet. The absence of flotation and sieving as common excavation practices in the region causes some small bones to be overlooked and not collected. Therefore, actual fish skeletal remains are available from a small number of sites. Sieving carried out at a Late Bronze Age site Temirkash located in central Kazakhstan yielded a small number of fish bones, which suggested that fish contributed little to the diet of local inhabitants (Outram et al., 2012). Zooarchaeological analysis of the Late Bronze Age assemblage from Konezavod I settlement located in northern Kazakhstan demonstrated the presence of a variety of fish species: pike, perch, roach, bream, crucian carp, and ide, with over 140 fish skeletal remains discovered in the settlement layers (Gaiduchenko, 2015a). Lipid residue analysis of Late Bronze Age pottery from the sites of north Kazakhstan, however, provided no evidence of fish lipids in ceramic vessels (Outram et al., 2012). Therefore the interpretation of high δ^{15}N values across Central Asia as evidence for fish consumption remains debatable. Compound-specific amino-acid analysis of nitrogen, however, has a great potential in further research of fish consumption (see chapters 7,8), (Itahashi et al., 2020).

5.7. Hunting

Forest-steppe regions of Kazakhstan include a variety of game animals, such as roe deer, red deer, elk, boar, etc. which allows for the local inhabitants to rely on hunting as well as other subsistence strategies. Evidence for the focus on hunting in the forest-steppe regions, however, comes from the earlier prehistoric periods (Ahinzhanov et al., 1992; Chalaya, 1973). The development of animal herding in the Bronze Age decreased the importance of hunting as a form of economy. However, in some regions hunting remained the economical focus throughout Bronze, Iron, and Middle Ages.

For example, zooarchaeological data from Bronze Age sites Atasu and Myrzhyk located in south Turgai points to the presence of ~20% of wild fauna, such as wild boar, kulan, saiga antelope and argali (Ahinzhanov et al., 1992; Makarova, 1977).

At the settlement of Atasu, dated to the Middle – Late Bronze Age, saiga skeletal remains (n=249) make 50% of all wild animal remains analyzed. The significant number of discovered saiga antelope remains demonstrates the importance of the animal in the hunting activities. Bones of saiga (n=66) are also present at Myrzhyk settlement site (Ahinzhanov et al., 1992), while the skeletal element representation is identical to Atasu. Zooarchaeological investigations carried out at a Bronze Age site Toksanbai located in the Ustyurt plateau indicated high proportions of saiga antelope and other wild animal remains in the assemblage, which suggests that hunting was one of the main subsistence activities (Gaiduchenko, 2012). Early Iron Age – Medieval hunting installations known as “desert kites” and spread across Ustyurt plateau (see section 4.5.2) also point to the importance of hunting in the region.

5.8. Metallurgy

The first evidence for the production of metals in Kazakhstan and surrounding territories comes the Eneolithic times, when first copper items started to appear in the region (Kalieva, 1998). However, at this point, the metalworking was not a major form of economy. Eneolithic copper items were likely produced by cold forging using slags discovered on the surface (Margulan et al., 1966). Extraction of metals and metalworking became an important activity during the Bronze Age. Few major centers of metal production appeared in the region, including the Ural Mountains, central Kazakhstan, and Altai. The local rock formations also contained a large amount of semi-precious stones (agate, malachite, sardonyx, jasper, quartzite, etc.), which were used in the production of tools and jewelry.

Archaeologists that investigated prehistoric mining in the Urals identified a large number of extraction points exploited in ancient times. Research of the large mining complex Kargaly demonstrated that the area contained rich copper deposits (Chernykh et al., 2002a). Almost all copper formations on the surface were discovered and exploited since the Early Bronze Age (beginning of the 3rd mil. BC). Sintashta and Abashevo communities of the Early-Middle Bronze Age spread around the Eastern Urals, produced metal objects out of copper using molds made from clay or stone. Many early objects were produced out of pure copper. Sintashta sites often yield evidence for metal production, such as furnaces, slag, or metal objects (Koryakova and Epimakhov, 2014). Multiple extraction points were also documented in central and northern Kazakhstan steppes (Ageeva et al., 1960a; Ageeva et al., 1960b). Geological research conducted around Dzhezkazgan (central Kazakhstan) revealed major copper extraction points, which were exploited in ancient times (Valukinskyi, 1950).

A major cultural phenomenon in the metallurgy production of Central Asia known as Seima-Turbino (Chernykh and Kuz'minyh, 1987) happened in the end of 3rd – beginning of 2nd mil. BC and started a new tradition in metalworking. Several hundred Seima-Turbino objects produced from metals as well as molding forms were discovered within five burial complexes of the Ural region. Individual finds of this tradition are found on a large territory from Mongolia to Finland (Koryakova and Epimakhov, 2014). Seima-Turbino objects are distinguished by their fine quality with both tin and copper used in the production. Chernykh and Kuz'minyh (1987) argue that the production center of Seima-Turbino objects was in Altay and Sayan region. The appearance of such advanced metal-production tradition in the region created the first competition for the Caucasus metalworking tradition (Koryakova and Epimakhov, 2014). Some Seima-Turbino objects produced without the use of tin were likely made in the Urals, where tin deposits are very poor.

The new metallurgical tradition introduced the use of tin-alloys and thin-sided casting forms with shafts, which increased the quality of the produced objects. Therefore, the greatest developments in metal production happened in the Late Bronze Age. Petrovka community inhabiting the Urals in this period produced an incredible amount of metal items (Koryakova and Epimakhov, 2014). Moreover, new metalworking methods were introduced by Petrovka artisans. New metal sources started to be exploited including the centers in Altai and central Kazakhstan. The exploitation of gold also began in the same period (Zaikov et al., 2002).

The mining industry of the Urals can be considered a city-forming enterprise for about 20 settlements, four burial complexes, and an individual kurgan were discovered only in Kargaly area (Chernykh et al., 2002a). The majority of the sites are dated to the Late Bronze Age. Complex archaeological investigations conducted on the largest settlement of Kargaly region – Gorny dated to the 1900-1250 cal. BC (Chernykh et al., 2002b) demonstrated that the site occupied the area of 30000-40000 m^2. The excavations yielded a great amount of ceramic, copper, stone, and bone objects. Similarly, in central Kazakhstan, high concentration of archaeological sites in some areas was related to the rich metal sources available in the vicinity. Mountainous areas of Kazakh Uplands, such as Kent and Ulytau, contained rich metal deposits.

During the Final Bronze Age, the focus of the metal industry moved to central Kazakhstan with such major metallurgical sites of this period as Atasu, Taldysai, and Alat (district of Kent settlement site) (Beisenov, 2016d; Evdokimov and Zhayimbayev, 2007). Such a transition can possibly be explained by the transformations in the metallurgical technologies. Central Kazakhstan had large sources of tin, which became an important component of metal objects. Moreover, towards the rise in social complexity and appearance of the elite, another metal was gradually becoming popular – gold. Central Kazakhstan, as well as Altai, had large sources of gold, which were exploited by the Iron Age communities during the production of fine golden decorations and jewelry that are commonly known in the western literature as Saka-Scythian artifacts of the animal style. Researchers noted that in the Late Bronze Age, the design of metal objects became more complex and the quality much better (Margulan, 1979). Even utilitarian items like arrow points were produced with a sense of art and style and decorated with symbols.

Objects made from iron started to appear in the Urals, Siberia, and Altai in the Early Bronze Age (Koryakova and Epimakhov, 2014). Multiple laboratory analyses showed that the first iron items in the region were made from meteoritic iron. In the Early Bronze Age Yamnaya culture, iron objects were considered luxury items and were deposited in the burials of higher status individuals (Vasilyev, 1980) Moreover, in the Afanasyevo culture of the Early Bronze Age only jewelry was made from iron.

In central Kazakhstan, early iron objects were discovered at sites Karkaraly II, Shortandy-Bulak, Alat in the archaeological contexts dated to the ~1300-1000 BC (Evdokimov and Zhayimbayev, 2007). The iron furnace discovered at the site of Alat was dated to the ~1300 BC (Culture, 2016). The massive production of iron objects began in the Kazakh steppe earlier than in other regions, such as Urals, Altai, or south-west Siberia (Koryakova, 1991; Kuz'minyh, 1983). Moreover, bronze instead of iron becomes even more widespread in Altai at the beginning of the Iron Age. In the Kazakh steppes, however, during the Iron Age, iron was mainly used for the production of tools, weapons, and utilitarian items, while gold, bronze, precious stones, and other materials were used for making jewelry, ritual and unique items.

6. Research methods

Apart from a detailed overview of the previously published sources and archaeological evidence, a wide range of empirical methods were used during this research. Data for the study was collected from a wider territory and chronological period, in order to analyze the place of Turgai region in the economic structure of the prehistoric Eurasian steppe populations. The empirical research included the use of archaeological excavations, landscape survey, fieldwork with sample collection; ^{14}C dating; zooarchaeological, macrobotanical, stable isotope, and ZooMS analyses.

6.1. Archaeological excavations of the Ashutasty settlement site

Archaeological excavations of a burial or settlement site tend to provide a wide range of artefactual and eco-factual evidence about the lifestyle, economy, technology, and social life of the ancient people. Unfortunately, the archaeological excavations of the individual mounds of the Ushtogaiskyi Square, Small Ashutasty Cross, and test pits at the Turgai ring, and the Big Ashutasty Cross did not yield any finds (Logvin et al., 2018a; Logvin et al., 2018b; Motuzaite Matuzeviciute et al., 2015b). In order to study the economy of the population that inhabited Turgai region and was involved in the construction of Turgai geoglyphs, more ecofactual data has to be collected from domestic contents. Through the excavation of a settlement site, it is possible to collect a wide range of data for the study of the economy, including faunal and macrobotanical remains and samples for the laboratory analyses.

Therefore, in order to investigate the economy and subsistence of the Turgai populations that may have been responsible for the construction of the geometric earthworks, it was decided to carry out excavation at a settlement site located close to the geoglyphs and within the area of their highest concentration – Arkalyk district. A settlement site Ashutasty (fig. 37), which was discovered through landscape research in 2013 by a group of archaeologists from Kostanay State University, is located in close proximity to three geoglyphs: the big Ashutasty cross (50°13'39.7"N 66°17'31.5"E), the small Ashutasty cross (50°13'26.8"N 66°16'49.6"E) and the Ashutasty line (50°13'33.5"N 66°18'21.6"E), and within Arkalyk district. During the first landscape survey in 2013, the group of archaeologists from the Kostanay State University discovered pottery sherds and stone tools characteristic of the Late Bronze Age - Early Iron Age period (I. Shevnina, personal communication), which is contemporaneous to the geometric earthwork construction (Motuzaite Matuzeviciute et al., 2015b).

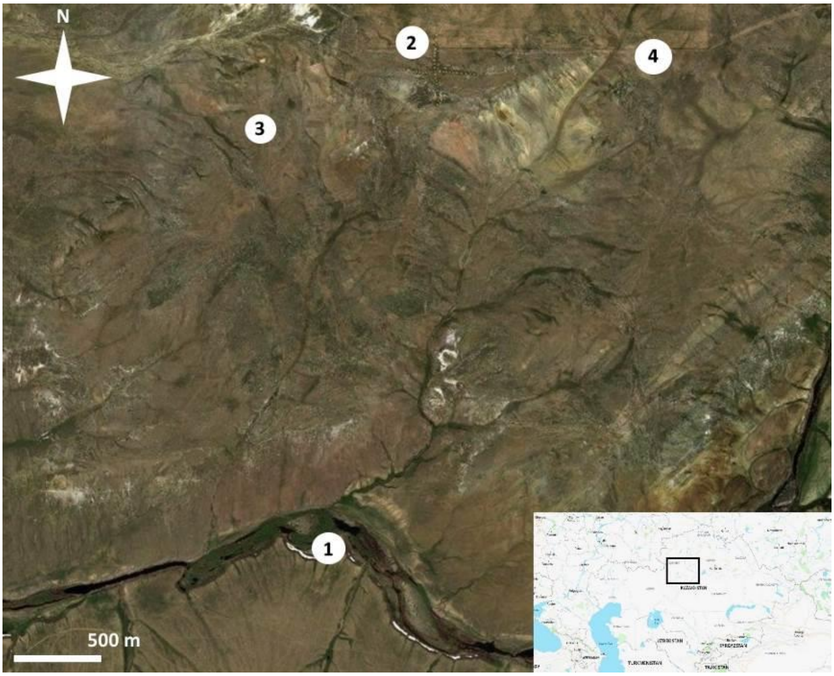


Figure 37: Map of Ashutasty landscape. 1 – Ashutasty settlement, 2 – big Ashutasty cross, 3 – small Ashutasty cross, 4 – Ashutasty line; The map was made with use of BingMaps 2020 data (Maxar, TomTom, HERE)

Therefore this settlement site, situated at the nearest access point to the Ashutasty River from the big Ashutasty cross, may have been occupied during the time of the geoglyph construction. A large number of animal bone fragments, ceramic shards, metal, and ceramic slag scattered on the surface around the area of ~600 m^2 point to the previous occupation history. In 2019 as a part of a collaboration project from Vilnius University (Lithuania), LLC Archaeological Expertize (Kazakhstan) and Institute of Central Asian Studies (Uzbekistan) full-scale archaeological research was conducted at the archaeological site Ashutasty. The PI of the project titled: “Solving the mystery of Turgai geometric earthworks (geoglyphs) in Kazakhstan” and funded by the Vilnius University Science Promotion Fund was the author of the present research.

6.1.1. Excavation methodology

The excavations were conducted for the first time, therefore, the exact locations of the subsurface accumulation of archaeological material and construction remains were not clear. Four test-trenches of 2x2 m. were planned (see section 7.1, fig. 49) within the 15 m. radius from the area with the largest accumulations of archaeological material on the surface. The decision to expand the trenches was made upon the discovery of archaeological features. The trenches were excavated with the use of shovels, trowels, and brushes (fig. 38), each 10 cm layer of non-cultural stratigraphy was studied and photographed. All artefactual and ecofactual finds were collected and carefully documented. Flotation samples were collected from all discovered archaeological features.

Figure 38: Volunteers working at Ashutasty archaeological site

6.1.2. Landscape survey

In parallel to the excavations of Ashutasty, search for the new archaeological sites in the vicinity was conducted by a team led by D. Dei. The team conducted radial surveys within the 5 km radius and took the coordinates of the points, where archaeological finds were discovered. The process of the archaeological excavation and the surrounding landscape features were documented with unmanned air vehicle Phantom 4 (fig. 39). The shooting was able to catch the variations in the elevation level as well as the natural water-collection channels (fig. 47). The use of the UAV allowed for documentation of a large territory surrounding the excavation area. The UAV was operated at a distance of 30-100 m. above the surface. The coverage was done following the “carpet” method, where multiple photo shots were taken with each shot covering ~80% of the previous shot in order to create a perfect resolution.

Figure 39: M. Gurulev (LLC Archaeological Expertise) taking shots of the Ashutasty site trench 4 with use of UAV.

6.1.3. Flotation and macro-botany analysis

Contents of the four discovered features: pits 1,2,3, and 4 of the first trench (fig. 51, 54) were collected into woven bags, and floated at the river bank near the site (fig. 40). Two types of mesh – 500 and 300 µm were used during the flotation of each sample. The float was dried, collected into individual bags, and taken back to the Centre for Bioarchaeology Research (Vilnius) for further investigations. The samples were analyzed by a macro-botany specialist using stereomicroscope.

Figure 40: Flotation of the sediments from Ashutasty is in the process

6.1.4. Radiocarbon dating

Materials for the ^{14}C dating were selected from the important archaeological features – first and second pits of the first trench, the first pit of the fourth trench, as well as from the deep stratigraphic contents – 90 cm depth of the second trench (see section 7.1, fig. 49). The preference was made to the use of unburnt animal bone for ^{14}C dating.

The radiocarbon dating was done at the Vilnius Radiocarbon laboratory of the Physical and Technological Scientific Centre (Vilnius, Lithuania). The BP dates were calibrated using OxCal v.4.2 and the IntCal13 calibration curve (Bronk Ramsey, 2009; Reimer et al., 2013). They are shown in cal. BP (calendar years before 1950), at 2-sigma confidence.

6.1.5. Zooarchaeological analysis and collagen peptide fingerprinting

All fragments of animal skeletal remains discovered during the excavation were analyzed and documented on site. Identification was done with the use of photographic atlases of animal skeletal remains (Adams and Crabtree, 2011; France, 2009; Gilbert, 1973; Gromova, 1950; Prehn et al., 2018; Schmid, 1972) as well as photographs of modern bones. Small bone fragments (>5 cm), which did not have any characteristic features or foramina were not identified and were put into "unidentifiable" group. Charring temperature of some specimens was identified by the coloring of the bone fragments (Gilchrist and Mytum, 1986). Better preserved fragments were measured according to van der Driesch (1976) methodology.

A selection of animal bone fragments (n=19) was analyzed with collagen peptide fingerprinting (aka “ZooMS”), which allows for the identification of the animal the collagen was extracted from (Buckley et al., 2009). Although this method is extremely valuable in sheep and goat separation, due to the slow evolution of the collagen, some identification can only be made to the genus level (Buckley et al., 2010). Therefore, the samples identified as *Capra*, for example, can include domestic (*Capra hircus*) or wild (e.g. *Capra sibirica*) goats.

Samples for the analysis were selected from the “unidentified” portion of the assemblage (Appendix 1). The samples only included the fragments, which displayed good preservation (e.g. not sunbleached or cracked) and were not subjected to high temperatures (>200° C). The aim of the analysis was to identify the potential genera that avoided the identification during the visual analysis of the assemblage (e.g. Cervidae).

The ZooMS analysis presented here was carried out at the University of Torino using the collagen extracted at Centre for Bioarchaeology Research (see collagen extraction methodology in section 6.2.1). After the samples were received by the University of Torino as lyophilized collagen extracts, the following protocol was applied:

- All the samples were dissolved in 200 μL of water (HPLC-grade)
- 20 μL of each aliquot was subsampled and transferred to separate eppendorfs (LoBind), evaporated using a centrifugal evaporator (Eppendorf concentrator plus) and resuspended in 100 μL 50 mM ammonium bicarbonate (ABC) solution.
- Samples were reduced with dithiothreitol (DTT) for 1 h at 65 °C and alkylated with iodoacetamide (IAA) at room temperature in the dark for 45 min.
- They were then digested using proteomics-grade trypsin at 37 °C for ~18 hrs (overnight).
- The protein digests (peptides in solution) were purified and concentrated using C18 zip-tips according to established protocols.

0.5 μL aliquots of peptide solution were mixed with a solution of theα-Cyano-4-hydroxycinnamic acid (HCCA) Maldi matrix, spotted on a MALDI Bruker stainless steel plate. Each sample was spotted in duplicate and analyzed in manual mode using a Bruker microflex MALDI-TOF mass spectrometer at the Department of Clinical and Biological Sciences (Ospedale San Luigi Gonzaga), University of Turin. The results were analyzed using the open access Mmass tool (Niedermeyer and Strohalm, 2012).

6.2. Stable isotope analysis of human and animal bone collagen

Stable isotope analysis has been widely used as one of the laboratory archaeological methods for the reconstruction of human and animal diets (Makarewicz and Sealy, 2015; Szpak et al., 2017). This analysis has been applied to the Central Asian material and revealed previously unknown dietary patterns in some studied regions (Hanks et al., 2018; Lightfoot et al., 2015; Motuzaite Matuzeviciute et al., 2016; Motuzaite Matuzeviciute et al., 2015a; Murphy et al., 2013; Svyatko et al., 2015; Svyatko et al., 2013; Ventresca Miller et al., 2014). However, there are still many questions that can be answered through the application of stable isotope analysis, such as the appearance and spread of broomcorn millet as dietary component, diversity of dietary resources consumed in various regions, and animal herding strategies. Moreover, some regions of Kazakhstan, including southern Turgai, west Kazakhstan, and Caspian – Aral region, have not been studied by means of stable isotope analysis. Therefore, this method was selected in the present research.

Food consumed by animals and humans during their lifetime corresponds with the chemical composition of their bones. Isotopic analysis of bone collagen indicates an average diet over adult life and might not demonstrate small changes in the food intake (Hedges and Reynard, 2007). It is important to study zooarchaeological data from the same geographic area as isotopic values might vary chronologically and spatially (Stevens and Hedges, 2004). Comparison of the human isotopic values against animal baseline values indicates whether the human relied on the animal protein for the subsistence or there were additional food sources.

Calculation of isotopic ratios

Using the mass-spectrometry, values of the two stable isotopes of carbon: ^{13}C and ^{14}C, and two isotopes of nitrogen: ^{15}N and ^{14}N in the bone collagen are calculated. Then measuring the results against the laboratory standards (PeeDeeBelemnite or an analogue for $\delta\,^{13}C$ and atmospheric nitrogen for

$\delta^{15}N$) with the following formulae we obtain the $\delta\ ^{13}C$ and $\delta^{15}N$ values (Brown and Brown, 2011):

$$\delta^{15}N = \left(\frac{{}^{15}N/{}^{14}N_{sample}}{{}^{15}N/{}^{14}N_{atmosN_2}} - 1 \right) \times 10^3$$

$$\delta^{13}C = \left(\frac{({}^{13}C/{}^{12}C)_{sample}}{({}^{13}C/{}^{12}C)_{standard}} - 1 \right) \times 1000‰$$

Carbon isotopes

Collagen carbon isotope values reflect mainly the protein part of a consumer's diet (Ambrose, 1993), which suggests that humans that consume both animal and plant food would be getting more proteins from animal products due to the high protein content of animal meat and milk. However, herbivore animals as the primary consumers get their isotopic values from the plants. The majority of the Earth's plants use C_3 or C_4 photosynthetic pathways, which causes them to exhibit different $\delta^{13}C$ values of −27.1 ± 2.0‰ and −13.1 ± 1.2‰ on average respectively (O'Leary, 1988). C_4 plant $\delta^{13}C$ values are ranging from -9‰ to -16‰ (Schoeninger and Moore, 1992). With each step in the trophic chain, collagen $\delta^{13}C$ values tend to get enriched by ~2-5‰ (Van der Merwe and Vogel, 1978). Therefore enriched $\delta^{13}C$ values in human bone collagen might indicate direct or indirect (through consumption of animals that grazed on C_4 pastures) intake of C_4 plant food.

Nitrogen isotopes

Isotope values of nitrogen indicate the trophic levels of analyzed animals and humans. Most of the plants show the $\delta^{15}N$ signal between 0 and 5‰, while herbivores tend to have $\delta^{15}N$ values of around 9‰. There is a 3–5‰ increase of $\delta^{15}N$ with each step in the food chain (O'Connell and Hedges, 1999), therefore the nitrogen isotope signal in human collagen reflects the scale of consumption of animal and plant protein and the type of animal consumed (herbivores, carnivores, fish).

Some C_4 plants constitute indigenous steppe ecosystems (Winter, 1981), and may, therefore, provide a C_4 signal if a human regularly consumes meat or dairy products of an animal grazing on pastures with C_4 vegetation. In modern times, C_4 plants can be encountered in Ustyurt plateau and Kyzylkum desert (Toderich et al., 2007). Although most of the popular cultivated plants like rice, wheat, and barley use C_3 photosynthetic pathways, Chinese millets, which have been identified at some archaeological sites in Kazakhstan (see Chapter 4), use C_4 photosynthetic pathways.

Other factors, such as climatic stress and pathology, can also affect isotopic values. More arid and temperate environments usually have a larger proportion of C_4 vegetation (Van Klinken et al., 2002). Carbon isotopic values of both C_3 and C_4 plants growing in such climatic zones tend to be elevated, $\delta^{15}N$ values of C^4 plants also increase in arid environments (Chase et al., 2012; Hartman, 2011; Murphy and Bowman, 2006), which affects the isotopic signal of the consumers. According to Hartman and Danin (2010) $\delta^{15}N$ values of C^3 plants do not change because of the aridity. Elevation causes an increase in $\delta^{13}C$ in plants – by up to 3‰ from 0 to 5000 masl (Körner et al., 1988).

Agricultural practices such as manuring of fields increase the $\delta^{15}N$ in crops, thus increasing the nitrogen values in bone collagen of humans that consume the crops from manured fields (Styring et al., 2015). Animals might also be foddered by chaff from the manured fields.

Due to the effect of nursing, babies are often one trophic level higher than their mothers (Beaumont et al., 2015). Nutritional stress and starvation cause an increase of $\delta^{15}N$ values, which is related to the changes of metabolic processes in the body when the organism starts to "feed of itself" (Beaumont and Montgomery, 2016; Fuller et al., 2005).

Moreover, few studies have discussed the role of animal metabolism on the diet-tissues nitrogen isotopic enrichment (Sponheimer et al., 2003; Van Klinken et al., 2002). Despite the absence of similar research on the carbon isotopic enrichment, the former studies suggest that the tissues of foregut and hindgut herbivores feeding on similar diets might display different isotopic values due to the specifics of their metabolism.

6.2.1. Extraction methodology

Samples were prepared at the Mass Spectrometry Laboratory, Centre for Physical Science and Technology and Centre for Bioarchaeology Research (both Vilnius, Lithuania) using collagen pre-treatment procedures outlined below (fig. 41).

1. The bone surface was cleaned with the use of a Dremmel™ 3000 polishing point.
2. Approximately 500 mg of bone was sampled from the middle of each specimen.
3. Samples were demineralized with 0.5 M aq. HCl solution at ~3–5°C for 1–5 days.
4. Samples were rinsed 3 times with deionized water, frozen with liquid nitrogen and freeze-dried.
5. Samples between 0.85 and 1.0 mg in weight were placed in tin capsules and prepared for the measurement.

An elemental analyzer coupled to the isotope ratio mass spectrometer (EA-IRMS, Flash EA1112—Thermo V Advantage) via ConFlo III interface was used for the $\delta^{13}C$ and $\delta^{15}N$ analysis (see details in Garbaras et al., 2019). Carbon isotopic ratio measurements presented here are expressed relative to the Vienna Pee-Dee Belemnite (VPDB) standard, while the nitrogen isotopic ratio coincides with the air N2. The analytical precision and calibration of reference gas CO2 (for $\delta^{13}C$ measurements) to VPDB were evaluated by the repeated analysis of secondary reference material caffeine IAEA-600, and oil. The IAEA- 600 standard was used for calibration of reference gases N2 ($\delta^{15}N$ measurements) to air.

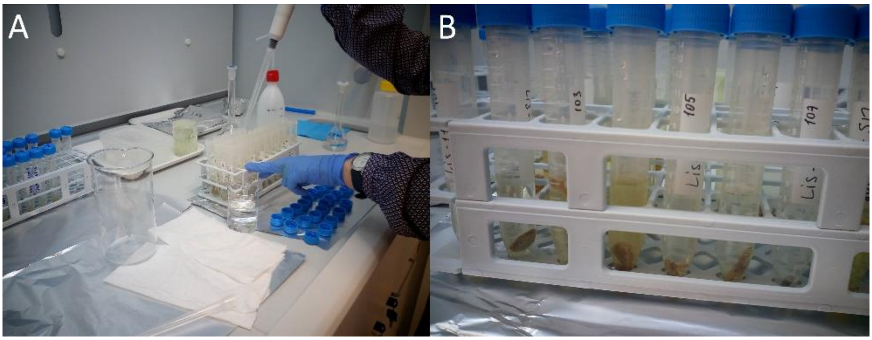


Figure 41: A-B: The process of demineralization of bone samples using 0.5 M HCl

6.2.2. Selected material

Human and animal bone samples for the study were collected during research trips in August 2017 and July-August 2018. The samples were collected at the Western Kazakhstan Centre for History and Archaeology (Uralsk), Lisakovsk Museum of History and Culture of Upper Tobol (Lisakovsk), Archaeological Laboratory at Kostanay State Museum named after A. Baitursynova (Kostanay), National Museum of the Republic of Kazakhstan (Nur-Sultan), L. N. Gumilev Eurasian State University (Nur-Sultan), Nazarbayev University (Nur-Sultan), Saryarka Archaeological Institute of the Buketov Karaganda State University (Karagandy), Margulan Institute of Archaeology (Almaty), Kazakhstan State Museum (Almaty), and “Archaeological Expertise” LLC (Almaty) (fig. 42).

Samples for the stable isotope analysis of human and animal bone collagen (n=343) were collected from various archaeological sites (n=70) dated to the Bronze – Middle Ages and spread around the territory of the modern Kazakhstan (fig. 43). The aim of the study was to collect and analyze data from the vast area spanning diverse ecosystems and chronological periods in order to not only study the economy and subsistence in the prehistoric Turgai but also compare the results across time and space. A bigger picture of the dietary and economic patterns would provide more information about potential trade and long-distance exchange and would outline the importance of the Turgai region on the global scale of the socio-economic landscape of Central Asia.

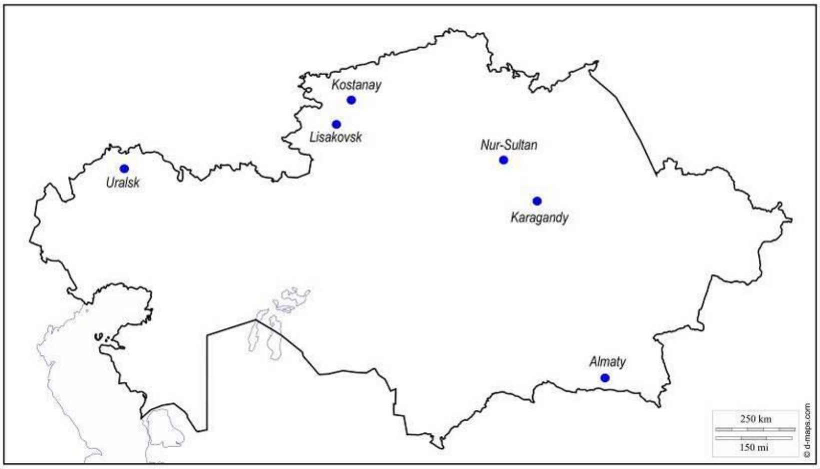


Figure 42: Map of Kazakhstan with marked locations of anthropological collections visited by the author for the sample collection that were used for the thesis (the map was downloaded from d-maps.com)

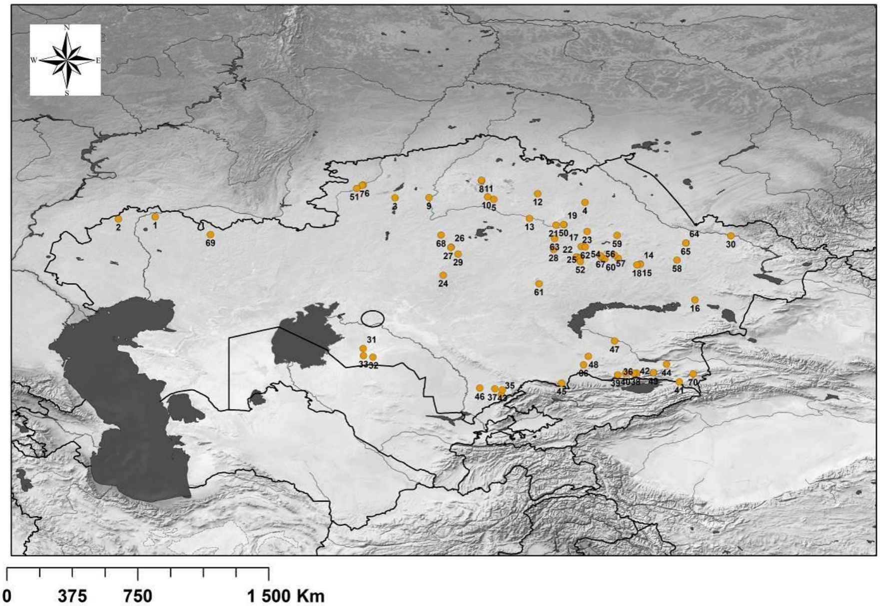


Figure 43: Archaeological sites where the samples for the stable isotope analysis were collected. 1.Taksai, 2.Taskala, 3.Bestamak, 4.Bozshakol, 5.Budenovka, 6.Halvai, 7.Karatomar-1, 8.Koshkarbai, 9.Nikel', 10.Ostrogorka, 11.Shagalaly, 12.Shondykorasy-2, 13.Syganak, 14.Ak-Koitas-4, 15.Ak-Koitas-5, 16.Aktogai, 17.Aschisu, 18.Kairan-1, 19.Karatugai, 20.Karazhartas, 21.Kudryavaya Sopka-1, 22.Senkibai-2, 23.Shantimes, 24.Taldysai, 25.Tankara, 26.Tersakkan, 27.Zhanteli-12, 28.Zhartas, 29.Zheken, 30.Zevakinskyi, 31.Babish-Mulla-7, 32.Balandy, 33.Chirik Rabat, 34.Alatau, 35.Burgulyuk, 36.Butakty, 37.Kaitpas, 38.Kamenka,

39.Kargalinka, 40.Kargaly-I, 41.Karkara, 42.Kyzyl-Bulak, 43.Madani, 44.Nurly, 45.Oi-Dzhailau, 46.Karauiltobe, 47.Serektas, 48.Shokpar, 49.Turgen-2, 50.Okule-5, 51.Tobolsky, 52.Akbeit, 53.Baike-2, 54.Bakybulak, 55.Dongal, 56.Karashoky-1, 57.Kent, 58.Karakemer, 59.Kyzylshilik, 60.Kyzylsuir-2, 61.Myrzhyk-6, 62.Tandaily, 63.Tegiszhol, 64.Karatobe, 65.Kotyrkora, 66.Shatyrkul', 67.Abylai, 68.PPK Saba, 69.Tortoba, 70.Katartobe. The map was created in ESRI ArcMap 10.4.1. with the use of Natural Earth free data.

Overall, 215 human and 127 animal bones were analyzed. Samples exhibiting C:N ratios between 2.9 and 3.6 indicate well-preserved collagen and, thus, were included in the analysis (DeNiro, 1985). 190 (88.4%) human and 97 (76.4%) animal bones fit this criterion.

6.2.3. Statistical testing

Statistical comparisons were carried out using the unpublished results (Appendix 3) and the isotopic data previously published in Ananyevskaya et al. (2018), de Barros Damgaard et al. (2018), Hanks et al. (2018), Hermes et al. (2018), Lightfoot et al. (2015), Motuzaite Matuzeviciute et al. (2016; 2015a), Murphy et al. (2013), Narasimhan et al. (2018), Privat (2004), Svyatko and Beisenov (2017), Ventresca Miller et al. (2014) (Appendix 3, 4). See figure 44 for the locations of sites where the isotopic samples were collected.

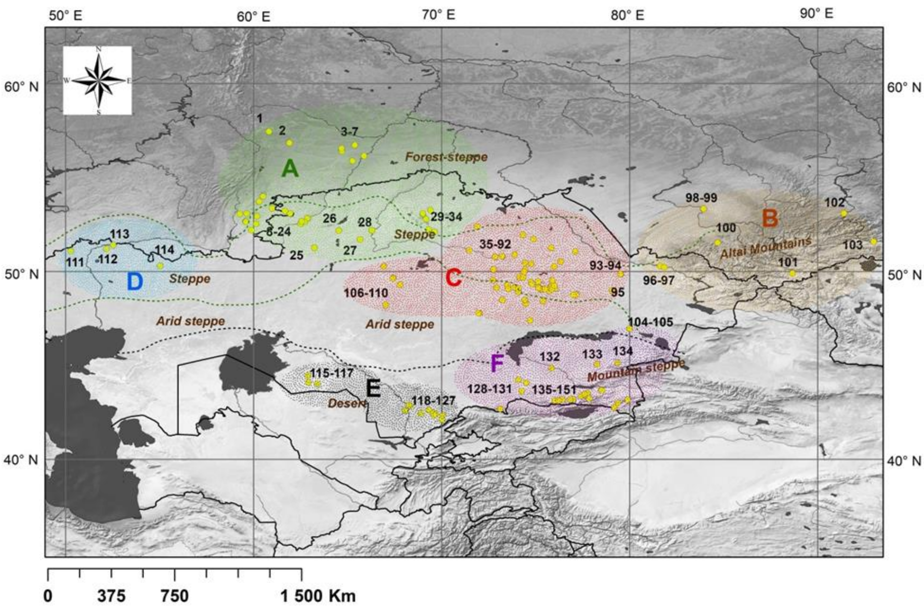


Figure 44: Archaeological sites with stable isotope data discussed in the thesis: 1.Shaidurikha, 2.Kurtuguz-1, 3.Pavlinova, 4.Murzino-1, 5.Gayovsky, 6.Baitovo, 7.Skaty-1, 8.Krivoe Ozero, 9.Ust'ye, 10.Peschanka-1, 11.Pobeda, 12.Bolshekaragansky, 13.Staraya Mel'nitsa, 14.Solonchanka, 15.Sintashta, 16.Kamennyi Ambar-5, 17.Varnenskye, 18.Kulevchi-6, 19.Isiney-1, 20.Halvai-3, 21.Karatomar-1, 22.Novoil'inovka, 23.Tobol'skyi, 24.Lisakovsk, 25.Akbidaik, 26.Bestamak, 27.Naurzum, 28.Nikel', 29.Kenelkel-18, 30.Shagalaly, 31.Koshkarbai, 32.Ormandy Bulak, 33.Ostrogorka, 34.Budenovka, 35.Shondykorasy-2, 36.Sygnak, 37.Kudryavaya Sopka-1, 38.Bozshakol, 39.Shidertinskoye-2, 40.Birlik, 41.Zhambyl, 42.Karatugai, 43.Okule-5, 44.Kurgan Borli, 45.Shantimes, 46.Ayapbergen, 47.Tagybaibulak, 48.Kyzylshilik, 49.Maitan, 50.Tashik, 51.Tegiszhol, 52.Temirkash, 53.Aschisu, 54.Tandaily, 55.Zhartas, 56.Daryinskyi, 57.Kyzylkoi, 58.Nurataldy-1, 59.Senkibai, 60.Karazhartas, 61.Tankara, 62.Akbeit, 63.Kopa-1, 64.Zhamantas, 65.Kosoba, 66.Abylai, 67.Nurken-2, 68.Karashoky-1, 69.Baike-2, 70.Kyzylsuir-2, 71.Bakybulak, 72.Taldy-2, 73.Kyzylkol, 74.Tasyrbai, 75.Akimbek,

76.Kent, 77.Satan, 78.Karagash, 79.Taisoigan, 80.Dongal, 81.Koitas, 82.Karashoky-6, 83.Nazar-2, 84.Complex 37 voinov, 85.Kyzyl, 86.Kairakty, 87.Myrzhyk-6, 88.Ak-Moustafa, 89.Bektauata, 90.Kairan-1, 91.Ak-Koitas-4, 92.Ak-Koitas-5, 93.Karatobe, 94.Kotyrkora, 95.Karakemer, 96.Karatumsk, 97.Zevakinskyi, 98.Firsovo-11, 99.Firsovo-14, 100.Kizil, 101.Sebystei, 102.Ai-Dai, 103.Aymyrlyg, 104.Aktogai, 105.Kazakh Mys, 106.PPK Saba, 107.Tersakkan, 108.Zhanteli-12, 109.Zheken, 110.Taldysai, 111.Taskala, 112.Taksai, 113.Kyrik Oba-2, 114.Tortoba, 115.Babish Mulla-7, 116.Chirik Rabat, 117.Balandy, 118.Konyr-Tobe, 119.Besinshitobe, 120.Kok-Mardan, 121.Karauyltobe, 122.Temirlanovka, 123.Kainar-Bulak, 124.Kaitpas, 125.Shymkent, 126.Madani, 127.Burgulyuk, 128.Oi-Dzhailau-7,8, 129.Khatau-1, 130.Shokpar, 131.Shatyrkul', 132.Serektas, 133.Karatal, 134.Dali, Byak Zherek, 135.Kargalinka, 136.Kyzylasker, 137.Kargaly-1, 138.Kamenka, 139.Alatau, 140.Butakty, 141.Esik, 142.Ornek, 143.Almaly, 144.Turgen-2 Complex, 145.Janaturmus, 146.Kyzyl-Bulak, 147.Karatuma, 148.Nurly, 149.Aktas, 150.Karkara, 151.Katartobe. Letters A-F mark the distributions of the site groups used in the paper. The map was created in ESRI ArcMap 10.4.1. with the use of Natural Earth free data.

For the purpose of statistical calculations and comparison of isotopic values, the studied data points were grouped according to the specific landscape features and the ecological zones that define each group (table 2, fig. 44).

Table 2: Geographic groupings of the isotopic data used in the study

Group name	Geographic area	Landscape	Extreme points of the studied area
Group A	Trans-Urals & northern Kazakhstan	Forest-steppe/steppe, mountain-steppe	51°15'N - 57°26'N; 59°34'E - 71°53'E
Group B	Altai piedmonts	Mountains/forest-steppe	49°53'N - 53°19'N; 81°37'E - 91°23'E
Group C	Central Kazakhstan	Steppe/arid steppe	47°23'N - 52°11'N; 65°40'E - 79°31'E
Group D	Western Kazakhstan	Steppe	51°05'N - 51°24'N; 50°16'E - 52°32'E
Group E	Oases of Syr Darya	Desert oases	42°06'N - 44°05'N; 62°54'E - 70°03'E
Group F	Southeast Kazakhstan	Arid steppe/mountain-steppe	42°19'N - 46°56'N; 73°07'E - 79°59'E

6.2.4. Bayesian bootstrap

Bayesian bootstrap (Rubin, 1981) implemented in the R "bayesboot" package (Baath, 2016) was used to identify statistically similar groups of the isotopic data. This method works well with small sample sizes, which are common in archaeological datasets. The bootstrapping methods also enable the comparison of the means of multiple communities simultaneously, which is a more streamlined approach than running numerous pairwise statistical tests between analytical groups. Outliers were not removed before the bootstrap was performed. Statistics were collected from the Bayesian bootstrap approximations (Appendix 5, tables 3-7). Analytical groups expressing isotopic means with overlapping 95% confidence intervals were not considered significantly different from one another.

6.2.5. Mann-Whitney U test

Populations that were identified as not different using the Bayesian bootstrap method were then compared through the Mann-Whitney U test (Appendix 5, table 8). This test was chosen because the analyzed data in the groups are unpaired and non-parametric.

The outliers were not removed from the groups deliberately, due to their importance to the main argument of the paper. It is important to note that while outliers in experimental data might indicate some kind of a mistake in the measurements, in the case of archaeological isotopic values, the presence of outliers is more likely to be caused by past human choices and behaviour. This is especially important for the groups with relatively small sample sizes for an outlier in such a group might be exactly the carrier of the new information that we seek to find. Outliers in the isotopic data tend to present the individuals who had a different diet than the majority. Therefore, these individuals might, for example, include people who consumed millet at the early stage of its introduction into a region.

6.2.6. Isotopic niche modelling

Isotopic niche modeling was used as a tool for analyzing the breadth of dietary resources consumed by people in the different geographical zones and chronological periods of Kazakhstan and surrounding territories. The concept of isotopic niche modeling is based on the assumption that ecological dimensions of a niche representing environmental factors and trophic components can be reconstructed using stable isotope data (Bearhop et al., 2004; Newsome et al., 2007). Therefore it is possible to build an isotopic niche in a two-dimensional space by using $\delta^{13}C$ and $\delta^{15}N$ isotopic values from a single community. This provides an understanding of the breadth of resources exploited by the community (Jackson et al., 2011). Comparing isotopic niches of different communities can help to understand if the groups practiced different subsistence strategies and the variety of resources they consumed (e.g. Hermes et al., 2018; Ventresca Miller and Makarewicz, 2019).

Standard ellipses were constructed using SIBER (Stable Isotope Ellipses in R). As suggested by Jackson et al. (2011), the standard ellipses are less sensitive to sample sizes than convex hulls; therefore, the technique is more advantageous for analyzing and comparing small communities of consumers. The Bayesian statistics were calculated using the jags software run in "R" through the package "rjags". The priors for running jags were identified as follows: 2000000 iterations were run, then the first 10000 sets of values were discarded, the posterior was thinned by 10, and 2 chains were run.

6.2.7. FRUITS mixing modelling

Mixing models allow identifying the relative amount of different food sources exploited by analyzed populations. The development of Bayesian mixing models allowed adding multiple sources of uncertainty. As FRUITS is one of the best-developed mixing models based on the Bayesian statistical inference (Fernandes et al., 2014), it was used in the current study. A number of stable isotopic studies have recently utilized the FRUITS model for the mixture sources predictions (e.g. Bownes et al., 2017; Fernandes et al., 2015).

The model was run in FRUITS software. Isotopic offset values of 2,0‰ between muscle-protein source and bone collagen for carbon and nitrogen were taken from Fernandes et al. (2014). The carbon isotopic offset was based on the data from the animal feeding experiments (Fernandes et al., 2012) . Digestible [C] and [N] values for domestic herbivores and plants were taken from Liu et al. (2016). Digestible [C] and [N] values for freshwater fish were taken from Phillips and Koch (2002). The values representing herbivore food source were calculated from the local and, if possible, contemporary, herbivore data. Fish data was taken from the southern Siberian Bronze Age site Chicha (Privat, 2004), and Bronze Age site Shauke 1 located in the eastern part of Kazakhstan (Svyatko et al., 2015). A single sample was used as an isotopic baseline for the C_3 crop source. The sample comes from the Iron Age context of a northern Kazakhstan site Alekseevskaya (Shishlina et al., 2018). Isotopic values for archaeological C_4 plants are not yet available from Kazakhstan and its nearest neighbouring regions, therefore, the values for C_4 plants were averaged out between western Chinese millet (Liu et al., 2016) and millet from north Caucasus region (Shishlina et al., 2018). Mean value from human isotopic data from selected sites located in each studied region were used as targets (consumers).

The sites for the FRUITS modeling were chosen on the basis of the sample size or uniqueness. Isotopic values from several sites per region/chronological period were run with the FRUITS modeling.

6.3.Compound-specific nitrogen analysis of amino acids

Compound-specific nitrogen analysis of amino acids was recently applied to the studies of ancient animal and human remains (Itahashi et al., 2019; Naito et al., 2013; Styring et al., 2015). Through the application of this approach, the trophic position of an organism can be estimated with more precision than with the nitrogen isotopic analysis of bulk bone collagen, because this method is based on the differences in the trophic isotopic values of two common amino acids (glutamic acid and phenylalanine) within an individual. This method allows for a more in-depth identification of human consumption patterns. It is also possible to estimate the contribution of animal proteins to the diet of the steppe populations during the Bronze and Iron Ages.

Bulk nitrogen isotopic compositions ($\delta^{15}N$) of predators tend to be 1.5–5‰ higher than that of the diet (McCutchan Jr et al., 2003; Minagawa and Wada, 1984). However, the results of the stable isotope investigations in prehistoric Central Asia demonstrated that $\delta^{15}N$ values of human bone collagen ($\delta^{15}N_{col}$) of steppe populations are often several steps higher ($\delta^{15}N$= 15.0-18.0‰) in the trophic chain than the $\delta^{15}N$ values of domestic herbivores ($\delta^{15}N$= 5.0-10.0‰) from the same region and chronology. Therefore, it has been suggested that high $\delta^{15}N$ values in Central Asian humans are related to consumption of fish, which has higher $\delta^{15}N$ values (O'Connell et al., 2003; Svyatko, 2016; Svyatko et al., 2015). Moreover, this observation raised the problem of a freshwater reservoir effect in relation to the radiocarbon dating of Kazakhstan archaeological material (Svyatko et al., 2015).

6.3.1. Methodology of the compound-specific nitrogen analysis of amino acids

Dietary reconstruction by isotopic analysis of individual amino acids is based on a significant difference in the trophic isotopic discrimination of two common amino acids: in the transition from prey to consumer, the $\delta^{15}N$ value of glutamic acid ($\delta^{15}N_{Glu}$) increases by +8.0±1.1‰, while phenylalanine ($\delta^{15}N_{Phe}$) increases by only +0.4±0.4‰ (Chikaraishi et al., 2010). Due to the insignificant change between foods and consumer, the $\delta^{15}N_{Phe}$ in animals tend to reflect the $\delta^{15}N_{Phe}$ of the primary producers in the same food chain, such as cyanobacteria, phytoplankton, algae in aquatic ecosystems and plants in terrestrial ecosystems (fig. 45).

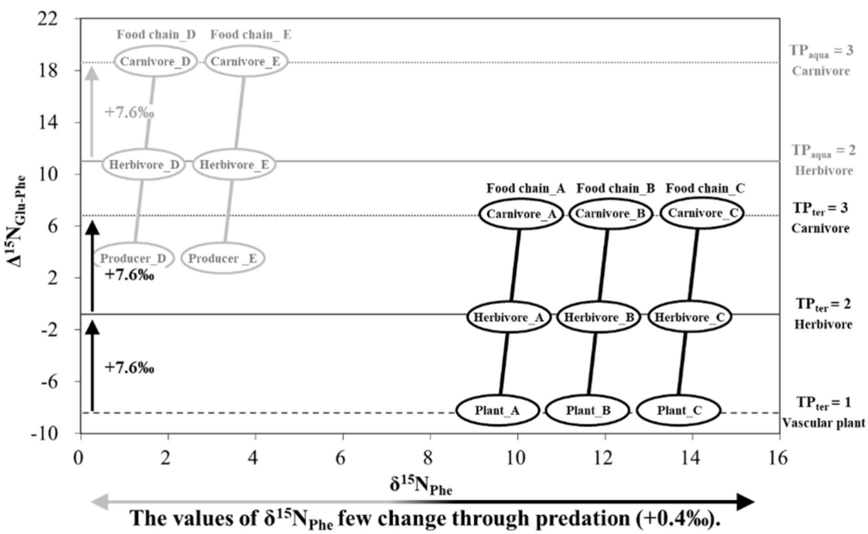


Figure 45: $\delta^{15}N_{Phe}$ and estimated trophic position based on $\Delta^{15}N_{Glu-Phe}$ for each food chain (Chikaraishi et al., 2010).

On the other hand, the trophic position (TP) of animals can be estimated by differences in the $\delta^{15}N_{Glu}$ and $\delta^{15}N_{Phe}$ ($\Delta\ ^{15}N_{Glu-Phe}$). $\Delta^{15}N_{Glu-Phe}$ shows the difference between the primary producers in aquatic and terrestrial ecosystems (−3.4‰ for aquatic cyanobacteria and algae, +8.4‰ for terrestrial vascular plants), (fig. 45). Therefore, the animals of aquatic ecosystem can be distinguished from the animals of terrestrial ecosystems by the $\Delta^{15}N_{Glu-Phe}$ (e.g. aquatic herbivore = 11.0‰; terrestrial herbivore =

−0.8‰). The TPs of aquatic ecosystems are calculated differently to the trophic positions of the terrestrial ecosystems and based on the difference of the margin of $\delta^{15}N_{Glu}$ and $\delta^{15}N_{Phe}$ between primary producers in aquatic ecosystems and in terrestrial ecosystems (Chikaraishi et al., 2007; Chikaraishi et al., 2010; Chikaraishi et al., 2014; Itahashi et al., 2017; Ohkouchi et al., 2017). Accordingly, Itahashi et al. (2019; 2017) identified consumers of aquatic resources from the terrestrial dependent consumer in prehistoric humans through the use of isotopic analysis of individual amino acids.

6.3.2. Material selected for the compound-specific nitrogen analysis of amino acids

Samples for the study were selected from three areas in Kazakhstan (fig. 46, table 3) and from Bronze Age – Medieval chronological periods. Such areas were chosen in order to understand the potential differences in diet across vast steppe landscapes. The analyzed data were collected from archaeological sites located in three geographic clusters. The west-central cluster includes the data from sites Tersakkan, Zheken, and Taldysai, the east-central cluster includes Ak-Koitas IV/V, Aktogai, and Kent sites, and the south-eastern cluster has data from Serektas, Turgen-2, Kyzyl-bulak 4, and Shatyrkul sites. Carnivore faunal data was collected from sites Kuigenzhar and Syghanak located in northern Kazakhstan, and fish data we collected from archaeological sites of Dzhankent and Kosasar situated at the lower Syr Darya reaches in close proximity to Aral Sea.

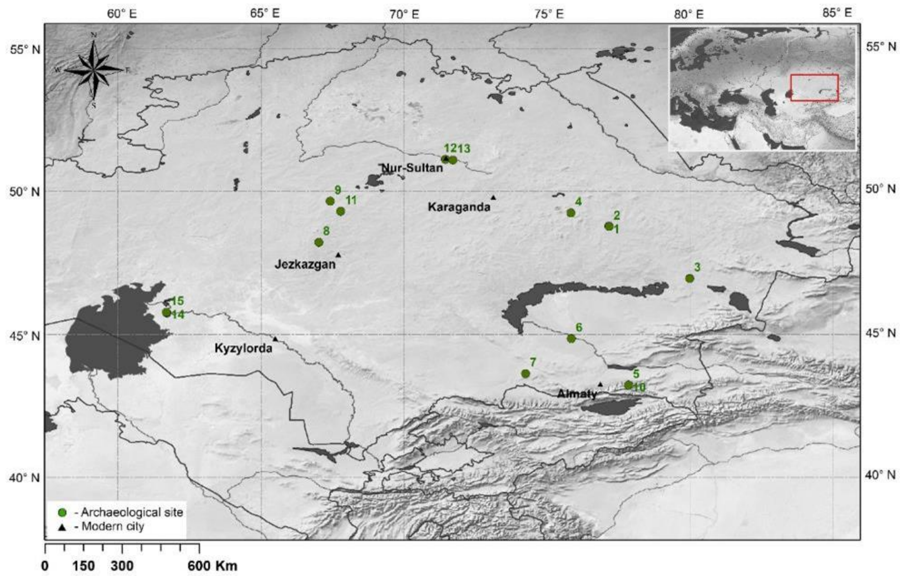


Figure 46: Location of the sites analyzed with amino acid study: 1) Ak-Koitas-IV, 2) Ak-Koitas-V, 3) Aktogai, 4) Kent, 5) Kyzyl-Bulak, 6) Serektas, 7) Shatyrkul', 8) Taldysai, 9)Tersakkan, 10) Turgen-2 complex, 11) Zheken, 12) Syghanak, 13) Kuigenzhar, 14) Dzhankent, 15) Kosasar. The map was created in ESRI ArcMap 10.4.1. with the use of Natural Earth free data.

Table 3: Details sites analyzed with amino acid study (average precipitation data marked with * was collected from De Pauw (2008), data marked with ** was collected from Williams and Konovalov (2008). Elevation is shown in meters above sea level (masl).

Geographic cluster	Site	Date	Samples	Average annual precipitation	Elevation
Northern	Syghanak	Iron Age	1 dog	400-600 mm*	348 m asl
Northern	Kuigenzhar	Bronze - Iron Age	1 wild boar	400-600 mm*	360 m asl
Near-Aral	Dzhankent	Medieval	2 fish	143 mm**	61 m asl
Near-Aral	Kosasar	Medieval	1 fish	140 mm**	58 m asl
West-central	Taldysai	Late Bronze Age	2 cattle, 3 sheep/goats	180 mm**	474 m asl
West-central	Tersakkan	Early Iron Age - Iron Age	6 human, 1 sheep/goat	180 mm**	454 m asl
West-central	Zheken	Iron Age/Medieval	2 humans, 1 sheep/goat	180 mm**	410 m asl
East-central	Aktogai	Middle Bronze Age/Iron Age	10 humans	300 mm**	411 m asl
East-central	Ak-Koitas-IV	Late Bronze Age	1 human, 1 caprine	270 mm**	878 m asl
East-central	Ak-Koitas-V	Late Bronze Age	1 human	270 mm**	873 m asl
East-	Kent	Final Bronze	10 sheep/goats	270 mm**	885 m asl

central		Age			
South-eastern	Turgen-2	Middle Bronze Age	5 cattle, 5 sheep/goats, 2 horses	638 mm**	1900 m asl
South-eastern	Kyzylbulak-4	Late Bronze Age/Early Iron Age	3 cattle	638 mm**	1882 m asl
South-eastern	Serektas	Final Bronze Age	3 cattle, 3 sheep/goats, 3 horses	272 mm**	383 m asl
South-eastern	Shatyrkul	Early Iron Age	12 humans	300-400 mm*	917 m asl
South-eastern	Turgen-2	Early Iron Age	13 humans	638 mm	2300 m asl

6.3.3. Collagen extraction and measurements

Collagen pre-treatment was carried out by G. Motuzaite Matuzeviciute following the protocols outlined in the section 5.2.1. The stable isotopic compositions of the collagen samples were determined using a Thermo Fisher Scientific elemental analyzer-isotope ratio mass spectrometer (EA-IRMS) at the University Museum, University of Tokyo by Y. Itahashi (Itahashi et al., 2019). Analytical errors (1σ) for nitrogen and carbon were < 0.2‰ based on USGS-40 and also were checked in each measurement by ten replicate analyses of reference alanine, glycine and histidine (SI Science Co., Ltd) after analysis of every six unknown samples. The purity of the collagen samples was evaluated on the basis of the carbon (%C) and nitrogen (%N) content in the extracted collagen samples. The atomic C/N ratio was expected to be in the range of 2.9–3.6 (DeNiro, 1985), otherwise, data were eliminated from the discussion.

The $\delta^{15}N$ values of the amino acids were determined by gas-chromatography–combustion–isotope-ratio mass spectrometer (GC–C–IRMS) at the University Museum, the University of Tokyo by Y. Itahashi (Itahashi et al., 2019). Standard mixtures of amino acids (SI Science Co., Ltd), with known $\delta^{15}N$ values, were analyzed every five runs. The analytical precision (1σ) for replicate analyses of the reference amino acids was < 0.5‰ for samples containing amino acids with more than 2 nmol N

7. Results

7.1. Ashutasty site excavation results

7.1.2. Landscape survey

Study of the Ashutasty landscape carried out with UAV and visual observations allowed to reconstruct the potential areas of activity around the site. Figure 47 demonstrates the distance from the Big Ashutasty Cross (A) to the area identified as Ashutasty site (B), natural water channel conveniently positioned around the site is visible as well (C), area marked as "D" shows a Neolithic site, and area marked as "E" shows the remains of Soviet-time animal corrals.

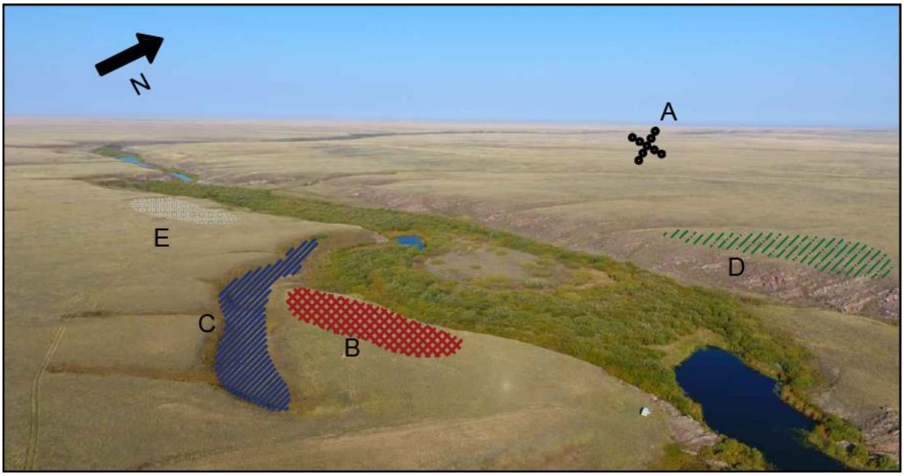


Figure 47: Landscape of Ashutasty with main activity areas identified (A – Big Ashutasty Cross, B – Area with scattered Final Bronze Age – Early Iron Age archaeological material, C – Natural channel for water collection, D – Area with scattered Neolithic material, E – Remains of soviet animal corrals

7.1.3. Archaeological excavations

Before the excavations were initiated, the surface material was studied. Amongst sunbleached fragments of animal bones and multiple ceramic shards, we observed metal and ceramic slags, which might point to the production industry. Moreover, a small metal item (fig. 48), which could be an element of head decoration, was discovered on the surface.

Figure 48: Small metal object discovered on the surface of the Ashutasty site

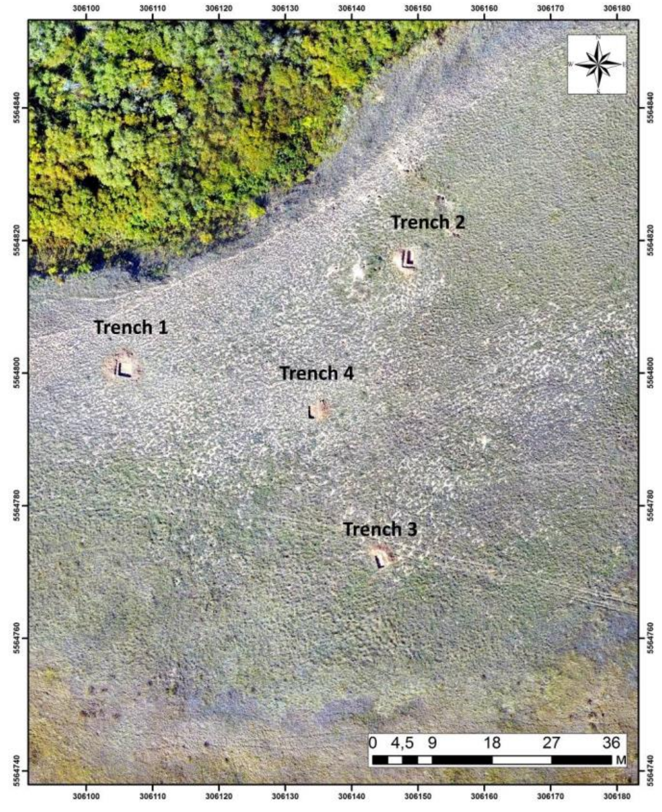


Figure 49: Plan of the excavations at Ashutasty site (NB: the photo was done on the first day of the excavations)

7.1.3.1. Trench 1

Trench one (fig. 49) was started as 2x2 m. area and expanded by 1 m. to the south and 1 m. to the east when the outlines of the pit 1 appeared in the southern cross-section (fig. 50). The final excavated area was 3x3 m (fig. 54). At the depth of 18 cm, an accumulation of animal bones was discovered in the southern expansion of the trench (fig. 51). The accumulation presented three bone fragments: two right, and one left distal humeri of cattle. The specific arrangement of the bones might be indicative of a ritual character. Directly below the bone accumulation, a domestic pit was discovered with a diameter of 86 cm., and 34 cm depth, reaching towards the S-E corner (fig. 50). The pit contained a large number of small charred bone fragments, several pottery shards, also charred, ceramic slags, and charcoals.

Figure 50: Outlines of the pit 1 in first southern cross-section of trench 1

At the depth of 80 cm, three more domestic pits/spots were discovered along the southern corner (fig. 52,53). The pits were very shallow (up to 10 cm depth), which suggests that they likely presented unintentional depositions. There was very little archaeological material discovered in the pits (1-3 small bone fragments).

Figure 51: Accumulation of bovine bones and outlines of the domestic pit 1 in trench 1

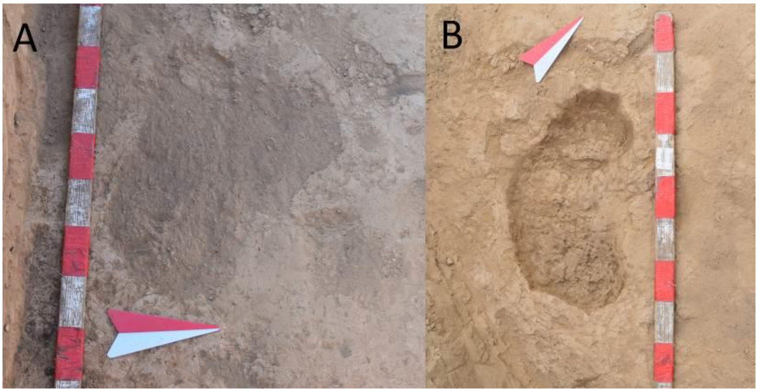


Figure 52: Pit 2 of the trench 1 before (A) and after (B) the excavation

Figure 53: Pit 4 of trench 1 after the excavation

Figure 54: Trench 1 after the excavation

7.1.3.2. Trenches 2 & 3

Second (2x2 m.) and third (2x1 m.) trenches (fig. 49, 55) did not reveal any archaeological features, and no cultural stratigraphic layers were identified. The number of finds was very small. Multiple tunnels made by small animals, such as suslik and badgers were observed during the excavations. A sheep/goat radius diaphysis was discovered at 90 cm depth in the trench 2 inside a yellow-red sandy clay layer, which contained no other finds.

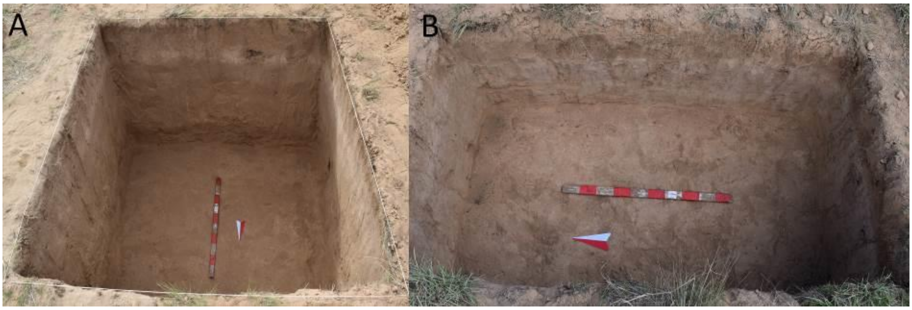


Figure 55: Trench 2 (left) and trench 3 (right) after the excavation

7.1.3.3. Trench 4

Fourth trench (2x3 m.), (fig. 50, 58) also yielded very little finds. A dark spot (feature 1, fig. 56) was identified at the depth of 55 cm. The first feature of trench 4 included two small fragments of a bone. Another small feature (feature 2, fig. 57) identified in NE corner at the depth of 112 cm most likely was a result of an animal (suslik?) activity and included only small fragments of wood charcoal.

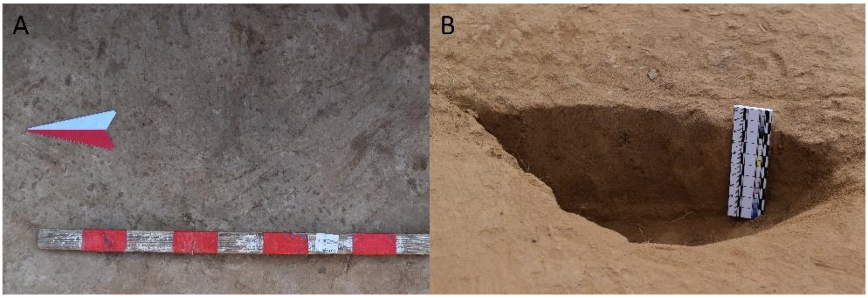


Figure 56: Feature 1 of the trench 4 before (A) and after (B) excavations

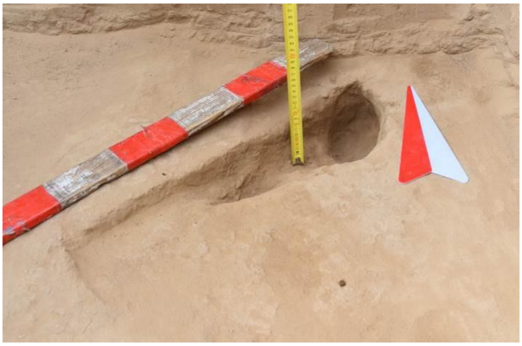


Figure 57: Cross-section of the feature 2 in the trench 4

Figure 58: Trench 4 after the excavations

7.1.4. Stratigraphy and cultural layers

All non-cultural stratigraphic layers before the 110 cm depth were represented by yellow-red sandy clay with almost no inclusions of small stones. Virgin soil documented at the level of 90 cm depth in the trench 2 and 116 cm depth in the trench 4 consisted of yellow-red sandy clay with inclusions of rotten reeds and chalk.

Cultural layers were represented by darker/redder sandy clay with inclusions of small fragments of bone and charcoal (pits 2,3,4 of trench 1 and features 1 and 2 of trench 4). One domestic pit documented at the depth of 18 cm (pit 1 of the trench 1) represented dark/black soil with many charcoals and animal bones.

7.1.5. Archaeological finds

Overall, 63 ceramic shards and two flint flakes were discovered inside the cultural layers of the excavated trenches. The majority of the ceramic shards (n=59) were discovered in trench 1. Only two shards had ornamentation (fig. 59), which can be associated with the Late Bronze Age pottery styles of the Kazakh steppes.

Figure 59: Ornamented ceramic shards from Ashutasty

7.1.6. Radiocarbon dating

Radiocarbon dating indicated that the major site use period was from 1605 to 1260 cal. BC (table 4, fig. 60), which coincides with Late Bronze Age in Central Asia. Dates derived from bone and charcoal showed similar results, which indicates that there was no “old-wood effect”. One date derived from a caprine radius discovered in the trench 2 indicated some activity at AD 885-1150 cal.

Table 4: Results of the ^{14}C dating of animal bones from the Ashutasty site

Context	Material	Lab number	^{14}C age B.P.	+/-	Calibrated age (B.C. 95.4%)
Tr. 1, bone accum.	bone	FTMC-VG71-4	3144	47	1506-1286 cal. BC
Tr. 1, pit 1, 55 cm	charcoal	FTMC-VG71-6	3105	43	1493-1260 cal. BC
Tr. 1, pit 2	bone	FTMC-VG71-3	3172	47	1600-1301 cal. BC
Tr. 4, feature 1	charcoal	FTMC-VG71-5	3178	47	1605-1304 cal. BC
Tr. 2, caprine bone	bone	FTMC-MG79-1	1047	49	AD 885-1150 cal.

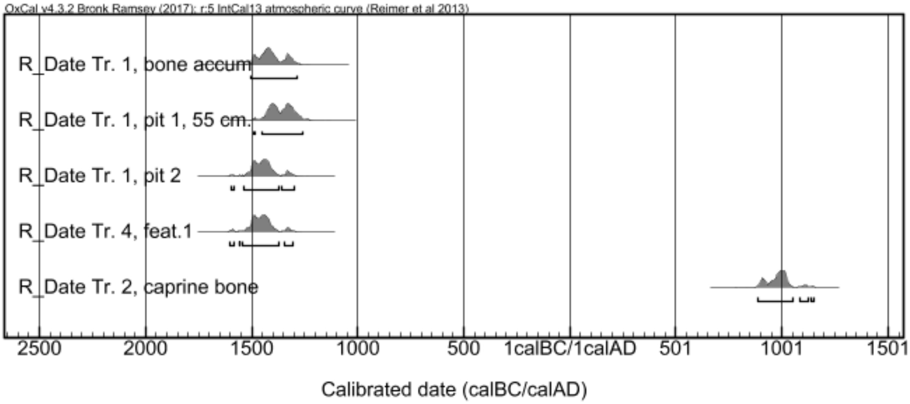


Figure 60: OxCal v.4.3.2 radiocarbon curves of the animal bone dates from the Ashutasty site

7.1.7. Zooarchaeological analysis

Overall, 206 animal bone fragments were collected during the excavations (Appendix 1, table 5). The majority of them presented very small fragments (1-2 cm) of bone, which could not be identified to species/genus or skeletal elements (fig. 61). A large number of discovered bone fragments (n=118) were charred or calcined. The highest amount of specimens (~45%) were charred at a temperature of 350° C, while 25% were subjected to even higher temperatures from 420° to 700° C (fig. 62).

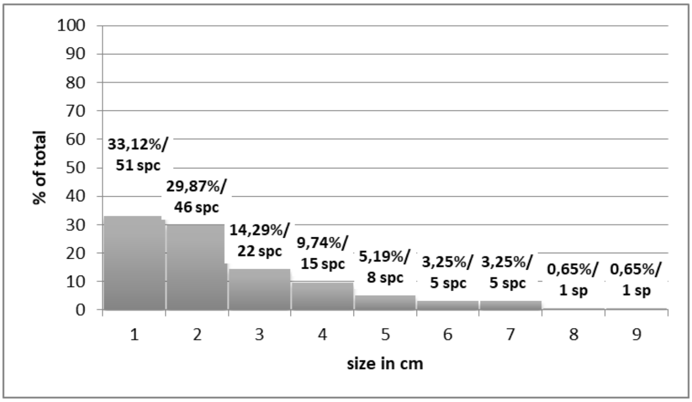


Figure 61: Proportions of discovered bone fragments by size in cm.

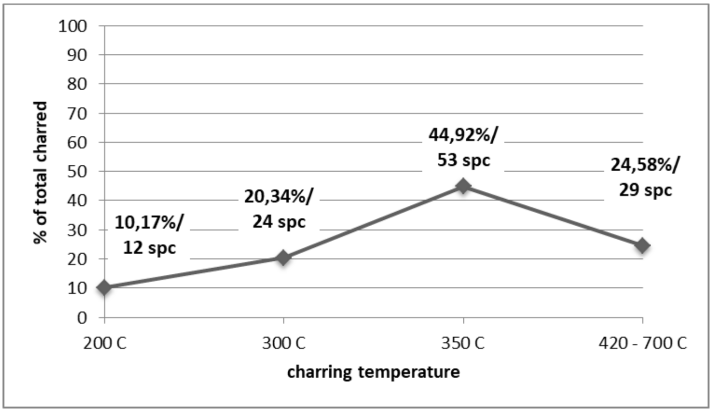


Figure 62: Proportions of bone fragments charred at different temperatures

Zooarchaeological analysis indicated that the highest numbers of identified specimens belonged to cattle (n=12) and sheep/goats (n=13), while only two bone fragments were identified as horse skeletal elements (table 5). A single fish scale from the first pit of the first trench was discovered during the flotation. The fish scale was identified as a small *Caprinidae* or *Percidae* family, possibly perch. Skeletal elements of susliks (*Spermophilia)* are likely intrusive and ended up in the archaeological context as a result of animal action.

Table 5: Summary of the identified skeletal remains from Ashutasty

	cattle	**sheep/goat**	**horse**	**suslik**	**fish**	**large mammal**	**medium mammal**	**small mammal**	**indeterminate**	**TOTAL no.**
Trench 1 (total)	11	11	2		1	18	5		116	164
Trench 1, pit 1	4				1	4	4		27	40
Trench 1, pit 2									9	9
Trench 1, pit 3									3	3
Trench 1, pit 4									1	1
Trench 2 (total)		2		15					11	28
Trench 3 (total)									1	1
Trench 4 (total)	1						1	1	10	13
Trench 4, pit 1							1	1		2
TOTAL sp.	**12**	**13**	**2**	**15**	**1**	**18**	**6**	**1**	**138**	**206**

7.1.8. Results of collagen peptide fingerprinting (ZooMS) analysis

Overall 19 samples were successfully (100% success rate) analyzed with collagen peptide fingerprinting (ZooMS) (Appendix 2). Of them, 10 samples were identified as *Bos* (cattle), 3 samples were identified as *Ovis* (sheep), 1 sample was recognized as *Ovis/Capra* (sheep or goat), 4 samples were identified as *Equus* (horse or donkey), 1 sample was identified as Cervidae/Antelopinae (red deer or saiga antelope). As only unidentified fragments were selected for ZooMS analysis, the results indicate a higher fragmentation rate of large mammal (cattle) bones. Possibly, it points to bone marrow exploitation. Overall, ZooMS indicated higher (over 50%) presence of cattle in comparison to other animals.

7.1.9. Macrobotany

Macrobotanical samples were collected after the flotation of three contexts: ~20 l. from the pit 1 of the trench 1, ~6 l. from the pit 2 of the trench 1, and ~7 l. from the pit 4 of the trench 1. Analysis of macro-botany demonstrated the absence of cultivated crops. Overall, 105 charred seeds of *Chenopodium*, 12 seeds of *Medicago/Trifolium/Melilotus*, 2 seeds of *Trigonella*, and 1 seed of *Plantaginaceae* were discovered. These plants are very typical of a steppe landscape. Present-day vegetation of Ashutasty landscape includes the same genera of plants (fig. 63).

Figure 63: Present day vegetation of Ashutasty landscape

7.1.10. Stable isotope analysis of animal bones from Ashutasty

Stable isotope analysis was conducted on 27 animal bone fragments from Ashutasty site (Appendix 3, table 1). Each sample was measured two times. The mean value was derived from the two measurements and considered in the analysis of the resuls. Figure 64 presents a scatter plot with the mean values for each sample. The isotopic data were matched to the results of ZooMS analysis. Overall, $\delta^{13}C$ values for the Ashutasty fauna suggest that mainly C_3 plants were contributing to the animal diet. One sheep (*Ovis* as identified by ZooMS), as well as deer/saiga, have slightly higher $\delta^{13}C$ values than other animals. Deer and saigas antelope are migratory animals that feed in a wider range of environments, which affects their isotopic values. The sheep could also be raised in a different environment.

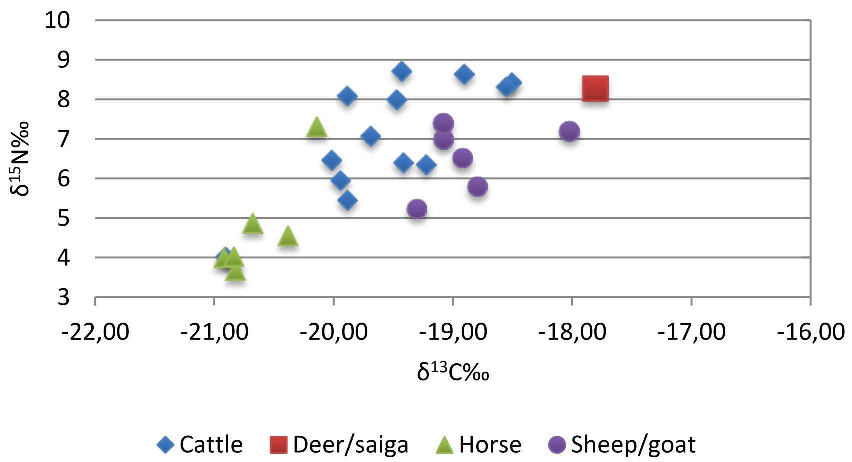


Figure 64: Scatter plot with stable isotopic values of Ashutasty fauna

7.1.11. Exploitation of the Ashutasty landscape

The results of the archaeological excavations and laboratory research of Ashutasty site material have shown that the site was not a permanent settlement. Cultural layers are very thin and contain very little material. Radiocarbon dates from the pit 1 discovered at the depth of 18-55 cm and pit 2 discovered at 80 cm depth showed the range of dates from 1605-1260 cal. BC, which coincides with the Eurasian Late Bronze Age period. Zooarchaeological analysis and ZooMS demonstrated the presence of domestic cattle, horses, sheep and goats, and wild saiga or red deer. Analysis of macro-botanical remains showed the absence of cultivated crops. While the evidence for the metal production, such as slags and metal objects, no further data supporting metal production was collected from the archaeological layers. Therefore, the surface material could have accumulated on the surface as a result of water erosion or flooding of the river terrace and might have originated elsewhere. The radiocarbon dating showed that the site was occupied earlier than the Big Ashutasty Cross was constructed (800 cal. BC) (Motuzaite Matuzeviciute et al., 2015b), therefore, the inhabitants of Ashutasty site cannot be associated with the constructors of the geoglyphs.

Overall, the evidence from the investigations at Ashutasty suggests that the site was likely used as a camp or a seasonal settlement of pastoralists, who also seemed to have opportunistically hunted wild animals. People that were stopping by the Ashutasty camp area could be driven there in the purchase of *Saiga tatarica* migrating southwards in the autumn or northwards in the spring. Ashutasty site is located close to the single possible river-crossing point in the vicinity of 20 km. It is known that hunting installations found in plateau Ustyurt are often discovered on the river-crossing points (Amirov et al., 2015, fig. 2). However, based on the collected evidence, the hunting was limited, and the main occupation of the Ashutasty inhabitants was pastoralism. As it has been previously suggested, some communities of the Kazakh steppes practiced a mixed pastoralism/hunting economy, which implied movement of herds across the pastures while hunting the migratory wild animals (Masanov, 1995; Vainshtein, 1980). It is possible to suggest that Ashutasty community also practiced a similar form of economy.

7.2. Stable isotope analysis of human and animal bone collagen

Samples for the stable isotope analysis of human and animal bone collagen (n=343) were collected from various archaeological sites (n=70) dated to the Bronze – Middle Ages and located in western, northern, central, eastern, south-eastern, and Aral regions of Kazakhstan. Overall, 215 human and 127 animal bones were analyzed. Below are presented the results of 190 (88.4%) human and 97 (76.4%) animal bones samples that showed good preservation of collagen by C:N ratios between 2.9 and 3.6 (DeNiro, 1985).

7.2.1. Turgai plateau and Northern Kazakhstan

Human isotopic values from north Kazakhstan and Turgai (n=35) spanning Bronze Age – Medieval periods range from -21.4‰ to -17.4‰ in $\delta^{13}C$ and from 10.5‰ to 15.6‰ in $\delta^{15}N$, and having the means of -18.7‰ in $\delta^{15}N$ (SD= 0.7) and 12.9‰ in $\delta^{13}C$ (SD=1.5). Isotopic data from the region do not include high $\delta^{13}C$ values, which would be indicative of C_4 crop consumption (fig. 65). Moreover, some human $\delta^{15}N$ values are more than one step higher in the food chain than the local herbivores, which might point to the exploitation of freshwater fish. Overall, the evidence from north Kazakhstan and Turgai point to the consumption of animal products with the potential presence of C_3 plants and freshwater fish in the diet.

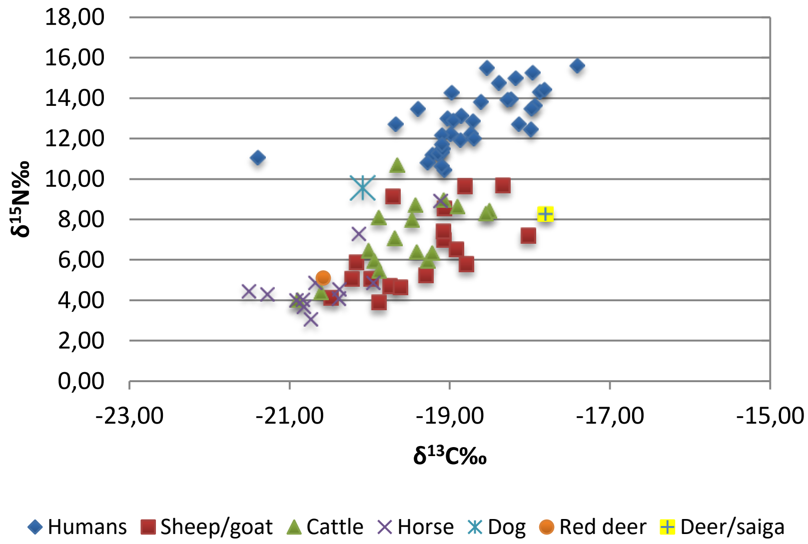


Figure 65: Stable isotopic values of humans and fauna from Turgai plateau and north Kazakhstan

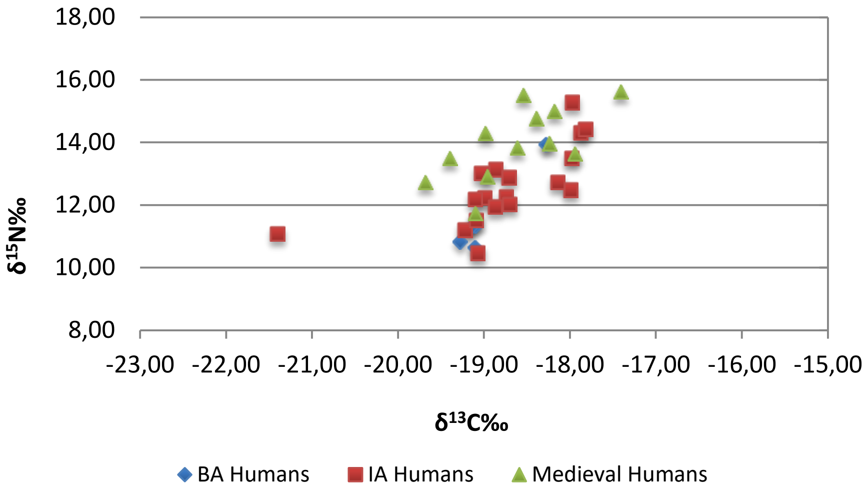


Figure 66: Scatter plot demonstrating human isotopic values from Turgai plateau and north Kazakhstan grouped according to the chronology

If the human data from northern Kazakhstan and Turgai are grouped by chronological periods (fig. 66), we can see that the Iron Age group is quite dispersed with one outlier present, which has $\delta^{13}C$ value of -21.4‰, while also having quite low $\delta^{15}N$, which might suggest a C_3 crops-based diet. This sample is coming from a Sarmatian burial at Shagalaly site located near the modern Kokshetau town. The sample exhibiting the highest $\delta^{13}C$ value comes from AD XVIII century burial of Zheken site located in the south-east Turgai.

7.2.3. Central Kazakhstan

Humans from central Kazakhstan (n=50) exhibit isotopic values ranging from -22.1‰ to -14.7‰ in $\delta^{13}C$ and from 10.3‰ to 15.7‰ in $\delta^{15}N$, while having the means of -18.1‰ (SD=1.1) in $\delta^{13}C$ and 13.8‰ (SD=1.1) in $\delta^{15}N$. The presence of elevated $\delta^{13}C$ values higher than -17.0‰ points to the exploitation of C_4 crops, such as broomcorn millet (fig. 67). High variation of $\delta^{15}N$ values in central Kazakhstan points to a variety of exploited resources, where high values reflect diets based on animal proteins and possible freshwater fish, and low values might point to the predominance of plant food in the diet.

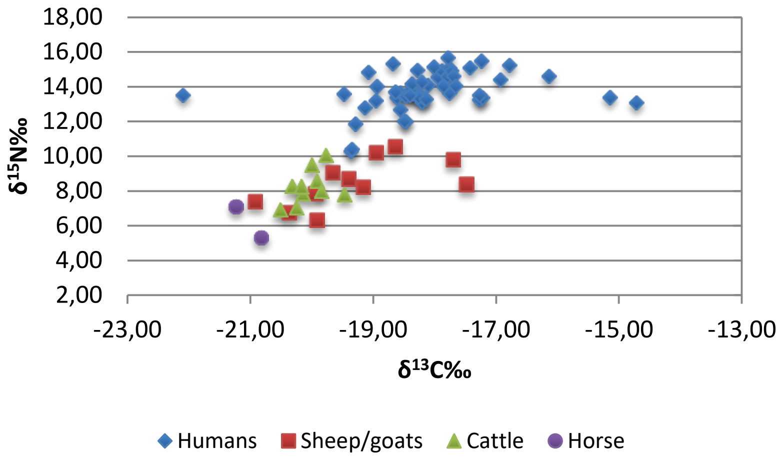


Figure 67: Stable isotopic values of humans and fauna from central Kazakhstan

Figure 68 shows that, in comparison to the Bronze Age group of values, the Final Bronze Age – Early Iron Age community exploited a wider range of resources. Such a dispersal of human isotopic values might also indicate the increasing mobility, which implies that people consumed food from various landscapes. We can also see that some Bronze Age and Final Bronze Age – Iron Age individuals exhibit high $\delta^{13}C$ values indicative of millet consumption.

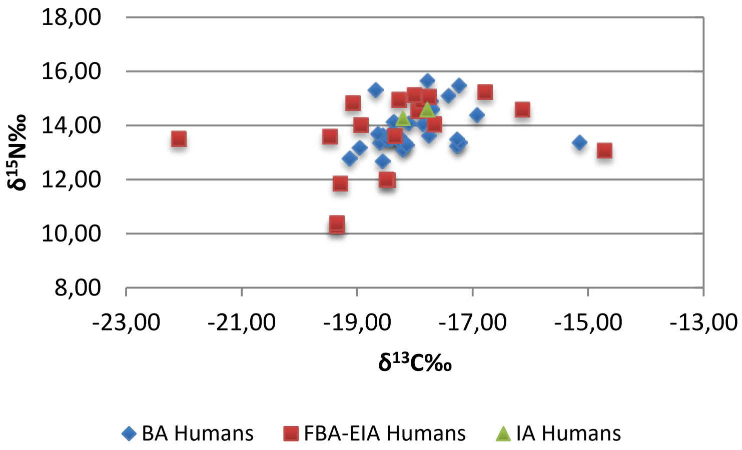


Figure 68: Scatter plot demonstrating human isotopic values from central Kazakhstan divided by chronology

7.2.4. Eastern Kazakhstan

Human isotopic values from eastern Kazakhstan (n=6) range from -17.8‰ to -14.0‰ in $\delta^{13}C$ and from 11.2‰ to 15.2‰ in $\delta^{15}N$, while having the means of -16.6‰ (SD=1.5) in $\delta^{13}C$ and 13.1‰ (SD=1.7) in $\delta^{15}N$ (fig. 69). The humans data from eastern Kazakhstan, although scarce, display high $\delta^{13}C$ values, which might point to the dietary intake of C_4 plants. Moreover, the isotopic data of humans in the Final Bronze Age – Early Iron Age exhibit higher $\delta^{13}C$ values than in the Iron Age.

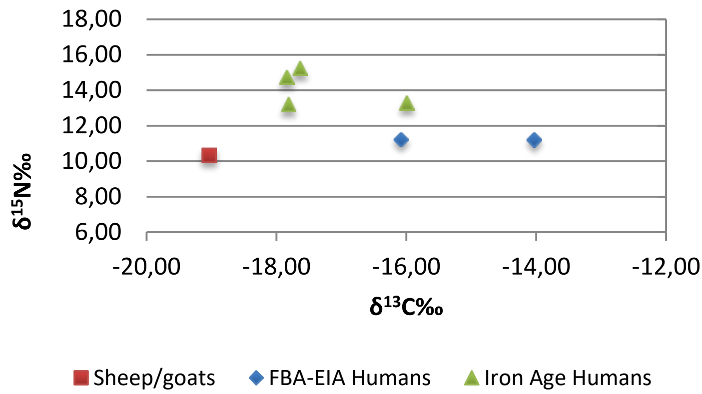


Figure 69: Scatter plot demonstrating faunal isotopic values and human isotopic values from eastern Kazakhstan divided by chronology

7.2.5. Western Kazakhstan

Isotopic values from west Kazakhstan (n=20) range from -19.0‰ to -13.4‰ in $\delta^{13}C$ and from 11.9‰ to 17.9‰ in $\delta^{15}N$, and having the mean values of -17.9‰ in $\delta^{13}C$ (SD=1.4) and 13.8‰ in $\delta^{15}N$ (SD=1.6). Figure 70 demonstrates that some Iron Age humans have high $\delta^{13}C$ values indicative of C_4 crop consumption. Data from herbivores, however, match the isotopic values of domestic herbivores from other regions and do not include high $\delta^{13}C$ values. Such variation of human isotopic values in western Kazakhstan might point to the exploitation of a variety of resources, including C_3 and C_4 types of crops, animal meat and milk, and, possibly, freshwater fish.

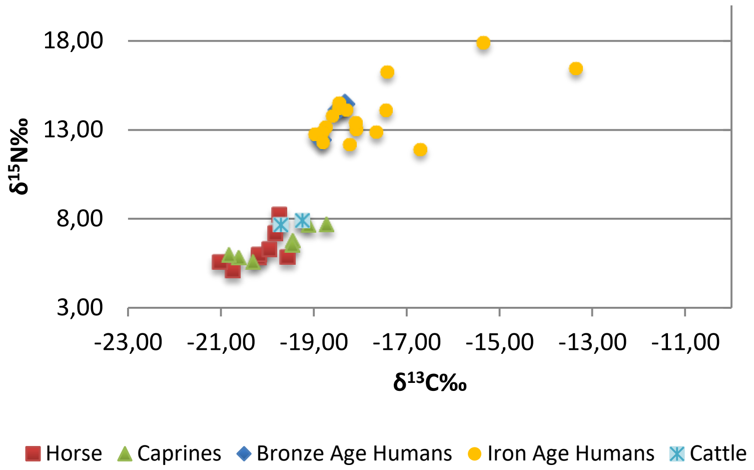


Figure 70: Scatter plot demonstrating animal isotopic values and human isotopic values from western Kazakhstan divided by chronology

7.2.6. Syr Darya region

Human isotopic values from the oases of Syr Darya (n=23) range from -22.5‰ to -14.2‰ in $\delta^{13}C$ and from 9.4‰ to 15.2‰ in $\delta^{15}N$ (fig 71). One human sample demonstrated distinctive $\delta^{13}C$ value of -22.5‰ with $\delta^{15}N$ value of 15.2‰, which makes it an outlier and might point to the consumption of freshwater resources. Domestic herbivore data range from -18.0‰ to -12.2‰ in $\delta^{13}C$ and from 8.6‰ to 10.2‰ in $\delta^{15}N$, which suggests a presence of C_4 resources in the animal diet (fig. 71). High $\delta^{13}C$ values of some humans, therefore, could be caused by the consumption of proteins from animals feeding on C_4 resource.

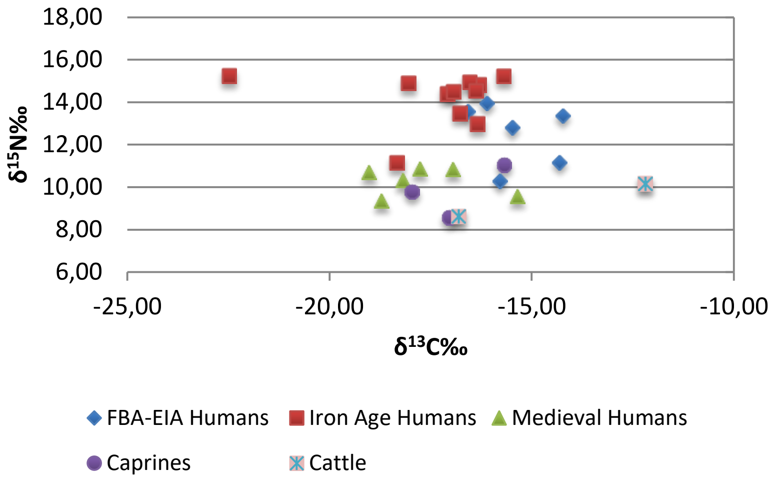


Figure 71: Scatter plot demonstrating animal isotopic values and human isotopic values from Syr Darya divided by chronology

7.2.7. South-east Kazakhstan

Human data from south-east Kazakhstan (n=56) spanning Bronze Age – Medieval periods (fig. 72) range from -19.5‰ to -11.7‰ in δ^{13}C and from 8.9‰ to 16.0‰ in δ^{15}N, and exhibit mean values of -16.1‰ (SD=1.6) in δ^{13}C and 12.7‰ (SD=1.7) in δ^{15}N. The wide range of isotopic values in all studied periods (fig. 73) points to the variety of exploited resources, including millet. Herbivore isotopic data also include high δ^{13}C values, which might indicate foddering by C_4 resource.

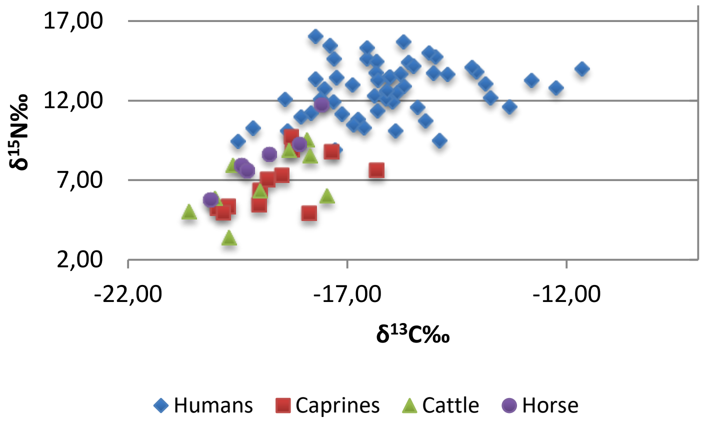


Figure 72: Stable isotopic values of humans and fauna from south-east Kazakhstan

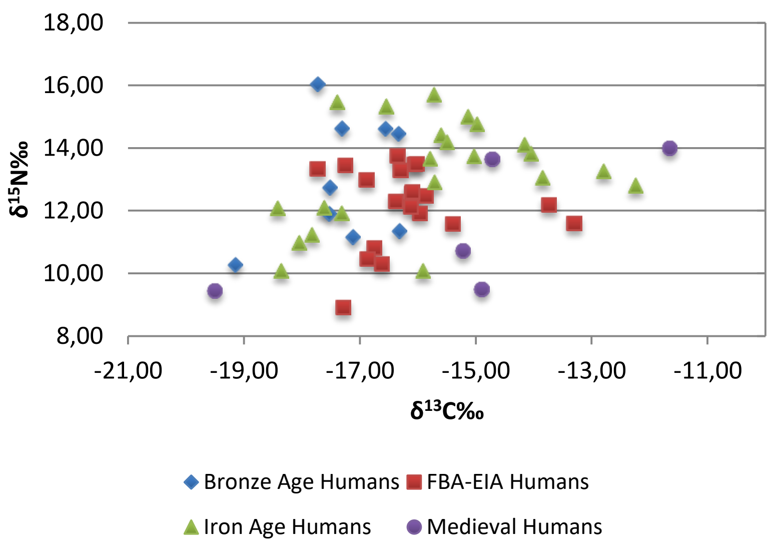


Figure 73: Scatter plot demonstrating human isotopic values from south-east Kazakhstan divided by chronology

7.3. Millet as a special diet?

The new data indicates that the earliest isotopic evidence for the consumption of millet in central Kazakhstan comes from Karazhartas cemetery, which includes the unique Begazy-Dandybayevo mausoleum dated to the 1729-1498 cal. BC (Kukushkin et al., 2017). In the later periods, more individuals in central Kazakhstan have high $\delta^{13}C$ values indicative of C_4 crop consumption. The majority of them come from the burials, which likely belonged to the elite based on the burial goods and the kurgan constructions (table 6). Many of these individuals also have trepanning holes in their skulls. Beisenov and Kitov (2014) argue that trepanning holes might indicate a high status of the individuals as trepanation could be a sign of medical treatment, which was not done for regular people.

Table 6: Details about central Kazakhstan samples with high $\delta^{13}C$‰ values (samples marked with ** indicate dating by cultural affiliation)

Sample ID	Date	Site	Context	Sex	Age	Other information	$\delta^{13}C$ ‰	$\delta^{15}N$ ‰	C/N at.	Source
KZ025	~1300-800 BC**	Tegiszhol	Kurgan 3	-	-	-	-16,4	13	3.1	Lightfoot et al. 2015
KZ053	~1300-800 BC**	Tasyrbai	Kurgan 10, grave 1	-	-	-	-15,7	17,7	3.2	Lightfoot et al. 2015
KZ092	~1300-800 BC**	Kyzyl	Kurgan 8	-	-	-	-16,8	13	3.2	Lightfoot et al. 2015
KZ104	~1300-800 BC**	Kent (settlement)	Cultural layers	-	Adult	single human femur discovered	-16	13,5	3.3	Lightfoot et al. 2015
LT-KZ-2	~900-400 BC**	Karashoky	Kurgan 7	M	35-45 y.o.	The individual has 7 trepanning holes in the skull	-16,1	14,6	3.3	Ananyevskaya et al. 2018
LT-KZ-18	~700-500 BC**	Myrzhyk 6	Kurgan 3	M	25+ y.o.	Buried with inventory of a «warrior»	-16,8	15,2	3.4	Ananyevskaya et al. 2018
UBA-23672	829-546 cal. BC	Akbeit	Kurgan 1	M	55+ y.o.	The individual has 3 trepanning holes in the skull	-15,7	16,2	3.3	Svyatko and Beisenov 2017
UBA-23674	791-542 cal. BC	Karashoky	Kurgan 1	-	Child or adult	The child has 4 trepanning holes in his skull	-16	16,9	3.2	Svyatko and Beisenov 2017
UBA-23664	791-536 cal. BC	Koitas	Kurgan 1	-	-	-	-14,1	14,3	3.2	Svyatko and Beisenov 2017
UBA-23667	807-540 cal. BC	Taldy-2	Kurgan 2	F (55 y.o. Or more) or M (45-55 y.o.)		female and male from plundered burial	-14,5	15,2	3.3	Svyatko and Beisenov 2017
UBA-23674	~900-600 BC**	Bektauata	Kurgan 1	M	35-45	2 trepanning holes, golden earrings present	-17,2	16,6	3.2	Svyatko and Beisenov 2017

UBA-23666	807-558 cal. BC	Bakybulak	Kurgan 15	M (35-45) or F (45-55)	golden earrings present	-17,1	15,8	3.2	Svyatko and Beisenov 2017
CGG_2_015470	800-540 cal. BC	Taldy-2	Kurgan 5	M		-16,8	14,5	3.2	de Barros Damgaard et al. 2018
CGG_2_015449	766-729 cal. BC	Kurgan Borli		F		-16,7	13,7	3.2	de Barros Damgaard et al. 2018
EA-SI-88	~1700-1500 BC**	Karazhartas	Enclosure 8			-17,3	13,5	3.5	This study
EA-SI-86	~1700-1500 BC**	Karazhartas	Enclosure 5			-17,3	13,3	3.3	This study
EA-SI-87	~1700-1500 BC**	Karazhartas	Enclosure 7			-17,2	13,4	3.3	This study
EA-SI-89	~1700-1500 BC**	Karazhartas	Enclosure 9	child		-16,9	14,4	3.4	This study
EA-SI-85	1729-1498 cal. BC	Karazhartas	Enclosure 1, burial outside of the enclosure		Begazy-Dandybayevo pyramide	-15,2	13,4	3.4	This study

Isotopic evidence from Eastern Kazakhstan Early Iron Age site Karatobe also points to the high $\delta^{13}C$ values (Ananyevskaya et al., 2018) of the individual that was buried with luxury items, such as golden plates, jewelry made of precious stones and gold, bronze ring, etc (Aitqaly, 2014). Amongst the burial goods, kurgan 2 also included grains of unidentified origin. Nevertheless, more data have to be acquired for a comparison of elite vs. common people's diet.

Isotopic values from western Kazakhstan Early Iron Age site Taksai demonstrated high $\delta^{13}C$ values exclusively in children (~0-10 y.o.), which likely points to the specific children's diet. A similar observation is coming from an Iron Age cemetery site Karatuma located in south-east Kazakhstan. Motuzaite Matuzeviciute (2016) presents the isotopic values of a child that was inhumated on top of a millet underlay, and had values of -14.9‰ in $\delta^{13}C$; and 8.98‰ in $\delta^{15}N$, which indicates that he had a C_4 diet. An increase of $\delta^{13}C$ values can also happen due to the nursing effect, when mothers feed children with their milk, thus putting the children one step higher in the food chain (Beaumont et al., 2015). However, children data from other analyzed sites in Kazakhstan does not demonstrate elevated $\delta^{13}C$ values (table 7), except for the individual from Karazhartas.

Table 7: Isotopic values of children (0-10 y.o.) from different sites of Kazakhstan

Site	Context	Age	Element	$\delta^{13}C$ ‰	$\delta^{15}N$ ‰	C/N atomic	Region
Taksai	Object 1, burial 1	1-5 y.o.	Skull	-13.4	16.5	3.2	Western KZ
Taksai	Object 1, burial 3	1-5 y.o.	3rd metacarpal	-16.7	11.9	3.2	Western KZ
Taksai	Object 1, burial 7	>2 y.o.	Rib	-15.4	17.9	3.3	Western KZ
Tersakkan 2	Object 1, burial 1	>1 y.o.	Right humerus	-19.1	11.7	3.2	Central KZ
Tersakkan 3	Object 1, burial 3	>1 y.o.	Right humerus	-19.7	12.7	3.2	Central KZ
Tersakkan 4	Object 1, burial 7	3-10 y.o.	Thoracic vertebra	-18.6	13.8	3.3	Central KZ
Zheken	Burial 1	>1 y.o.	Left scapula	-18.5	15.5	3.1	Central KZ
Zheken	Burial 6	5-10 y.o.	Left clovicle	-19.0	14.3	3.1	Central KZ

Karazhartas	Enclosure 9, child burial	2-10 y.o	Radius	-16.9	14.4	3.4	Central KZ
Bestamak	Burial 138, skeleton 4	Young	Vertebra	-19.1	12.2	3.3	Northern KZ
Chirik Rabat	Object 1, burial 2(?), western sector	>5 y.o; possibly newborn	Skull	-22.5	15.2	3.3	Syr Darya
Turgen 2	House 4, sq. D7, child burial	Child	Bone	-19.2	10.3	3.4	South-Eastern KZ

7.4. Analysis of animal isotopic data across Kazakhstan

All available isotopic data, including previously published (see Appendix 3,4) values from four main domestic herbivores were divided into “horse”, “cattle”, and “sheep/goats” groups, in order to analyze the differences in the $\delta^{13}C$ and $\delta^{15}N$ values. Figure 74 demonstrates that $\delta^{13}C$ values of horse collagen are lower in all analyzed groups in relation to the values of cattle and sheep/goats, while the $\delta^{13}C$ values of the caprines are highest in almost all analyzed groups, except for the Syr Darya oases group, where cattle have highest values of carbon. However, this group included cattle (n=2) with very high $\delta^{13}C$ values indicative of the presence of a C_4 resource in the diet. Herbivore $\delta^{15}N$ data display a similar correlation, where horses tend to have the lowest nitrogen values in relation to cattle and caprines. Southeast Kazakhstan is the only group where $\delta^{15}N$ values of horses are higher than the nitrogen isotopic values of other animals. Horse data in this group comes from Serektas (fig. 44), which is an archaeological site located in an extremely arid environment with an average annual precipitation of 100-300 mm (Pauw, 2008). Aridity might increase the $\delta^{15}N$ values in plants (Murphy and Bowman, 2006), which in turn can be the reason for the high $\delta^{15}N$ values of Serektas horses bone collagen.

Vertical transhumance, practiced in the mountain regions might also alter the $\delta^{13}C$ of animals, due to the exploitation of vegetation in highlands, where C_3 plants exhibit higher $\delta^{13}C$ values (Körner et al., 1988). Herbivore data from southeast Kazakhstan (fig. 74) demonstrate that horses, cattle, sheep/goats all exhibit higher $\delta^{13}C$ values in comparison to the other regions. Sometimes herbivore $\delta^{13}C$ values above -18‰ are interpreted as the presence of C_4 crops in the diet (Pearson et al., 2007). However, consumption of highland vegetation might also cause herbivore bone collagen to demonstrate $\delta^{13}C$ values above -18‰.

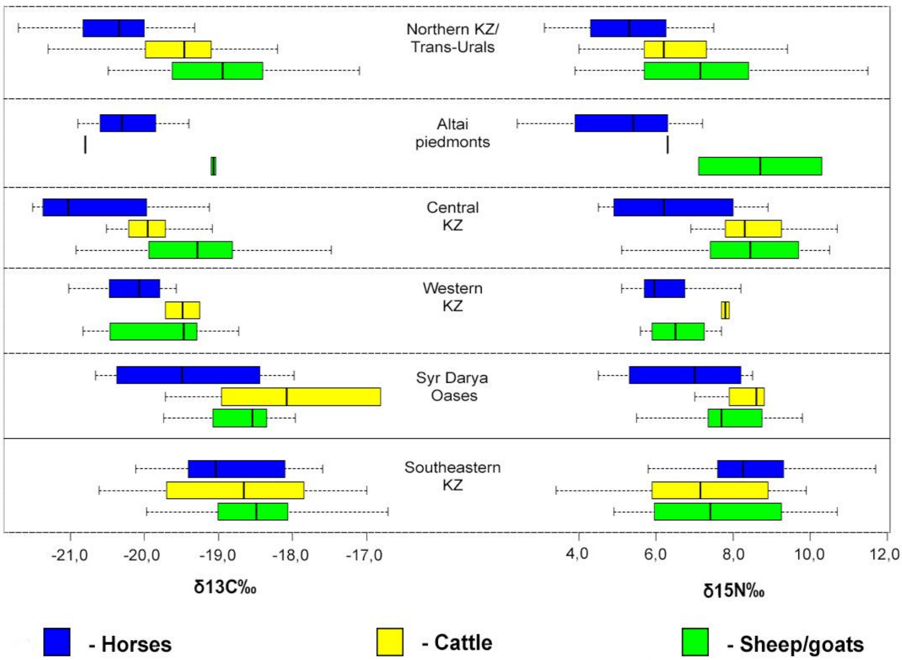


Figure 74: Box plot demonstrating isotopic values of horses, cattle and sheep/goats grouped by regions

Analysis of combined data from different regions for horses, cattle, and caprines demonstrate significant differences in $\delta^{13}C$ and $\delta^{15}N$ values of about 0.5‰ and 1.0‰, respectively, for all animals (fig. 75) (Ananyevskaya et al., in press). Ventresca Miller et al. (2018) reviewed the herbivore isotopic data from northern Kazakhstan in relation to the pasturing strategies and suggested that lower $\delta^{13}C$ and $\delta^{15}N$ values in horse bone collagen could be related to the exploitation of a wider pasture area by horses in comparison to cattle and caprines. The data presented here, however, indicate that the variations in $\delta^{13}C$ and $\delta^{15}N$ values between horses, cattle, and caprines are observed across whole North Central Asia, which suggests that those differences can be potentially caused by metabolic processes (Sponheimer et al., 2003; Van Klinken et al., 2002) as well as the differences in pasturing strategies. Thus, reliance on different animals for subsistence might also influence the variation in isotopic values of human bone collagen.

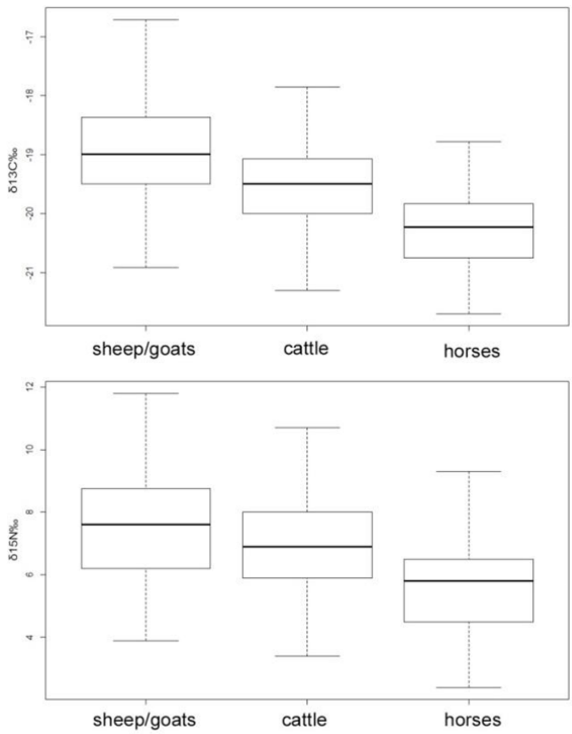


Figure 75: Box plot demonstrating the average isotopic differences in the analyzed data from sheep/goats, cattle and horses

7.5. Statistical analyses and isotopic niche modelling

7.5.1. Northern Kazakhstan & Trans-Urals

The statistical means (Appendix 5, table 1) for the isotopic data from Trans-Urals and north Kazakhstan (n=227) are -18.8‰ in $\delta^{13}C$ and 12.4‰ in $\delta^{15}N$. The application of Bayesian bootstrapping indicated that the Bronze Age and Iron Age groups from Trans-Urals and northern Kazakhstan are statistically different in both carbon and nitrogen values as their 95% confidence intervals do not overlap (Appendix 5, table 4). Data from the Bronze Age community (n=171) is higher in $\delta^{13}C$ values in comparison to the Iron Age (n=49) group, while the $\delta^{15}N$ values of the two groups are not different. Isotopic niche modeling indicated that a wider variety of resources was exploited in north Kazakhstan and Trans-Urals during the Iron Age (fig. 76, 77) in comparison to the Bronze and Middle Ages.

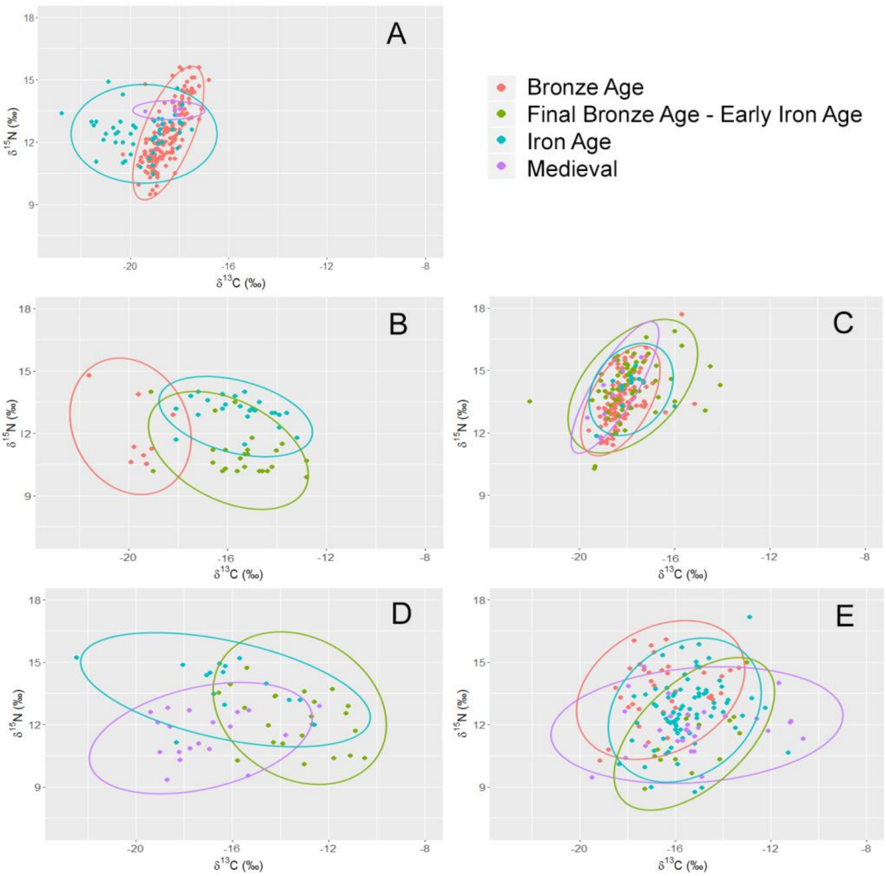


Figure 76: Isotopic niches of human groups of values: A – north Kazakhstan and Trans-Urals, B – Altai piedmonts, C – central Kazakhstan, D – Syr Darya oases, E – southeast Kazakhstan

Stable isotope analysis has previously shown that the local populations did not consume millet during the Bronze or Iron Age (Hanks et al., 2018; Privat, 2004; Ventresca Miller et al., 2014; Ventresca Miller and Makarewicz, 2019). The new isotopic data presented in this study shows the absence of high $\delta^{13}C$ values in the region (Ananyevskaya et al., in press-a), which confirms the previous observations. It has been suggested that the introduction of C_3 resources, such as wheat and barley, could take place in the mid-second millennium BC (Ventresca Miller and Makarewicz, 2019). Isotopic niche modeling conducted using the new data indicates the increase of exploited resource niche in the Iron Age, while the $\delta^{13}C$ mean of the community is -19.5‰ as opposed to the -18.8‰ mean of the Bronze Age group. This might reflect the consumption of wheat and barley with more depleted $\delta^{13}C$ values.

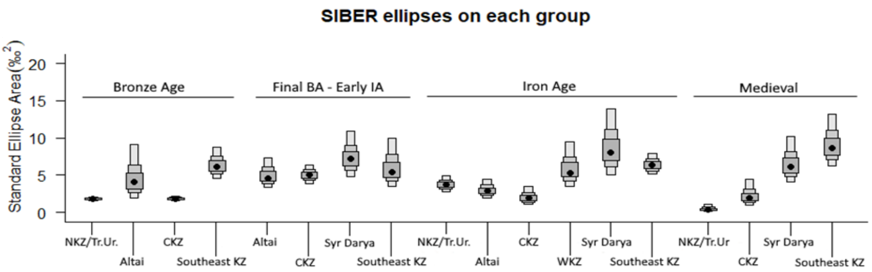


Figure 77: Ellipse areas on each group of human isotopic values analyzed (boxes mark the credible intervals of 50% - dark grey, 75% - lighter grey, and 95% - lightest grey, while black dot marks the mean of the area), (NKZ/Tr.Ur. – northern Kazakhstan/Trans-Urals, CKZ – central Kazakhstan, Southeast KZ – southeast Kazakhstan, WKZ – western Kazakhstan)

7.5.2. Central Kazakhstan

Central Kazakhstan steppe (n=213) community has $\delta^{13}C$ and $\delta^{15}N$ means of -18.1‰ and 13.8‰, respectively. Bayesian bootstrap and statistical testing indicated that the $\delta^{13}C$ values of the Bronze Age (n=129) community are significantly different from all other groups (Appendix 5, table 4). The $\delta^{13}C$ and $\delta^{15}N$ values of the Final Bronze Age – Early Iron Age (n=63) and Iron Age (n=12) communities are not significantly different. Isotopic niche modeling (fig. 76, 77) demonstrated that the Final Bronze Age – Early Iron Age community exploited a more extensive range of resources in comparison to the other groups, which coincides with the time of millet introduction into the region (Ananyevskaya, 2018; 2019a; Ananyevskaya et al., in press; Ananyevskaya et al., 2018; Beisenov et al., 2019; Lightfoot et al., 2015; Svyatko and Beisenov, 2017; Ventresca Miller and Makarewicz, 2019). The $\delta^{13}C$ values of the Medieval (n=8) group are lower in comparison to the isotopic values from the previous periods, which might indicate the decrease in millet consumption and might point to the increase in C_3 crop consumption. Small-scale agriculture was likely practiced at the sites located at the mountain foothills in central Kazakhstan.

7.5.3. Western Kazakhstan

The majority of the data from the west Kazakhstan region (n=21) are coming from the Iron Age. Carbon isotopic ratios of the Iron Age group indicate the presence of a C_4 source in the diet of some individuals (Ananyevskaya et al., in press). Isotopic niche modeling demonstrated that the Iron Age group exploited a wide range of resources (fig. 77). SIBER ellipse area of west Kazakhstan Iron Age community is wider than the niches of the Iron Age communities of groups A, B, and C (north Kazakhstan and Trans-Urals, Altai piedmonts and central Kazakhstan), and similar in size to the niches of groups E and F (Syr Darya oases and southeast Kazakhstan). This might point to the exploitation of both C_3 and C_4 types of cultivated plants in west Kazakhstan.

7.5.4. Altai piedmonts

The statistical means for isotopic values from Altai piedmonts (n=56) are -16.1‰ in $\delta^{13}C$ and 12.1‰ in $\delta^{15}N$. Bayesian bootstrap demonstrated that Bronze Age (n=8) group is significantly different from the Final Bronze Age – Early Iron Age (n=24) and Iron Age (n=24) communities in $\delta^{13}C$ values (Appendix 5, table 4). Ventresca Miller and Makarewicz (2019) suggested that an increase in the isotopic space in the Late Bronze Age – Iron Age in Minusinsk Basin demonstrates intensification in C_4 crop consumption. New data from the Final Bronze Age – Early Iron Age Altai community include the high $\delta^{13}C$ values likely indicative of C_4 crop consumption, which is still not visible in the Bronze Age group of values (Ananyevskaya et al., in press-a). However, the standard ellipse areas are similar in size in all three communities (Bronze Age, Final Bronze Age – Early Iron Age, Iron Age), with the Final Bronze Age – Early Iron Age community expressing the widest isotopic niche (fig. 76, 77). Distributions of the niches suggest that the groups exploited different types of resources. Earlier Bronze Age populations probably relied on fishing and hunting (Svyatko et al., 2015). Millet, which was likely consumed on a high-scale in the Early Iron Age, increased the isotopic niche size, but fish was possibly not as widely eaten during this time as suggested by the distribution of the isotopic niche. However, in the Iron Age, human $\delta^{15}N$ values increase, while the isotopic niche size does not increase. This pattern might indicate an increase in the consumption of food sources with high $\delta^{15}N$ values.

7.5.5. Syr Darya oases

Statistical means of the community that inhabited Syr Darya River (n=57) equal -15.4‰ for $\delta^{13}C$ and 12.4‰ for $\delta^{15}N$. Final Bronze Age – Early Iron

Age (n=23) group has more enriched $\delta^{13}C$ values in comparison to the later periods, which might indicate that the contribution of millet to the diet was higher in that period. Isotopic niche modeling (fig. 76, 77) demonstrated that the niches of the Syr Darya oases human communities were extensive at all studied periods (Ananyevskaya et al., in press), which points to the exploitation of a wide range of resources.

7.5.6. South-eastern Kazakhstan

Southeast Kazakhstan steppe and mountain-steppe (n=156) community has a mean of -15.7‰ for $\delta^{13}C$ and 12.7‰ for $\delta^{15}N$. Statistical comparisons indicated that the Bronze Age (n=36) group is significantly different from the other groups, which coincides with the more depleted $\delta^{13}C$ values in relation to the later periods (Appendix 5). Isotopic niche modeling (fig. 76, 77) demonstrates the dietary diversity in all periods, including the Bronze Age. Overall, south-eastern and southern Kazakhstan populations, including group E (Syr Darya oases), have the most extensive isotopic niches, which points to the consumption of a large variety of resources, such as both C_3 and C_4 type crops and animal proteins (Ananyevskaya, 2019a; Ananyevskaya, 2019b; Ananyevskaya et al., in press).

7.6. FRUITS mixing modelling

Details and the outcome of the FRUITS mixing modeling are presented in the Appendix 7. The modeling was conducted on selected data from each region and chronological period. The mixing model of mean consumers from a Middle Bronze Age site Bestamak located in Northern Kazakhstan indicates a stronger focus on freshwater fish exploitation in comparison to the other resources (fig. 78). The potential consumption of C_3 crops was also identified. The results of FRUITS modeling for Bestamak are influenced by the high $\delta^{15}N$ values of the human bone collagen. It has already been previously suggested that Bestamak populations were partly dependent on freshwater resources (Ventresca Miller et al., 2014), however, no other archaeological evidence for the fish consumption at Bestamak has been discovered.

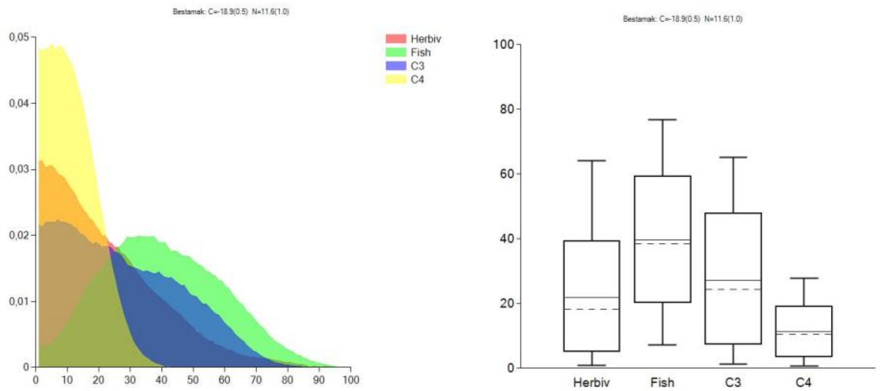


Figure 78: Model estimates for the isotope mean of Bestamak populations (probability distributions on the left and credible intervals on the right). Boxes represent a 68% CI, the whiskers represent a 95% CI, the horizontal continuous line represents the estimated mean and the dashed line indicates the median.

Data from a Late Bronze Age site Lisakovsk located in north Turgai plateau also points to fish consumption (fig 79). However, a lipid residue analysis carried out on the ceramic material from Lisakovsk showed the absence of fish lipids (Outram et al., 2012). Instead, it indicated that the Lisakovsk pots were used for the preparation of storage of horse meat and ruminant (cattle, sheep, goats) meat and dairy products. Moreover, Lisakovsk settlement material had mostly ruminant meat and dairy products, while cemetery material occasionally included horse products.

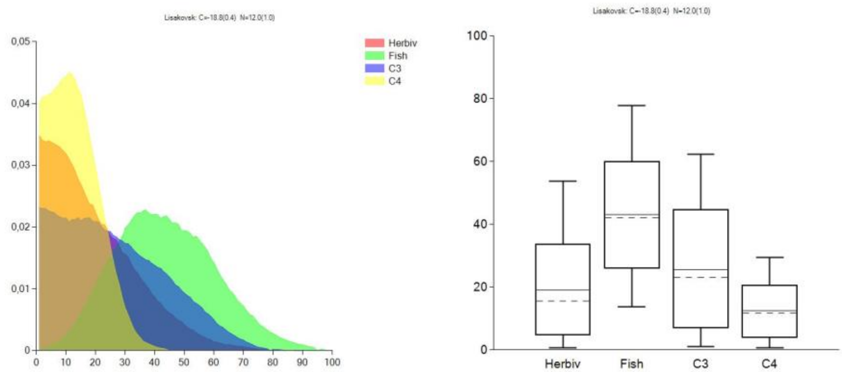


Figure 79: Model estimates for the isotope mean of Lisakovsk populations (probability distributions on the left and credible intervals on the right). Boxes represent a 68% CI, the whiskers represent a 95% CI, the horizontal continuous line represents the estimated mean and the dashed line indicates the median.

FRUITS estimates from the Iron Age sites located in the southern Urals (Kurtuguz, fig. 80) and northern Kazakhstan (Shagalaly, fig. 81) regions also points to the exploitation of freshwater resources, while the contribution of all other types of resources: C_3 and C_4 crops and herbivore proteins remain quite low.

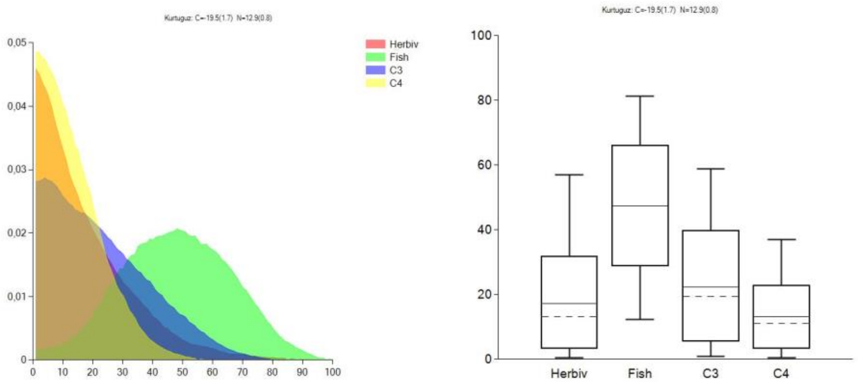


Figure 80: Model estimates for the isotope mean of Kurtuguz populations (probability distributions on the left and credible intervals on the right). Boxes represent a 68% CI, the whiskers represent a 95% CI, the horizontal continuous line represents the estimated mean and the dashed line indicates the median.

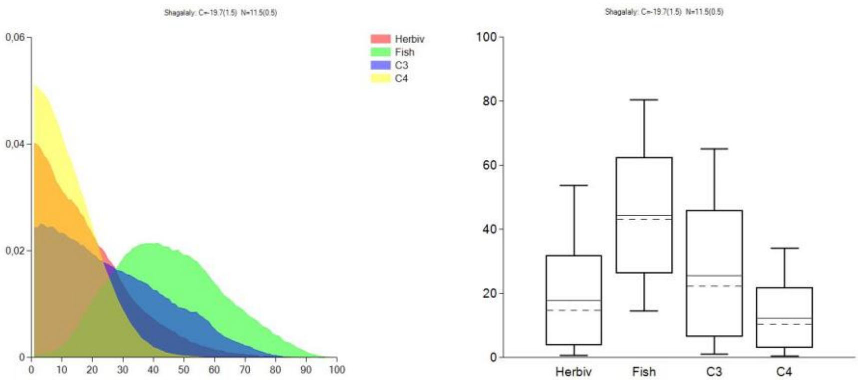


Figure 81: Model estimates for the isotope mean of Shagalaly populations (probability distributions on the left and credible intervals on the right). Boxes represent a 68% CI, the whiskers represent a 95% CI, the horizontal continuous line represents the estimated mean and the dashed line indicates the median.

Analysis of data from an Early Bronze Age site located in the eastern Kazakhstan also indicates consumption of freshwater fish (fig. 82), which coincides with the zooarchaeological evidence (Svyatko et al., 2015). The fish bones discovered in Shauke are used as a baseline for the FRUITS modelling of ancient Kazakhstan consumers. The potential contribution of herbivore meat/milk was also estimated as high (0.26/1 probability).

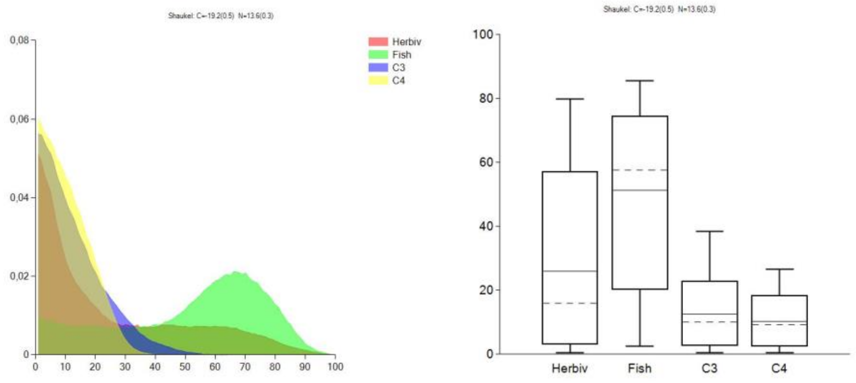


Figure 82: Model estimates for the isotope mean of Shauke populations (probability distributions on the left and credible intervals on the right). Boxes represent a 68% CI, the whiskers represent a 95% CI, the horizontal continuous line represents the estimated mean and the dashed line indicates the median.

FRUITS results for Ai-Dai (fig. 83) and Aymyrlyg (fig. 84) Iron Age sites located in the Minusinsk basin and Tuva republic suggest consumption of C_4 crops. Data from Aymyrlyg also points to the importance of freshwater resources. Moreover, the relative contribution of fish to the diet of Aymyrlyg inhabitants seems to exceed the contribution of C_4 crops.

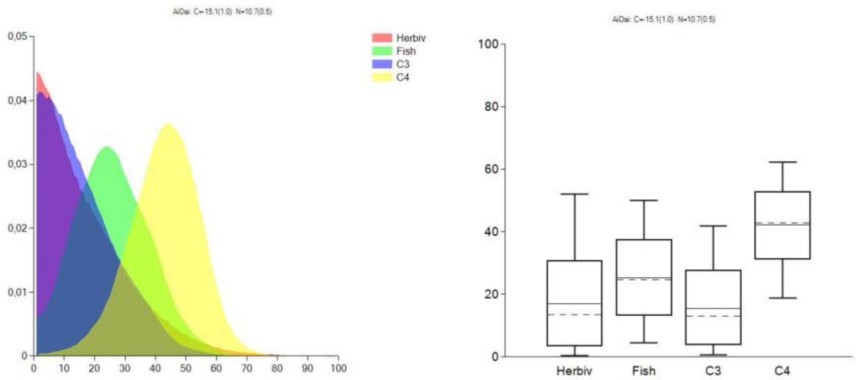


Figure 83: Model estimates for the isotope mean of Ai-Dai populations (probability distributions on the left and credible intervals on the right). Boxes represent a 68% CI, the whiskers represent a 95% CI, the horizontal continuous line represents the estimated mean and the dashed line indicates the median.

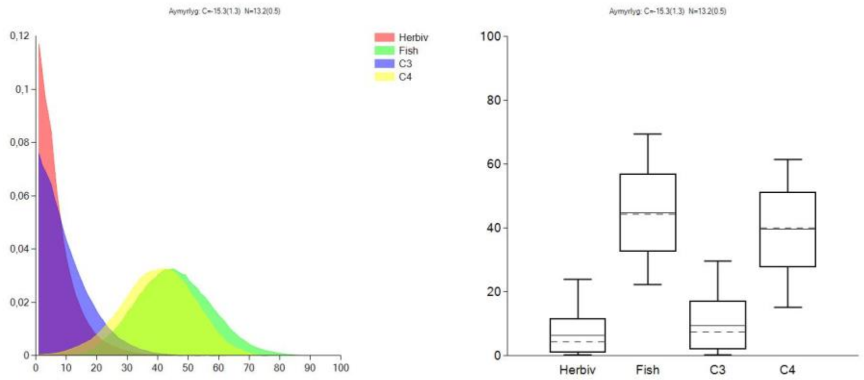


Figure 84: Model estimates for the isotope mean of Aymyrlyg populations (probability distributions on the left and credible intervals on the right). Boxes represent a 68% CI, the whiskers represent a 95% CI, the horizontal continuous line represents the estimated mean and the dashed line indicates the median.

Data from central Kazakhstan Bronze (Kairan, fig. 85) and Iron Age (Akbeit, fig. 86) sites indicates a strong reliance on herbivore products. The potential contribution of freshwater fish to the diet of the Bronze Age Kairan inhabitants was estimated as 0.22/1, however, the contribution of C_3 and C_4 crops is quite low (0.12-0.17/1).

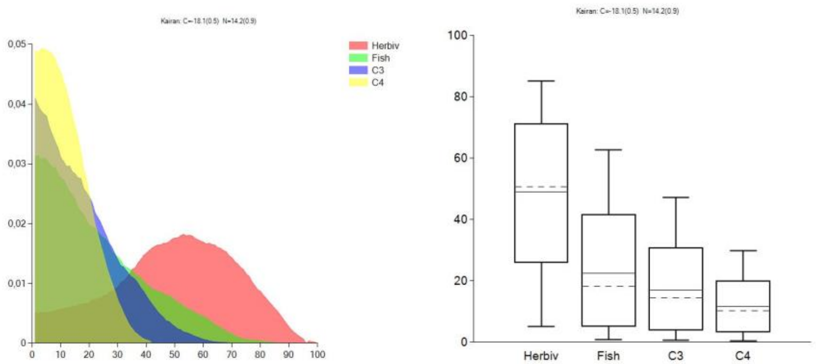


Figure 85: Model estimates for the isotope mean of Kairan populations (probability distributions on the left and credible intervals on the right). Boxes represent a 68% CI, the whiskers represent a 95% CI, the horizontal continuous line represents the estimated mean and the dashed line indicates the median.

It is interesting that at the central Kazakhstan Early Iron Age site Akbeit (fig. 86) FRUITS model estimated the 0.64/1 contribution of herbivore products to the diet of local inhabitants and only 0.14/1 contribution of C_4 plants, despite the strong isotopic evidence for the C_4 consumption coming from this site. It appears that the majority of the population was relying on herbivore products, while only certain individuals consumed millet.

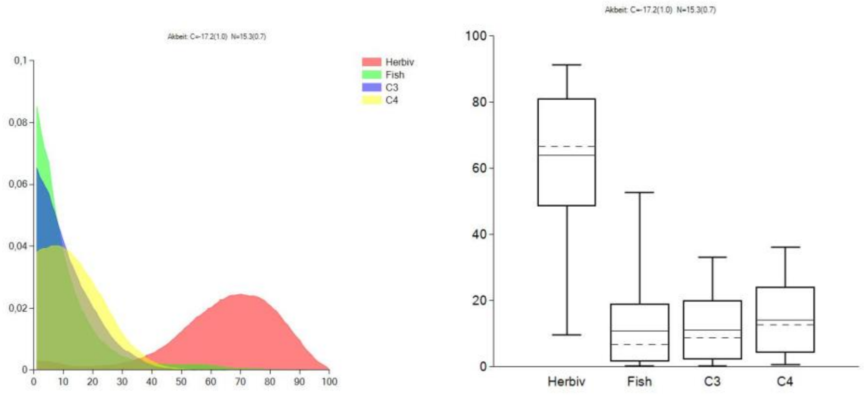


Figure 86: Model estimates for the isotope mean of Akbeit populations (probability distributions on the left and credible intervals on the right). Boxes represent a 68% CI, the whiskers represent a 95% CI, the horizontal continuous line represents the estimated mean and the dashed line indicates the median.

FRUITS models for the Late Bronze Age Oi-Dzhailau site located in southeast Kazakhstan also indicated the high contribution of the herbivore products to the diets of the local inhabitants (fig. 87). The contribution of C_4 crops was estimated as 0.21/1.

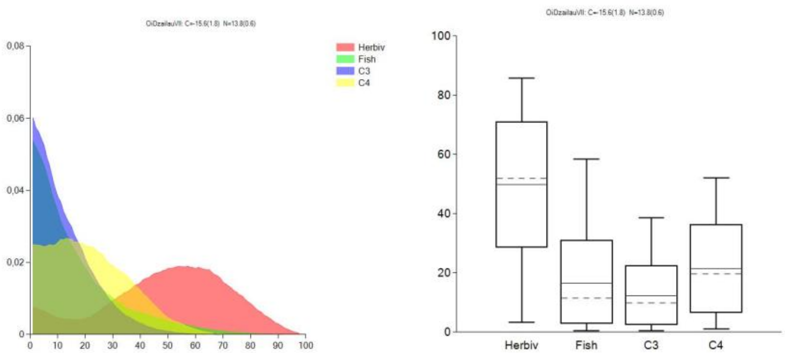


Figure 87: Model estimates for the isotope mean of Oi-Dzailau populations (probability distributions on the left and credible intervals on the right). Boxes represent a 68% CI, the whiskers represent a 95% CI, the horizontal continuous line represents the estimated mean and the dashed line indicates the median.

FRUITS analysis of the Iron Age Shatyrkul populations (fig. 88) demonstrated a high reliance on the herbivore products (0.4/1), however, the contribution of C_4 crops also becomes more prominent (0.33/1). The reliance on broomcorn millet in south-east Kazakhstan has been widely debated and strengthened by both macro-botanical and isotopic evidence (Doumani et al., 2015; Frachetti et al., 2010; Motuzaite Matuzeviciute et al., 2015a; Spengler et al., 2014b). Recent evidence, however, has shown that at the time of its introduction into the region, broomcorn millet was used as animal fodder (Hermes et al., 2019). Therefore, it is possible that people were obtaining high $\delta^{13}C$ values indirectly through consumption of herbivore products and the trophic enrichment between dietary source and the body tissues. Exploitation of highland pastures by the animal herds could also contribute to the high $\delta^{13}C$ values (see section 7.3.).

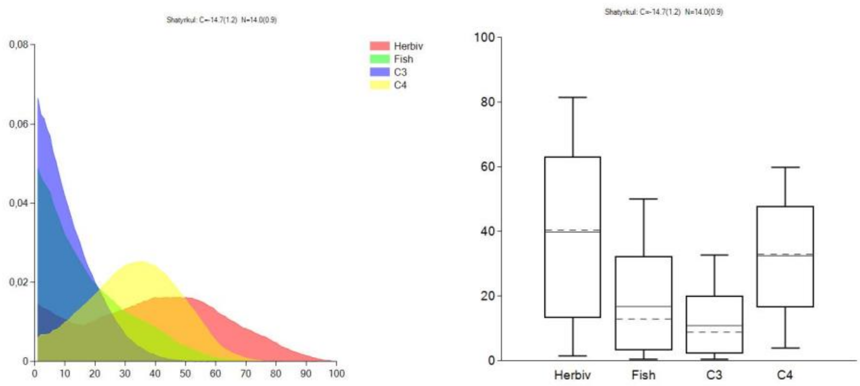


Figure 88: Model estimates for the isotope mean of Shatyrkul populations (probability distributions on the left and credible intervals on the right). Boxes represent a 68% CI, the whiskers represent a 95% CI, the horizontal continuous line represents the estimated mean and the dashed line indicates the median.

Evaluation of the values from Syr Darya region Chirik Rabat site suggests consumption of herbivore products (fig. 89) despite the presence of C_4 indicators in the raw human isotopic data (Appendix 3, table 2). Local herbivore values that were used as a baseline for the mixing model also have elevated $\delta^{13}C$ values. This suggests that they consumed C_4 plants. It is unclear whether the Syr Darya animals were foddered with millet or could obtain high $\delta^{13}C$ values from the local wild C_4 flora growing in the Kyzylkum desert, Ustyurt plateau and near Aral landscapes (Toderich et al., 2007; Global Biodiversity Information Facility).

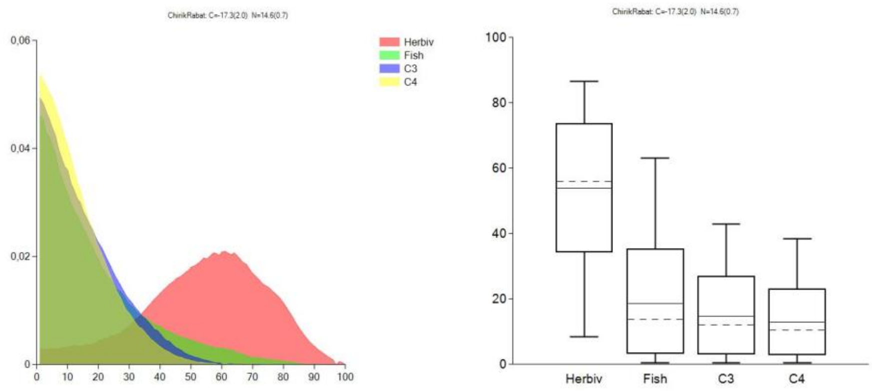


Figure 89: Model estimates for the isotope mean of Chirik Rabat populations (probability distributions on the left and credible intervals on the right). Boxes represent a 68% CI, the whiskers represent a 95% CI, the horizontal continuous line represents the estimated mean and the dashed line indicates the median.

FRUITS estimates from the western Kazakhstan Iron Age site Taksai point to the higher contribution of fish to the diet (fig. 90) with lower and equal potential contribution of all other food sources. This evidence matches the isotopic niche modelling data, which pointed to a wide variety of resources exploited by the west Kazakhstan populations. It is likely that the local community had access to many foodsources including freshwater fish.

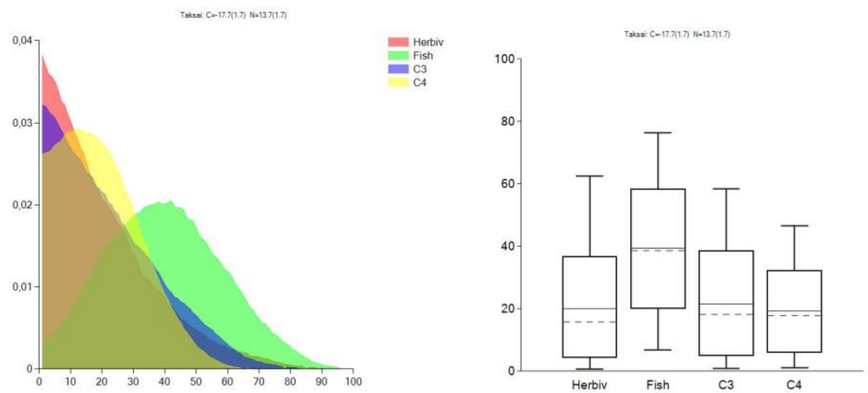


Figure 90: Model estimates for the isotope mean of Taksai populations (probability distributions on the left and credible intervals on the right). Boxes represent a 68% CI, the whiskers represent a 95% CI, the horizontal continuous line represents the estimated mean and the dashed line indicates the median.

7.7. Results of the compound-specific nitrogen analysis of amino acids

The trophic positions of animals were estimated by the terrestrial equation (TP_{ter}). Results from the analysis of horse, sheep, and goat, samples showed that their TP_{ter} equals 2.0, which indicated that these animals were terrestrial herbivores (Appendix 8, table 1). Wild boar TP_{ter} value was 2.1, despite the omnivorous form of subsistence, which means that the wild boar had an herbivore diet. The domestic dog from the Iron Age site of Syghanak had TP_{ter}, 2.8, which is slightly higher than the TPter of the analyzed dog/wolf, 2.7.

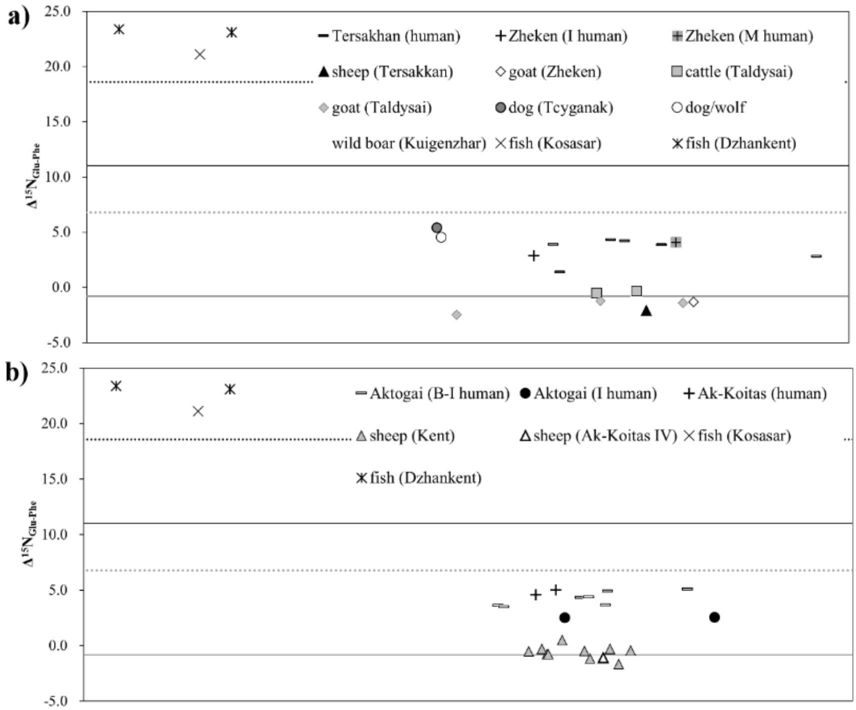
Three analyzed fish samples from Medieval sites had the following $\delta^{15}N$ amino acid values: $\delta^{15}N_{Glu} = 27.4 \pm 1.4$, $\delta^{15}N_{Phe} = 4.9 \pm 1.1‰$ and the mean trophic positions of these fish were 3.5, based on the aquatic equation (TP_{aqua}). Due to the significant difference of the isotopic values of $\delta^{15}N_{Glu}$ and $\delta^{15}N_{Phe}$ in fish and terrestrial mammals ($\delta^{15}N_{Glu}$ 11.0 ± 2.1, $\delta^{15}N_{Phe}$ 12.1 ± 2.0‰), it would be possible to distinguish the humans that consumed fish and the humans that relied on terrestrial food resources for subsistence.

In southern Turgai, one human sample from Tersakhan showed a low TPter of 2.3, while the other Iron Age humans from Tersakhan had TP_{ter} of 2.6 ± 0.1 (fig. 91-a; Apendix 8, table 2). Furthermore, the $\delta^{15}N_{Phe}$ values for these humans ranged from 11.8‰ to 14.3‰, except for one individual (EA-SI-24; $\delta^{15}N_{Phe}$ = 17.4‰), which comes from an earlier period. This range was similar to the $\delta^{15}N_{Phe}$ value for mammals from Tersakkan and a Bronze Age site Taldysai located 165 km from Tersakkan. One individual (EA-SI-24) might have exploited food resources from a different environment, because this sample demonstrated a $\delta^{15}N_{Phe}$ value, which was higher than the $\delta^{15}N_{Phe}$ value of other humans and herbivores from this geographic cluster. A medieval human from Zheken (EA-SI-64) had a TPter of 2.6, which is similar to the individual from the Iron Age Zheken (EA-SI-61). A medieval sheep/goat from Zheken had a $\delta^{15}N_{Phe}$ value of 14.9‰, which is similar to the medieval human $\delta^{15}N_{Phe}$ value of 14.6‰, but quite different from the Iron Age human $\delta^{15}N_{Phe}$ value of 11.8‰.

In the east-central cluster, the Bronze-Iron Age humans of Aktogai demonstrated TP_{ter} values of 2.7 ±0.1, while the Iron Age humans of Aktogai showed TP_{ter} = 2.4 ±0.0 (fig. 91-b). The Bronze Age humans of Ak-Koitas IV/V showed TP_{ter}, 2.7 ±0.0. Since no animal samples from Aktogai were available for the analysis, Aktogai human data were compared to Ak-Koitas

IV/V and Kent sheep/goat values. The $\delta^{15}N_{Phe}$ values for sheep from Ak-Koitas IV/V (12.6 ± 0.7‰) and Kent (13.1‰) were similar to the $\delta^{15}N_{Phe}$ values of humans from Ak-Koitas IV/V and almost all individuals from Aktogai (12.8 ± 1.3‰). Two Aktogai humans, EA-SI-52 ($\delta^{15}N_{Phe}$ = 14.8) of the Bronze Age and EA-SI-55 ($\delta^{15}N_{Phe}$ = 15.3) of the Iron Age, probably belonged to a different terrestrial food chain.

In the south-eastern cluster, the Early Iron Age humans of Turgen-2 showed TP_{ter} value of 2.7 ± 0.1, while the TP_{ter} values of Shatyrkul' individuals were 2.8 ± 0.1 (fig. 91-c). Although the Iron Age humans of Turgen-2 had $\delta^{15}N_{Phe}$ of 12.0 ± 1.0‰, which is similar to sheep/goats and horses from the Bronze Age contexts of Turgen-2, the cattle demonstrated $\delta^{15}N_{Phe}$ of 8.9 ± 1.5‰, which is different from the humans. Since no animal bones from Shatyrkul' were available for the analysis, humans from Shatyrkul' were compared to animals from the Bronze Age Serektas site which is located ~150 km from Shatyrkul'. The human $\delta^{15}N_{Phe}$ value of 13.7 ± 1.1‰ is similar to the $\delta^{15}N_{Phe}$ value of animals (13.1 ± 1.9‰).



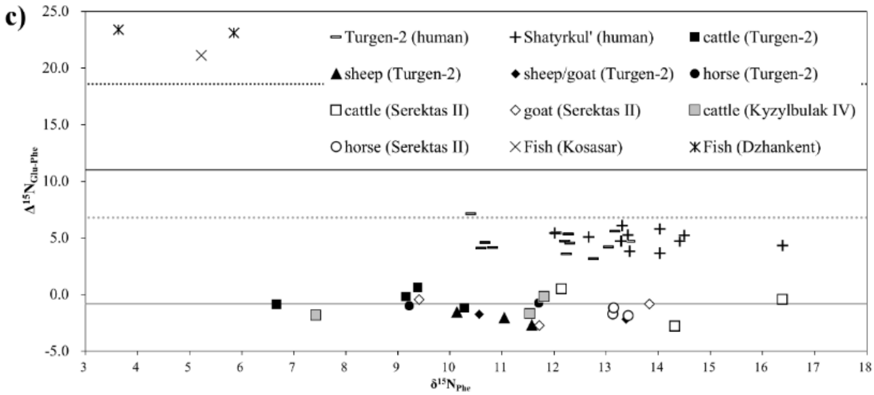


Figure 91: The $\delta^{15}N_{Phe}$ and $\Delta^{15}N_{Glu\text{-}Phe}$ of a) humans and animals from Tersakhan and Zheken in west-central cluster (Turgai) and Taldysai and Kuigenzhar in northern Kazakhstan, b) humans from Aktogai, Ak-Koitas IV/V and sheep Kent and Ak-Koitas IV in east-central cluster, c) humans from Turgen-2 and Shatyrkul' and animals from Turgen-2, Serektas and Kyzylbulak in south-eastern cluster plotted. As fish, we used samples from Kosasar and Dzhankent from near Aral Sea sites. B-I, I and M indicate Bronze-Iron Age, Iron Age and Medieval Age. Solid lines represent expected $\Delta^{15}N_{Glu\text{-}Phe}$ for either TP_{ter} = 2 (gray) or TP_{aqua} = 2 (black), and the dashed lines represent the expected $\Delta^{15}N_{Glu\text{-}Phe}$ for either TP_{ter} = 3 (gray) or TP_{aqua} = 3 (black).

8. Discussion

The results generated from the extensive fieldwork and laboratory analyzes contributed to the knowledge on the economy of the prehistoric populations inhabiting the modern territory of Kazakhstan. Thorough review of the previously published sources as well as newly generated data shed new light on the socio-economic circumstances in Turgai and the neighbouring region during the Bronze and Iron Ages. The discussion of the major contributions of the thesis is presented in this chapter.

8.1. Past economy in Kazakhstan in the light of the new stable isotope data

The isotopic evidence presented here argues against the "nomadic pastoralism" theory (see Chapter 4) and points to the increasing diversification of economic practices across different landscapes of Kazakhstan in the Final Bronze Age. It has been previously argued that the Late – Final Bronze Age was the time of increasing complexity, exchange, and dietary diversification in the Central Asian steppes and Mongolia (Taylor et al., 2020; Ventresca Miller and Makarewicz, 2019; Wilkin et al., 2020). Stable isotopic data presented here support this view and indicates that from the end of the Bronze Age, the variation of the dietary patterns became greater than was observed in the previous periods (Ananyevskaya et al., in press). The isotopic niches generally increase in all studied regions at the Final Bronze Age – Early Iron Age (see section 7.4). These findings point to the consumption of a wider variety of resources from a broader territory, which suggests an expansion of exchange networks happening at the time of the geoglyphs' construction.

The new stable isotope data presented here covers chronological periods from Bronze to Middle Ages across Kazakhstan, including previously unstudied regions such as western Kazakhstan and the Syr Darya. The new isotopic evidence is in line with the previously published data from northern Kazakhstan, including Turgai, and Trans-Urals, which indicated that millet did not contribute to the subsistence of local inhabitants (Ventresca Miller et al., 2014; Ventresca Miller and Makarewicz, 2019). However, the great increase of the isotopic niche area size in the Late Bronze Age - Iron Age likely points to the intensification in the consumption of C_3 resources, such as wheat and barley.

New data also demonstrates the beginning of C_4 crop consumption in central Kazakhstan as early as Middle-Late Bronze Age. However, at the moment, such evidence is limited to the elite burial site Karazhartas, which includes the unique mausoleum of the Begazy-Dandybayevo culture. Therefore, this data might suggest, that broomcorn millet was available only to the higher status individuals in the early stages of its cultivation in the region. This hypothesis, however, has to be tested further. Evidence from Medieval central Kazakhstan suggests that the contribution of millet to the human diet might have decreased, which might be related to the shift towards C_3 type agriculture.

8.1.1. Influence of animal herding practices on stable isotope values in humans

This research has addressed an important problem of the differences of the faunal isotopic values across Kazakhstan and how this diversity might affect the human isotopic data (Ananyevskaya et al., in press-a). In the published studies, it has been a regular practice to combine the isotopic values from bone collagen of cattle, sheep/goats, and horses into such groups as "herbivores" or "domestic herbivores" (e.g. Lightfoot et al., 2015; Ventresca Miller and Makarewicz, 2019). However, bone collagen of those animals demonstrates varying isotopic values, which could be caused by differences in metabolic processes (Sponheimer et al., 2003; Van Klinken et al., 2002) or exploitation of different pasturing strategies as noted by Ventresca Miller et al. (2018). The reliance on different animals for subsistence might be responsible for the variation of human isotopic values. Furthermore, certain herding practices, such as "vertical transhumance" imply that the animals spend around 3-4 months annually at the highland pastures, where they consume the local plants, which tend to have higher $\delta^{13}C$ values in relation to the elevation (Körner et al., 1988). Contribution of meat and milk of the animals with high $\delta^{13}C$ values to the human diet further alters the isotopic composition of human tissues and can result in higher $\delta^{13}C$ values of human bone collagen.

Animal herding practices also varied across different mixed-steppe ecozones. Zooarchaeological evidence points to the prevalence of horses and cattle in the faunal assemblages of Trans-Urals and north Kazakhstan, including Turgai region, while the collections of animal remains in southeast Kazakhstan are dominated by sheep and goat remains (see Chapter 5). Zooarchaeological data do not always reflect the scale of daily milk and meat consumption, since the animals could be exploited also for different purposes, such as transportation, wool and bone material for crafting, or agricultural labor. Nevertheless, the proportions of remains of different domestic animals in the food-waste assemblages might provide an idea of the herd compositions and indicate which animal products were more regularly consumed by the local population.

Human isotopic data from northern Kazakhstan, Turgai, and Trans-Urals demonstrate lower $\delta^{13}C$ values in comparison to central and south-east Kazakhstan data, which might be related to the higher consumption of horse and cattle products as evident through the zooarchaeological data from the region. Dietary intake of horse and cattle products might lower the $\delta^{13}C$ values in human bone collagen by ~0.5-1.0‰ (Chapter 7, fig. 70) in comparison to the isotopic values of human groups reliant on sheep/goat products, which in the case of Central Asia might conceal small-scale consumption of C_4 crops. The preference of horses and cattle over sheep and goats might be related to the higher general precipitation in the region. Cattle demand more water and good pastures and suffer from dehydration more than caprines (Kay, 1997; Nardone et al., 2006), which suggests that herds dominated by cattle cannot be easily maintained in the arid regions of Central Asia.

Isotopic data and FRUITS modeling from central Kazakhstan suggested that the animal proteins were the major components of the human diet from the Bronze to the Middle Ages. The open-steppe landscape of central Kazakhstan provides good pastoral lands, which are easy to cross for the animals and the humans, while the climate might be quite arid for the large-scale agriculture. Zooarchaeological data from central Kazakhstan pointed to the exploitation of sheep/goats mainly for meat, and cattle, and horses mainly for secondary products and transportation (Haruda, 2018; Outram et al., 2012). Significant contributions of sheep/goat meat to the diet of central Kazakhstan community implies that the human bone collagen of the local humans would generally be high in $\delta^{13}C$, which indicates the C_4 presence in the subsistence of central Kazakhstan populations more strongly than in the north Kazakhstan and Trans-Uralian communities.

The landscape of Altai and southeast Kazakhstan allows for the exploitation of highland pastures. Pastoralists that practice “vertical transhumance” take their animals to the rich mountain pastures from spring to autumn. High $\delta^{13}C$ values of highland vegetation (Körner et al., 1988) cause an increase of $\delta^{13}C$ values of herbivore tissues, which in turn affects the humans eating animal meat and milk. Furthermore, zooarchaeological data from southeast Kazakhstan indicate that the local communities kept large numbers of caprines for meat production, while cattle and horses were kept for the exploitation of secondary products (Haruda, 2018). Local humans were receiving more caprine proteins, which resulted in higher $\delta^{13}C$ of human bone collagen. A combination of such factors as the exploitation of sheep/goat meat and vertical transhumance practice might greatly affect the stable isotopic values of the local population. Therefore, high $\delta^{13}C$ values of southeast populations could be partly caused by the consumption of local animal proteins, while the dietary intake of millet might be overestimated.

Finally, the data presented in this research covers chronological periods from Bronze to Middle Ages across Kazakhstan, which allowed for a detailed comparison of human isotopic data from different regions against herbivore values. This research argued that the reliance on different animals for subsistence could affect the isotopic values of humans in different ecozones of North Central Asia. Animal data have shown lower $\delta^{13}C$ values in horses in comparison to cattle and sheep/goats while caprines display the highest $\delta^{13}C$ values in almost all analyzed regions. Zooarchaeological data suggest that north Kazakhstan, Turgai, and Trans-Ural populations were more dependent on cattle and horse products, while central and southeast Kazakhstan groups relied on caprines for meat production that is likely reflected in the isotopic expression of the analyzed humans making the $\delta^{13}C$ values in north Kazakhstan, Turgai and Trans-Urals more negative and in central and southeast Kazakhstan more positive. Certain herding strategies such as "vertical transhumance" practiced in mountain regions of Altai and southeast Kazakhstan could also be responsible for the increase of $\delta^{13}C$ values in animal tissues due to altitude effect rather than C_4 plant contribution to the diet. Therefore, the variation of $\delta^{13}C$ values amongst human groups in various regions of North Central Asia could be affected not only by the direct dietary intake of C_4 plants but also by the varying scale of cattle, horse, and caprine products consumption in different regions of Central Asia as well as whether the high altitude transhumance was practiced in the region.

8.1.2. High $\delta^{15}N$ values of humans in Kazakhstan do not reflect consumption of fish or C_4 plants

The compound-specific amino-acid study of nitrogen demonstrated that in the case of Kazakhstan human isotopic data, the high $\delta^{15}N$ values were not caused by the consumption of freshwater resources or broomcorn millet (Itahashi et al., 2020). It has been considered that $\delta^{15}N_{col}$ increase by 1.5–5‰

with each step in the food chain (McCutchan Jr et al., 2003; Minagawa and Wada, 1984). A $\delta^{15}N_{col}$ increase between humans and herbivores of more than one step in the food chain, therefore, tends to be interpreted as a possible contribution of aquatic resources, such as fish, to the human diets. In order to investigate the contribution of fish to human subsistence, the observed $\delta^{15}N_{Phe}$ of the terrestrial animals were measured to understand the range of the terrestrial food web. Thus, humans that displayed the values below this range could be interpreted as consumers of aquatic resources. However, the results demonstrated that the $\delta^{15}N_{Phe}$ values of the Bronze-Iron Age humans were distributed close to the $\delta^{15}N_{Phe}$ values of analyzed terrestrial animals, but very far from the fish values. Also, $\Delta^{15}N_{Glu\text{-}Phe}$ human values were constant regardless of $\delta^{15}N_{Phe}$, which implies that an increase in $\Delta^{15}N_{Glu\text{-}Phe}$ did not correlate with a decrease in $\delta^{15}N_{Phe}$. Overall, the data suggested that there was no major contribution of aquatic resources to the diets of the Bronze and Iron Age communities in Kazakhstan.

As reported by Lightfoot et al. (2016) modern C_4 vegetation in controlled conditions might have higher bulk $\delta^{15}N$ values than non-leguminous C_3 plants, therefore, high $\delta^{15}N$ values of human bone collagen can also be linked with the consumption of C_4 plants. However, the results of the analysis showed no correlation between the contribution of C_4 plants as evident through the bulk isotope analysis and trophic position analyzed through the compound-specific nitrogen isotopic analysis of amino acids.

Iron Age and Medieval data from southern Turgai (Tersakhan and Zheken) showed lower trophic positions than in other regions, which might be explained by a shift towards the exploitation of plant resources. Based on the bulk collagen isotopic values from the two sites, it might be suggested that C_3 crops contributed more towards the subsistence of the inhabitants than C_4 plants. Overall, however, the trophic positions of humans in Kazakhstan are higher than the TP_{ter} values of Neolithic farmers in Europe and West Asia (Itahashi et al., 2019; Itahashi et al., 2018; Styring et al., 2015), which suggests that Bronze-Middle Age people in Kazakhstan consumed more animal products than the Neolithic farmers of Europe and West Asia. It is possible, that the consumption of a significant amount of dairy products increased the contribution of animal proteins and, therefore, affected the TP_{ter} values of Kazakhstan populations.

8.2. Socio-economic changes in the transitional period from the Bronze to Iron Ages

8.2.1. Increase in social stratification

Archaeological evidence undoubtedly points to the increase in complexity at the turn of the Bronze and Iron Age instead of the rise of the primitive "barbaric nomadism" as was suggested in the early 20th century literature. The rich material culture and architectural evidence reviewed in this work points to the appearance of artistic thinking through the increase in diversity and complexity of monuments and artifacts, such as metal objects, jewelry, etc. In the Final Bronze Age, we start to see the appearance of sophisticated and elaborate burial constructions in Central Asia in the form of Begazy-Dandybayevo culture of central Kazakhstan. The uniqueness and complexity of the Begazy mausoleums on the example of Karazhartas complex (see Chapter 4), point to the increase in social stratification. It is clear that these constructions required collection of materials, planning, and vast input of time and effort.

At the turn of the epoch, we see a great increase in rich burial complexes and kurgans. Tasmola culture spread from the Kazakh steppes to Altai and Trans-Urals left behind a large number of princely burials, such as Taldy, Karashoky, Akbeit, etc. Inside these burials, archaeologists discovered fine items made from a variety of materials from bone and stone to gold and precious gems. The obvious evidence for the complex Iron Age civilization of the steppe is currently available in the museum expositions across Kazakhstan and other countries. Burials chambers of the Iron Age period include very complex constructions such as dromos of central Kazakhstan Tasmola kurgans or wooden chambers of Arzhan kurgan. The diversity of the burial rituals practiced in the Iron Age suggests that communities of Central Asia expressed their social identity through the funerary ceremony and burial construction.

At the present time, there is no clear answer to what has influenced the cultural transformations. The related hypotheses reviewed in the previous chapters propose a range of explanations from climatic changes (see Chapter 3) to population increase and the arrival of a new community. However, the archaeological data collected in the past decades indicate that these transformations affected all aspects of culture and economy.

8.2.2. Introduction and spread of the agriculture

In the Late Bronze Age we start to see the spread of millet as a food source across Kazakhstan. Stable isotope evidence from south-east Kazakhstan points to the increase of C_4 crop consumption in the Late Bronze Age (Ananyevskaya et al., in press; Motuzaite Matuzeviciute, 2016; Motuzaite Matuzeviciute et al., 2015a). The data from the earlier periods, however, suggest that millet was used as animal fodder (Hermes et al., 2019). In the Late-Final Bronze Age, millet similarly spreads into central Kazakhstan (Ananyevskaya, 2018; 2019a; Ananyevskaya et al., in press; Ananyevskaya et al., 2018; Lightfoot et al., 2015). Isotopic evidence suggests that populations inhabiting Turgai region and north Kazakhstan did not consume millet. A small-scale consumption of a C_4 source, however, might be masked by certain herding practices and reliance on animals with low $\delta^{13}C$ values for subsistence (Ananyevskaya et al., in press).

Recent evidence from Mongolia based on stable isotope analysis of bone collagen and enamel bioapatite demonstrated that millet consumption was a major component of the economy starting from the Early Iron Age (~800 BC) (Wilkin et al., 2020). Diversified economy in the Iron Age Mongolia, which included exploitation of animals and agriculture, likely influenced the formation of complex state units.

Due to the major developments in the field of stable isotope analysis, exploitation of C_4 crops is now more visible in the archaeological contexts than the presence of C_3 crops in the diet. Evidence from C_3 crop consumption and cultivation in Central Asia is mainly based on macro-botanical finds and pottery impressions. Early macrobotanical remains of cultivated crops of C_3 type, such as wheat or barley, have been discovered at the archaeological sites of south-eastern Kazakhstan, such as at the Bronze Age sites of Begash and Tasbas (Doumani et al., 2015; Frachetti et al., 2010; Spengler et al., 2014b), where they potentially arrived from the western towns, such ar Anau and Sarazm (Miller, 1999; Spengler and Willcox, 2013) or Altai, where wheat grains dated to ca. 3200 BC have recently been discovered (Zhou et al., 2020).

Archaeological evidence suggests that by the Late Bronze Age, wheat and barley spread across Central Asia. Finds of wheat grains have been reported at the Late Bronze Age settlement Cherkassy located in the Southern Urals region of Russia (Lebedeva, 2005) and the Early Iron Age cemetery Novyi Kumak II situated in Trans-Urals (Akbulatov, 1999). Macrobotanical remains of wheat and barley were discovered at south-east Kazakhstan Iron Age sites of Mukri, Taldy Bulak-2, Tuzusai, Tseganka-8 (Spengler et al., 2013; Spengler et al., 2017). Finds of barley grains were recently discovered at an Early Iron Age settlement Abylai in central Kazakhstan (Beisenov et al., 2019). Wheat grains from the north Kazakhstan archaeological complex Alekseevskoye dated to the Iron Age period (Shishlina et al., 2018) point to the exploitation of C_3 agriculture in Turgai. As suggested by the isotopic niche modeling analysis carried out by Ventresca Miller and Makarewicz (2019), the expansion of the niche size in the Late Bronze Age in north Kazakhstan might be related to the intensification of the C_3 cereal exploitation. It is possible that inhabitants of north Kazakhstan gave preference to the cultivation of wheat and barley instead of millet.

8.2.3. The appearance of specialized economies

Zooarchaeological evidence from Kazakhstan also points to the appearance of specialized economies in the Final Bronze Age – Early Iron Age. Analysis of faunal assemblages and lipid residues in ceramics from the Late - Final Bronze Age sites in Kazakhstan points to the ritual use of horses and the importance of horse meat for ceremonial purposes (Outram et al., 2011). Moreover, complete horse skeletons as well as elements of the bridle in the Iron Age burials (Berel, Pazyryk) indicate the increasing importance of horse riding. Evidence for the mobility and expansion of trade networks in the Late Bronze Age and Iron Age (Ventresca Miller and Makarewicz, 2019) points to the development of specialized economies of horse breeding for riding and transportation (Taylor et al., 2020).

At the same time in the central Tian Shan, sheep wool production economy starts to develop. Zooarchaeological data as well as material culture from the Final Bronze Age farmstead Chap I points to the highly specialized wool economy with around 75% of domestic fauna identified as sheep/goats (Ananyevskaya et al., 2020). ZooMS evidence points to the higher presence of sheep opposed to goats, which likely related to the preference of sheep wool instead of goat hair. Mortality profiles demonstrate the presence of older sheep, which points to the exploitation of secondary products. Material culture in the form of stone sickles, likely used for sheep shearing, ceramic looms, bone tools that could be used for spinning wool, and wide range of ceramic shards with textile impressions all point to the importance of wool production at Chap I (Motuzaite Matuzeviciute et al., 2020b). Interestingly, the potential use of sheep for wool production can be noticed from the results of zooarchaeological analyses at other Central Asian sites such as Kent or Turgen (Haruda, 2018). The presence of older individuals (Ventresca Miller et al., 2020) points to the secondary products exploitation (Cribb, 1985; Payne, 1973). However, the assemblages are not as caprine focused and the accompanying material culture evidence seems to be absent or not reported, therefore it can be argued that the Kent and Turgen economies were not specialized for wool production. On the other hand, mortality profiles and material culture evidence from the Iron Age sites in south-east Kazakhstan (Taldy Bulak 2 and Tuzusai) point to the exploitation of sheep wool (Benecke, 2003; Chang, 2017). These data together with the reviewed previously published evidence indicate the appearance of specialized productive economies in the Final Bronze Age.

8.3. Geoglyphs of Turgai as a socio-economic phenomenon of the Early Iron Age

According to the only available direct dating of the Turgai geoglyphs, they were constructed around the 800-750 cal. BC (Motuzaite Matuzeviciute et al., 2015b), which coincides with the beginning of the Iron Age period. The vast amount of artefactual and ecofactual data available from the Final Bronze Age and subsequent Early Iron Age periods indicates that this transitional time brought the cultural progress and many innovations, which transformed the socio-economic reality of Central Asia. The appearance of unique funerary monuments, elaborate decorative objects, the spread of new foodstuffs, and the expansion of trade networks marked the beginning of the new era.

The evidence presented in this research together with the previously published data point to the increase in complexity, expansion of exchange networks, and dietary diversification. Some researchers further suggested that the increased importance of horse riding might have facilitated the social stratification and the rise of the elite through the appearance of horse-based wealth (Hämäläinen, 2003). Some people acquired control over larger territories through horse riding, which could further affect trade and warfare. Thus, the development of equestrianism in the Late Bronze Age could affect the appearance of the social inequality, which was also expressed in the construction of the mega-structures, like Begazy-Dandybayevo mausoleums, Tasmola kurgans, khirigsuurs of Mongolia or Turgai geoglyphs. Construction and maintenance of the large monuments also involved community-based interaction activities with strictly defined social roles

(Honeychurch et al., 2009). The appearance of the unique geometric earthworks of Turgai, therefore, presents the evidence for the socio-economic transformations happening at the transitional period from Bronze to Iron Ages. Economic investments into the construction of the geometric earthworks were justified by the rise of social inequality and increasing non-egalitarianism in the Early Iron Age communities.

9. Conclusions

In the light of the extensively collated literature on the economy, archaeology, and environment, and together with scientific analyses conducted in this study the following conclusions can be drawn:

1. A review of the previously published palaeoclimatic evidence suggests that climatic oscillations happened in the end of the Bronze Age – beginning of the Iron Age.
2. A review of the economic evidence from Kazakhstan and Central Asia pointed to the diversification of dietary patterns, spread of agriculture, and increasing focus on exploitation of horses in the Late – Final Bronze Age.
3. Stable isotope analysis conducted on 370 human and animal bones from archaeological sites located in different regions of Kazakhstan and dated between Bronze – Middle Ages indicated that the C_4 plants (probably millet) was first adapted in south-eastern Kazakhstan during the early-middle Bronze Age and by the Late Bronze Age – Early Iron Ages it got spread across most regions of Kazakhstan. Isotopic data from central Kazakhstan presented in this research shows that the consumption of C_4 source begins around the time of Turgai geoglyphs' construction. The C_4 signal is missing only in northern Kazakhstan in all studied periods. However, as suggested in this research, the small scale consumption of C_4 crops might be masked by the reliance on cattle and horse products. Isotopic data from south-east Kazakhstan demonstrated the high reliance on C_4 food source, although, this can also be explained by the animal herding strategies practiced by the communities of the piedmont regions (Ananyevskaya, 2018; 2019a; Ananyevskaya, 2019b; Ananyevskaya et al., in press; Ananyevskaya et al., 2018).
4. Compound-specific nitrogen analysis of amino acids conducted on human, animal, and fish samples from Bronze – Middle Age sites of Kazakhstan located in three geographic areas: south Turgai, central Kazakhstan, and south-east Kazakhstan demonstrated that fish was not a major component of human diet at any of the studied sites. Therefore, high nitrogen isotopic ratios in Kazakhstan cannot always be interpreted as evidence for fish consumption. Moreover, data from the southern Turgai pointed to the increasing exploitation of C_3 crops in the Iron and Middle Ages (Itahashi et al., 2020).
5. The data presented here also points to the appearance of specialized economies in the Final Bronze Age (Ananyevskaya et al., 2020).

Zooarchaeological investigations carried out in central Tian Shan and comparison with the previously published faunal data suggested that focused wool production economies appear at various Final Bronze Age sites across the vast landscape of Central Asia.

6. Overall, the conducted analyses and comparison with other lines of scientific evidence showing that in the transitional period from Bronze to Iron Ages, the Kazakh steppe population went through major transformations that affected all aspects of human life from culture to economy. The conclusions presented here are in line with the recently collected data from other regions of Central Asia. Recent research carried out in Mongolia suggested that the socio-economic transformations of the Late Bronze Age were related to the intensification in the horse riding. However, these transformations did not bring the "barbaric nomadism" and primitivism as was considered by the early 20th century researchers. On the contrary, the transformations marked the appearance of specialized economies, social complexity, and dietary diversification, which are reflected in the archaeological evidence from the studied period.

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Appendix 1: Zooarchaeology data from Ashutasty site

Context	specie	element	part	Number	side	fusion	Burning	Measurements	Fracture/ cutmarks/ gnawing/ add.info
Tr. 1, 0-85 cm	cattle	3rd plnx	incomplete	1	left				carnivore gnawing marks
Tr. 1, 0-85 cm	indeterminate	femur artic.	piece	1				8,5 cm	
Tr. 1, 0-85 cm	indeterminate	axial bone	piece	1				4 cm	
Tr. 1, 0-85 cm	indeterminate	axial bone	piece	1				3 cm	
Tr. 1, 0-85 cm	caprine	ulna	piece	1			700 C	3,5 cm	
Tr. 1, 0-85 cm	indeterminate	long bone	piece	1			700 C	2,5 cm	
Tr. 1, 0-85 cm	med-sized	long bone	piece	1			300-350 C	1,5 cm	
Tr. 1, 0-85 cm	caprine	carpus/tarsus	complete	1				2 cm	small carnivore gnawing marks
Tr. 1, 0-85 cm	large mammal	vertebra	articul.	1		UF		6 cm	
Tr. 1, 0-85 cm	cattle	tooth	small piece	1					
Tr. 1, 0-85 cm	indeterminate	indeterm	small piece	1			350 C	2 cm	
Tr. 1, 0-85 cm	horse	scapula	dist artic	1				5,5 cm	

Tr. 1, 0-85 cm	large mammal	long bone	piece	1				10 cm	
Tr. 1, 0-85 cm	large mammal	rib	piece	1				5 cm	
Tr. 1, 0-85 cm	horse	cuboid	complete	1					
Tr. 1, 0-85 cm	large mammal	long bone	piece	1				4,5 cm	
Tr. 1, 0-85 cm	large mammal	long bone	piece	1			300 C	9 cm	
Tr. 1, 0-85 cm	indeterminate	axial bone	piece	1				7 cm	
Tr. 1, 0-85 cm	cattle	tooth	piece	1					
Tr. 1, 0-85 cm	caprine	rib	piece	1				7 cm	
Tr. 1, 0-85 cm	caprine	pelvis	acetabulum piece	1				5 cm	
Tr. 1, 0-85 cm	large mammal	long bone	shaft piece	1			350-420 C	5 cm	
Tr. 1, 0-85 cm	indeterminate	long bone	piece	1				6,5 cm	
Tr. 1, 0-85 cm	indeterminate	axial bone	piece	1			300 C	6 cm	
Tr. 1, 0-85 cm	indeterminate	long bone	articul.	1			200 C	4 cm	
Tr. 1, 0-85 cm	indeterminate	long bone	articul.	1			300 C	4 cm	carnivore gnawing marks
Tr. 1, 0-85 cm	caprine	carpus/tarsus	complete	1			350 C		
Tr. 1, 0-85 cm	large mammal	axial bone	piece	1				3,5 cm	

Tr. 1, 0-85 cm	indeterminate	long bone	piece	1				3,5 cm	
Tr. 1, 0-85 cm	cattle	tooth	piece	1					
Tr. 1, 0-85 cm	indeterminate	long bone	piece	1				4 cm	
Tr. 1, 0-85 cm	indeterminate	spongy bone	articul.	1			350-420 C	2 cm	
Tr. 1, 0-85 cm	indeterminate	spongy bone	piece	1				4 cm	
Tr. 1, 0-85 cm	indeterminate	spongy bone	piece	9			350-420 C	1-3 cm	
Tr. 1, 0-85 cm	indeterminate	spongy bone	piece	1			350 C	2 cm	
Tr. 1, 0-85 cm	indeterminate	indeterm	piece	3			300 C	2-3 cm	
Tr. 1, 0-85 cm	indeterminate	indeterm	piece	1			700 C	3,5 cm	
Tr. 1, 0-85 cm	indeterminate	long bone	piece	1				2 cm	sunbleached, green staining
Tr. 1, 0-85 cm	indeterminate	spongy bone	piece	6				1-2 cm	
Tr. 1, 0-85 cm	indeterminate	spongy bone	piece	1				3 cm	
Tr. 1, 0-85 cm	indeterminate	long bone	piece	4			420-700 C	1-2 cm	
Tr. 1, 0-85 cm	indeterminate	spongy bone	piece	1			300 C	1,5 cm	
Tr. 1, 0-85 cm	cattle	scapula	dist artic	1					
Tr. 1, 0-85 cm	caprine	pelvis	acetabulum piece	1	left	F			

Tr. 1, 0-85 cm	indeterminate	skull piece	piece	1			350 C	4 cm	
Tr. 1, 0-85 cm	indeterminate	spongy bone	piece	1				7 cm	sunbleached
Tr. 1, 0-85 cm	caprine	tibia	complete	1		both UF			sunbleached, newborn likely
Tr. 1, 0-85 cm	indeterminate	long bone	piece	1				4,5 cm	
Tr. 1, 0-85 cm	large mammal	long bone	piece	1				4,5 cm	
Tr. 1, 0-85 cm	large mammal	long bone	piece	1				12 cm	
Tr. 1, 0-85 cm	caprine	ulna	olecranon	1				3,5 cm	
Tr. 1, 0-85 cm	indeterminate	spongy bone	piece	1			420 C	2,5 cm	
Tr. 1, 0-85 cm	large mammal	skull piece	piece	1				5,5 cm	
Tr. 1, 0-85 cm	cattle	scapula	dist artic	1				4,5 cm	
Tr. 1, 0-85 cm	caprine	tibia	complete	1		both UF			newborn likely
Tr. 1, 0-85 cm	large mammal	long bone	piece	1				7 cm	
Tr. 1, 0-85 cm	indeterminate	spongy bone	piece	1			300 C	1 cm	
Tr. 1, 0-85 cm	caprine	radius	complete	1		both UF			newborn likely
Tr. 1, 0-85 cm	indeterminate	indeterm	piece	9			350 C	1-3 cm	
Tr. 1, 0-85 cm	indeterminate	indeterm	piece	6			200-300 C	1-3 cm	

Tr. 1, 0-85 cm	indeterminate	indeterm	piece	2				1-4 cm	sunbleached
Tr. 1, 21-85 cm	large mammal	femur artic.	dist artic	1		F	300-350 C		chopped; polished
Tr. 1, 21-85 cm	indeterminate	long bone	piece	1			300-700 C	6 cm	
Tr. 1, 21-85 cm	indeterminate	indeterm	piece	2				1-2 cm	
Tr. 1, 21-85 cm	indeterminate	indeterm	piece	1			700 C	1,5 cm	
Tr. 1, 21-85 cm	cattle	metatarsal	prox piece, area 1	1			350-700 c	2,5x1,5 cm	chopped off at articul.
Tr. 1, 21-85 cm	caprine	tooth	small piece	1			350 C		
Tr. 1, 21-85 cm	indeterminate	long bone	shaft	1			200 C	1,5 cm	
Tr. 1, 21-85 cm	indeterminate	spongy bone	piece	1			200 C	2 cm	
Tr. 1, 21-85 cm	large mammal	long bone	piece	1				2 cm	marks from small carnivore
Tr. 1, 21-85 cm	large mammal	long bone	piece	1			300 C	2 cm	
Tr. 1, 21-85 cm	indeterminate	long bone	piece	1			350 C	2 cm	
Tr. 1, 21-85 cm	indeterminate	indeterm	piece	3			350-700 C		
Tr. 1, 21-85 cm	indeterminate	spongy bone	piece	1					
Tr. 1, 80-100 cm	indeterminate	articul piece	piece	1			350 C	2 cm	

Tr. 1, 85-100 cm	indeterminate	axial bone	piece	1			350 C	2 cm	
Tr. 1, pit 1	indeterminate	long bone	piece	1			200 C	3 cm	
Tr. 1, pit 1	indeterminate	indeterm	piece	1				3 cm	
Tr. 1, pit 1	med-sized	long bone	piece	1			350 C	3 cm	
Tr. 1, pit 1	large mammal	long bone	piece	1			420-700 C	4 cm	
Tr. 1, pit 1	large mammal	long bone	piece	1			300 C	2,5 cm	
Tr. 1, pit 1	indeterminate	long bone	piece	1			350 C	2 cm	
Tr. 1, pit 1	indeterminate	long bone	piece	1			300 C	2,5 cm	gnawing marks from small carnivore
Tr. 1, pit 1	indeterminate	indeterm	piece	1			300 C	2,5 cm	
Tr. 1, pit 1	indeterminate	indeterm	piece	1			200 C	2 cm	
Tr. 1, pit 1	med-sized	vertebra	piece	1			300 C	3 cm	chopmark present
Tr. 1, pit 1	med-sized	vertebra	piece	1			350-700 C	4,5 cm	
Tr. 1, pit 1	indeterminate	axial bone	piece	1			300 C	2 cm	
Tr. 1, pit 1	indeterminate	axial bone	piece	1			350-700 C	1 cm	
Tr. 1, pit 1	med-sized	long bone	piece	1			300 C	2,5 cm	
Tr. 1, pit 1	large mammal	long bone	piece	1			200 C	1,5 cm	
Tr. 1, pit 1	indeterminate	indeterm	piece	5			350-700 C	1 cm	
Tr. 1, pit 1	indeterminate	long bone	piece	1			200 C	2 cm	
Tr. 1, pit 1	indeterminate	long bone	piece	1			350 C	2 cm	
Tr. 1, pit 1	indeterminate	axial bone	piece	1			350 C	2 cm	
Tr. 1, pit 1	indeterminate	indeterm	piece	1			350 C	2 cm	

Tr. 1, pit 1	cattle	tooth	piece	1			300-350 C		
Tr. 1, pit 1	indeterminate	indeterminate	piece	2			350 C	0,5 cm	
Tr. 1, pit 1	indeterminate	indeterminate	piece	5				1 cm	
Tr. 1, pit 1	indeterminate	cartilage	piece	1			350 C	1,5 cm	
Tr. 1, pit 1	indeterminate	spongy bone	piece	1			300-350 C	2 cm	
Tr. 1, pit 1	indeterminate	spongy bone	piece	1				4 cm	
Tr. 1, pit 1	large mammal	long bone	piece	1			300-350 C	3 cm	
tr. 1, pit 1, accumulation	cattle	humerus	3,4,5,6,7,8	1	left	F		Bd=105,4; Dd=92,2	
tr. 1, pit 1, accumulation	cattle	humerus	3,4,5,6,7,8	1	right	F		Bd=78,5; Dd=74	
tr. 1, pit 1, accumulation	cattle	humerus	3,4,5,6,7,8	1	right	F		Bd=95,6	
Tr. 1, pit 2	indeterminate	indeterminate	piece	5			350 C	0,5 cm	
Tr. 1, pit 2	indeterminate	long bone	piece	1			350 C	2 cm	
Tr. 1, pit 2	indeterminate	vertebra	artic. Piece	1		UF	300-350 C		
Tr. 1, pit 2	indeterminate	axial bone	piece	1			350 C	4 cm	
Tr. 1, pit 2	indeterminate	spongy bone	piece	1				2,5 cm	
Tr. 1, pit 3	indeterminate	long bone	indeterminate	1			300-350 C	2 cm	
Tr. 1, pit 3	indeterminate	long bone	piece	2			350 C	1 cm	
Tr. 1, pit 4	indeterminate	spongy bone	piece	1			200 C	2,5 cm	

Tr. 2, 100 cm	indeterminate	spongy bone	piece	1			700 C	1,5 cm	
Tr. 2, 100 cm	indeterminate	long bone	piece	1			350 C	1 cm	
Tr. 2, 100 cm	indeterminate	long bone	piece	1				0,5 cm	
Tr. 2, 100 cm	indeterminate	long bone	piece	1				0,5 cm	worked bone, polished
Tr. 2, 60-100 cm	caprine	tibia	dist and shaft	1	left	d-UNF		Bd=25.1; Dd=21.3; SD=15.7	multiple gnawing marks from small carnivore
Tr. 2, 60-100 cm	indeterminate	femur artic.	piece	1				1,5 cm	
Tr. 2, 60-100 cm	indeterminate	long bone	piece	1				2,5 cm	
Tr. 2, 60-100 cm	indeterminate	long bone	piece	1			750 C	1,5 cm	green staining?
Tr. 2, 60-100 cm	caprine	metatarsal	prox artic piece	1				1 cm	
Tr. 2, 60-100 cm	indeterminate	long bone	piece	1			200 C	1,5 cm	
Tr. 2, 60-100 cm	indeterminate	axial bone	piece	1			350 C	2,5 cm	
Tr. 2, 60-100 cm	indeterminate	axial bone	piece	1			300 C	1 cm	
Tr. 2, 60-100 cm	indeterminate	axial bone	piece	1				2,5 cm	cutmarks present
Tr. 2, 60-100 cm	suslik	bones	complete	15					
Tr. 3, 60-80 cm	indeterminate	spongy bone	piece	1			700 C		

Tr. 4, 0-55 cm	cattle	humerus	prox artic piece	1		UF			small carnivore gnawing marks
Tr. 4, 0-55 cm	indeterminate	indeterm	piece	2				0,5 cm	
Tr. 4, 0-55 cm	indeterminate	spongy bone	piece	4			700 C	0,5 cm	
Tr. 4, 0-55 cm	indeterminate	axial bone	piece	1			700 C	1 cm	green staining
Tr. 4, 112 cm	indeterminate	skull	piece	1					
Tr. 4, 112 cm	indeterminate	indeterminate	piece	1			700 C	1 cm	
Tr. 4, 112 cm	indeterminate	indeterminate	piece	1			350 C	0,5 cm	
Tr. 4, pit 1	small mammal	skull piece	piece	1					
Tr. 4, pit 1	med-sized	rib	small piece	1			300 C	1 cm	

Appendix 2: ZooMS spectrum images from Ashutasty site

Figure 1: Spectrum image of sample A2 (left) and A2 duplicate (right). Sample A2 (left) did not give enough marker peaks, therefore identification was not possible.

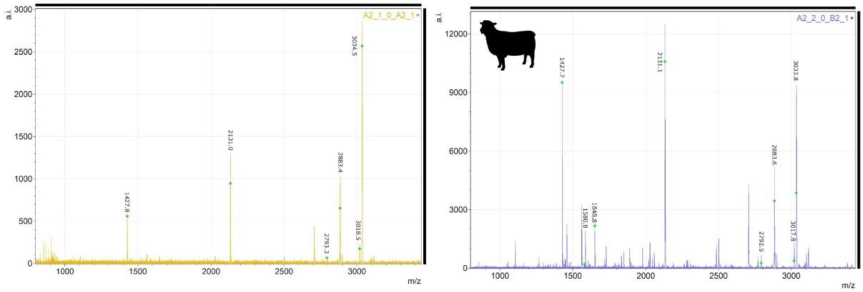


Figure 2: Spectrum image of sample A3 (left) and A3 duplicate (right)

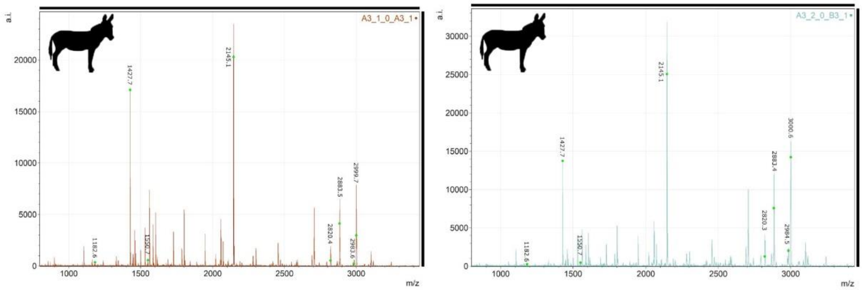


Figure 3: Spectrum image of sample A4 (left) and A4 duplicate (right)

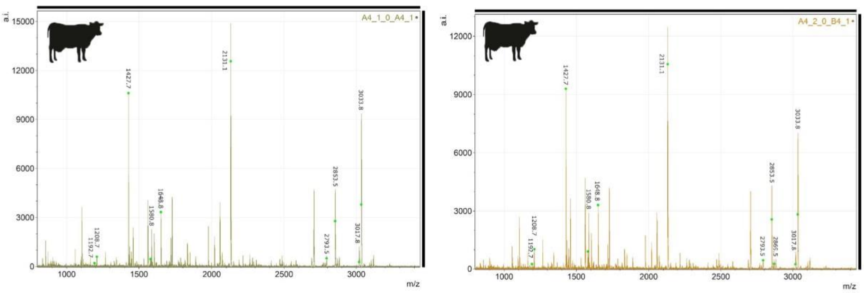


Figure 4: Spectrum image of sample A5 (left) and A5 duplicate (right)

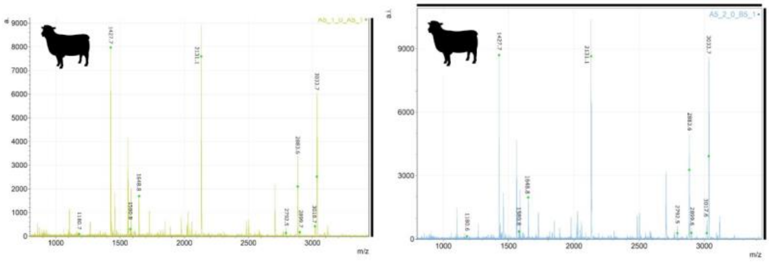


Figure 5: Spectrum image of sample A7 (left) and A7 duplicate (right)

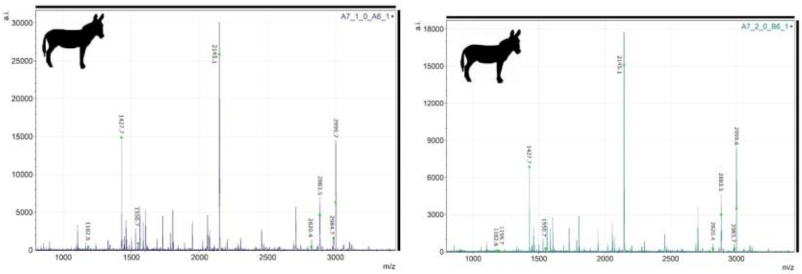


Figure 6: Spectrum image of sample A8 (left) and A8 duplicate (right)

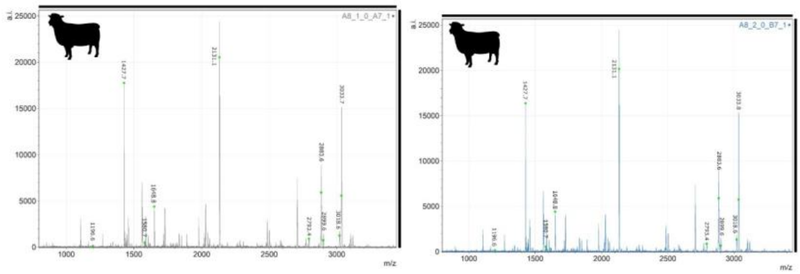


Figure 7: Spectrum image of sample A9 (left) and A9 duplicate (right)

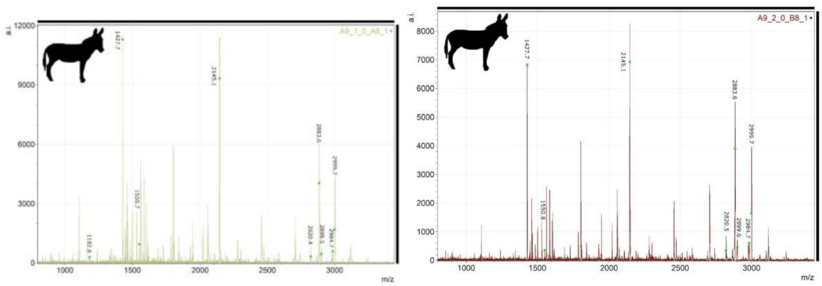


Figure 8: Spectrum image of sample A11 (left) and A11 duplicate (right)

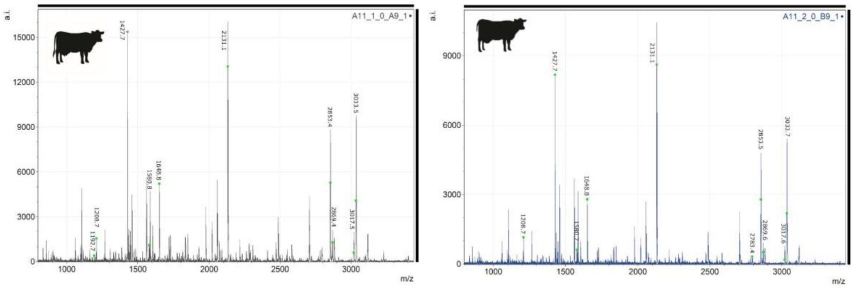


Figure 9: Spectrum image of sample A13 (left) and A13 duplicate (right)

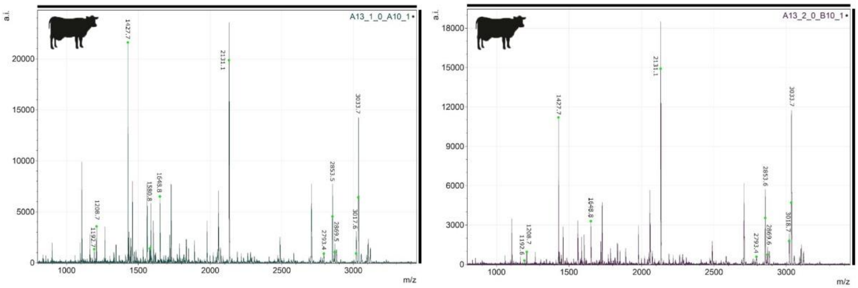


Figure 10: Spectrum image of sample A14 (left) and A14 duplicate (right)

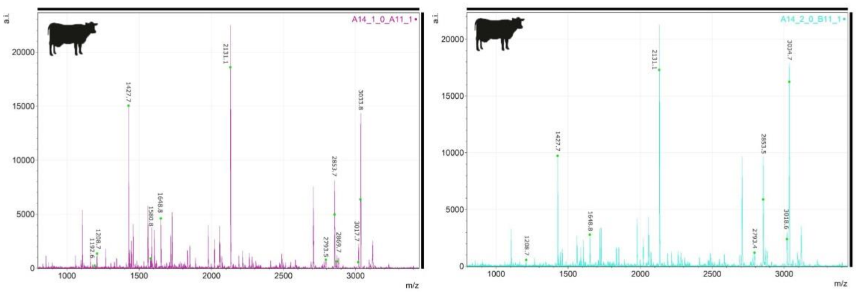


Figure 11: Spectrum image of sample A15 (left) and A15 duplicate (right)

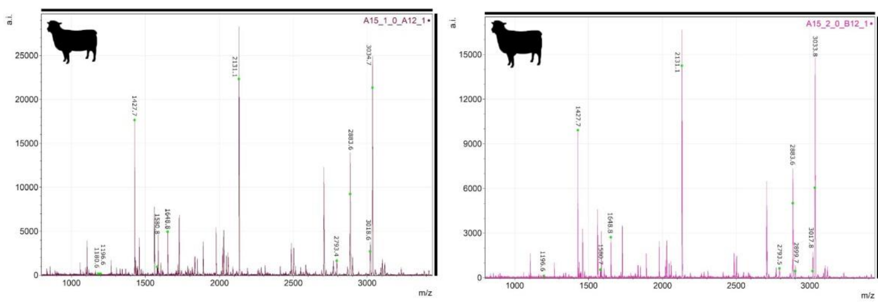


Figure 12: Spectrum image of sample A16 (left) and A16 duplicate (right)

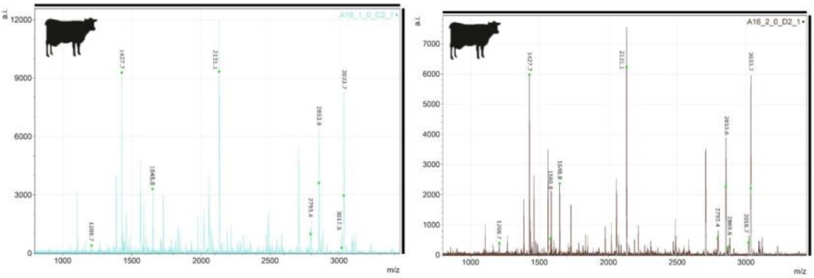


Figure 13: Spectrum image of sample A17 (left) and A17 duplicate (right)

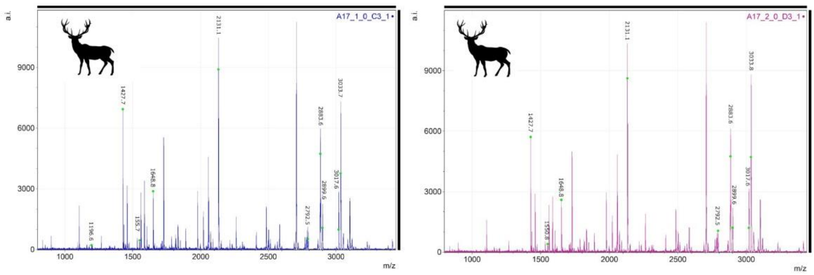


Figure 14: Spectrum image of sample A18 (left) and A18 duplicate (right)

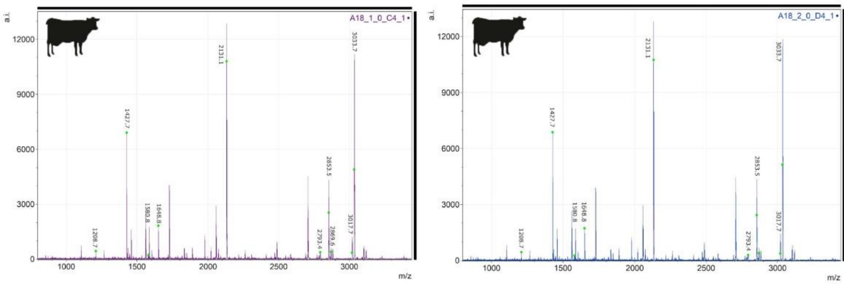


Figure 15: Spectrum image of sample A19 (left) and A19 duplicate (right)

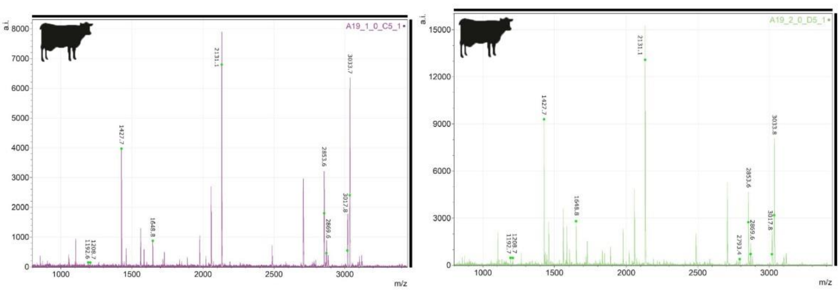


Figure 16: Spectrum image of sample A20 (left) and A20 duplicate (right)

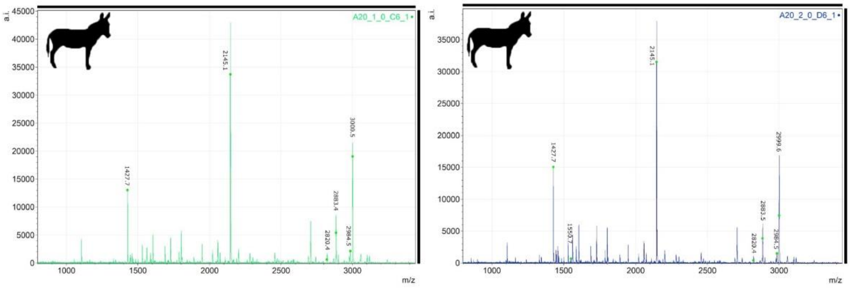


Figure 17: Spectrum image of sample A21 (left) and A21 duplicate (right)

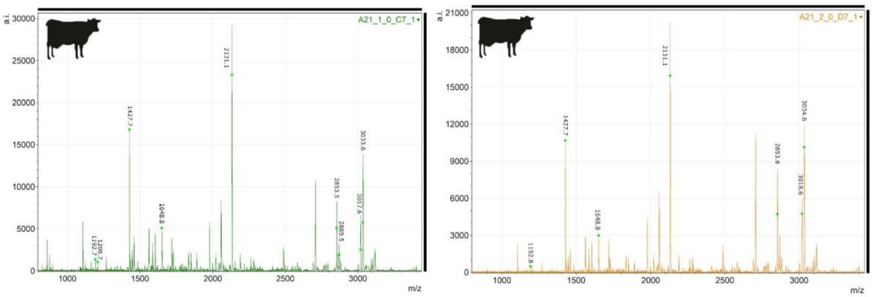


Figure 18: Spectrum image of sample A24 (left) and A24 duplicate (right)

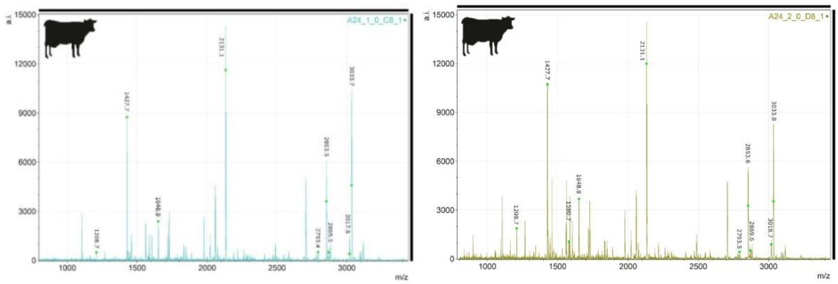
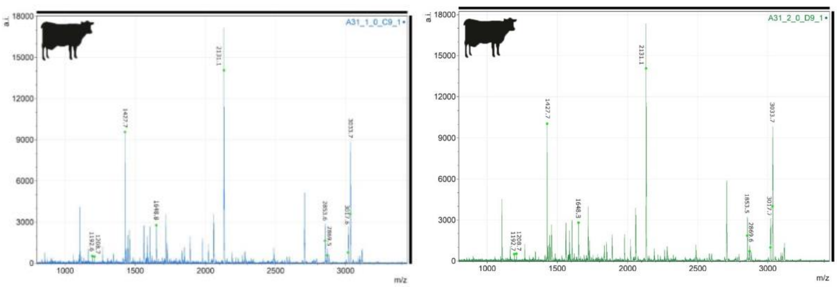


Figure 19: Spectrum image of sample A31 (left) and A31 duplicate (right)



Appendix 3: Stable isotope values of human and animal bone collagen

Table 1: Ashutasty stable isotope animal values (samples marked with * were analyzed with ZooMS)

LabCode	Context	Species	d13C	Duplicate d13C	**Mean d13C**	d15N	Duplicate d15N	**Mean d15N**	C%	Duplicate C%	**Mean C%**	N%	Duplicate N%	**Mean N%**	**C/N at.**
A2	Tr 1, 55-85 cm	Ovis*	-18,14	-17,91	**-18,03**	7,30	7,10	**7,20**	38,78	43,83	**41,30**	13,77	15,53	**14,65**	**3.3**
A3	Tr 1, 55-85 cm	Equus*	-21,02	-20,83	**-20,92**	4,12	3,88	**4,00**	39,40	37,15	**38,28**	14,30	13,35	**13,82**	**3.2**
A4	Tr 1, 0-50 cm	Bos*	-21,01	-20,80	**-20,91**	4,15	3,90	**4,03**	43,52	39,74	**41,63**	15,72	14,30	**15,01**	**3.2**
A5	Tr 2, 60-100 cm	Ovis*	-18,91	-18,68	**-18,80**	5,93	5,67	**5,80**	40,84	39,92	**40,38**	14,78	14,27	**14,53**	**3.2**
A7	Tr 1, pit 1	Equus*	-20,96	-20,69	**-20,83**	3,78	3,59	**3,69**	39,89	37,43	**38,66**	14,57	13,44	**14,01**	**3.2**
A8	Tr. 1, 0-50 cm	Ovis*	-19,38	-19,23	**-19,30**	5,36	5,11	**5,24**	41,64	39,08	**40,36**	15,06	13,97	**14,52**	**3.2**
A9	Tr 1, 0-50 cm	Equus*	-20,24	-20,05	**-20,14**	7,48	7,15	**7,32**	40,22	33,46	**36,84**	14,42	11,89	**13,16**	**3.3**
A11	Tr 1, pit 1	Bos*	-20,04	-19,74	**-19,89**	8,25	7,94	**8,10**	44,64	40,56	**42,60**	16,05	14,76	**15,41**	**3.2**
A13	Tr 1, pit 1	Bos*	-19,51	-19,32	**-19,42**	6,50	6,30	**6,40**	41,31	39,90	**40,61**	14,81	14,18	**14,49**	**3.3**
A15	Tr. 1, 0-50 cm	Ovis*	-19,23	-18,93	**-19,08**	7,13	6,87	**7,00**	41,46	44,09	**42,77**	15,06	16,05	**15,55**	**3.2**
A16	Tr. 1, 0-50 cm	Bos*	-20,13	-19,91	**-20,02**	6,59	6,34	**6,47**	34,40	36,73	**35,57**	13,13	13,28	**13,20**	**3.1**
A17	Tr 2, 60-100 cm	Cervidae or Antelopi	-17,96	-17,66	**-17,81**	8,42	8,13	**8,28**	40,54	40,25	**40,40**	14,93	14,50	**14,72**	**3.2**

		nae*												
A18	Tr 1, 0-50 cm	Bos*	-19,82	-19,56	**-19,69**	7,18	6,97	**7,08**	44,53	43,56	**44,05**	16,30	15,73	**16,01**	**3.2**
A19	Tr 1, 21-85 cm	Bos*	-18,62	-18,39	**-18,51**	8,54	8,33	**8,44**	39,46	37,03	**38,25**	14,21	13,40	**13,81**	**3.2**
A20	Tr 1, 0-50 cm	Equus*	-20,81	-20,55	**-20,68**	4,97	4,78	**4,88**	43,08	43,41	**43,24**	15,56	15,35	**15,46**	**3.3**
A21	Tr 1, 0-55 cm	Bos*	-19,00	-18,81	**-18,91**	8,78	8,50	**8,64**	44,68	39,90	**42,29**	16,01	14,11	**15,06**	**3.3**
A24	Tr 1, pit 1	Bos*	-19,57	-19,38	**-19,47**	8,12	7,87	**8,00**	45,44	44,99	**45,21**	16,62	16,03	**16,32**	**3.2**
A28	Tr 1, 0-55 cm	Cattle	-19,27	-19,18	**-19,22**	6,46	6,25	**6,36**	32,35	33,75	**33,05**	11,60	11,71	**11,66**	**3.3**
A29	Tr 1, 0-55 cm	Horse	-20,46	-20,31	**-20,39**	4,70	4,41	**4,56**	36,62	32,68	**34,65**	13,30	11,82	**12,56**	**3.2**
A30	Tr 1, 0-55 cm	Cattle	-19,95		**-19,95**	5,96		**5,96**	37,29		**37,29**	13,31			**3.3**
A31	Tr 1, 0-55 cm	Bos*	-18,56	-18,55	**-18,55**	8,44	8,19	**8,32**	42,52	42,84	**42,68**	15,09	14,89	**14,99**	**3.3**
A32	Tr 2, 60-100 cm	Suslik	-18,48	-18,44	**-18,46**	7,18	7,01	**7,10**	47,29	44,50	**45,90**	17,39	16,39	**16,89**	**3.2**
A34	Tr 1, 0-50 cm	Horse	-20,86	-20,82	**-20,84**	4,14	3,93	**4,04**	44,01	44,26	**44,13**	16,14	15,88	**16,01**	**3.2**
A35	Tr 1, pit 1, 20 cm	Cattle	-19,92	-19,85	**-19,89**	5,58	5,33	**5,46**	39,06	38,08	**38,57**	14,32	14,03	**14,18**	**3.2**
A36	Tr 1, 55-85 cm	Sheep/goat	-18,91	-18,94	**-18,92**	6,52	6,52	**6,52**	44,79	42,96	**43,88**	15,53	14,77	**15,15**	**3.4**
A37	Tr 1, pit 1	Cattle	-19,44	-19,43	**-19,43**	8,71	8,72	**8,72**	48,00	41,96	**44,98**	17,31	15,05	**16,18**	**3.2**
A38	Tr 1, pit 1	Sheep/goat	-19,12	-19,05	**-19,08**	7,39	7,41	**7,40**	42,86	42,02	**42,44**	15,12	14,95	**15,03**	**3.3**

Table 2: Human stable isotope data from Kazakhstan (samples marked with * were published in Ananyevskaya et al. (2018)

Sample ID	Site	Context	Date	Element	$\delta^{13}C$‰	$\delta^{15}N$‰	C/N $_{at}$	C%	N%	Region
EA-SI-101	Bestamak	Burial 103, upper burial	IA	skull	-17.99	12.47	3.6	20.05	6.52	Northern KZ
EA-SI-102_2	Bestamak	Burial 138, skeleton 1,	IA	1st plnx	-19.03	13.01	3.4	38.32	13.12	Northern KZ
EA-SI-103	Bestamak	Burial 138, skeleton 2	IA	phalanx	-18.86	13.13	3.3	46.76	16.47	Northern KZ
EA-SI-104	Bestamak	Burial 138, skeleton 3	IA	1st pnx	-18.99	12.23	3.3	45.80	16.30	Northern KZ
EA-SI-105	Bestamak	Burial 138, skeleton 4	IA	vertebra	-19.10	12.18	3.3	43.58	15.35	Northern KZ
BTC-20	Budenovka-5	Kurgan 2	Medieval	phalanx	-19.40	13.49	3.5	40.18	13.28	Northern KZ
EA-SI-109	Halvai-3	Pit numb. 7	IA	metapodia	-19.22	11.20	3.5	22.23	7.42	Northern KZ
EA-SI-110	Halvai-3	Pit numb. 8A	IA	metapodia	-19.07	10.46	3.2	44.57	16.10	Northern KZ
EA-SI-108	Halvai-3	Pit numb. 3A	Medieval	phalanx	-17.94	13.63	3.3	46.26	16.49	Northern KZ
EA-SI-106	Karatomar-1	Pit numb. 5	IA	1st plnx	-18.71	12.87	3.4	41.26	14.32	Northern KZ
EA-SI-107	Karatomar-1	Pit numb. 5A	IA	phalanx	-18.87	11.93	3.3	44.39	15.87	Northern KZ
EA-SI-78	Nikel'	Kurgan 1	FBA-EIA	metatarsal	-18.74	12.25	3.4	43.68	15.22	Northern KZ
EA-SI-79	Ostrogorka		Medieval	cervical vertebra	-18.24	13.96	3.3	45.13	16.18	Northern KZ
EA-SI-71	Shagalaly	House 3, Burial 1	BA	cervical vertebra	-19.10	11.33	3.2	45.31	16.57	Northern KZ
EA-SI-74	Shagalaly	House 3, Kv. 6, Burial 4	BA	radius	-19.28	10.83	3.3	44.08	15.79	Northern KZ
EA-SI-69	Shagalaly	Late Sarmatian burial	II-III AD	skull	-21.40	11.07	3.5	31.75	10.53	Northern KZ
EA-SI-70	Shagalaly	House 3, Burial 1, separate skull	BA	lower jaw	-19.15	11.28	3.1	43.77	16.47	Northern KZ
BTC-14	Shagalaly-2	House 6	BA	phalanx	-19.10	10.64	3.2	53.23	19.58	Northern KZ

EA-SI-72	Shagalaly-4		IA	metacarpus	-18.70	12.01	3.1	42.02	16.07	Northern KZ
EA-SI-75	Shagalaly-5		IA	cervical vertebra	-19.09	11.50	3.3	41.53	14.67	Northern KZ
BTC-19	Shondykorasy -2		BA	phalanx	-18.28	13.93	3.2	44.15	15.97	Northern KZ
EA-SI-126	Zevakinskiy		VIII-V BC	skull	-14.03	11.19	3.5	41.34	13.94	Eastern KZ
EA-SI-127	Zevakinskiy	Enclosure 38	VIII-V BC	skull	-16.08	11.22	3.4	31.94	11.03	Eastern KZ
LT-KZ-41*	Karatobe	Kurgan 1	II BC — AD II	radius fragment	-17.84	14.73	3.3			Eastern KZ
LT-KZ-40*	Karatobe	Kurgan 2	II BC — AD II	ulna fragment	-15.99	13.29	3.4			Eastern KZ
LT-KZ-39*	Karatobe	Kurgan 3	II BC — AD II	radius fragment	-17.64	15.24	3.3			Eastern KZ
LT-KZ-42*	Kotyrkora	Kurgan 1	IA	bone fragment	-17.81	13.19	3.3			Eastern KZ
EA-SI-58	Ak-Koitas-4	Kurgan 1, from stone layers in the southern part	XIV-XII BC	humerus	-19.13	12.78	3.2	46.49	16.89	Central KZ
EA-SI-59	Ak-Koitas-5	Kurgan 1	XIV-XII BC	hand phalanx	-18.21	13.11	3.0	38.89	15.20	Central KZ
EA-SI-94	Aschisu	Kurgan 5	BA	fibula	-17.76	13.63	3.3	48.50	16.92	Central KZ
BTC-39	Bozshakol-5	burial n 91	FBA-EIA	mandible	-14.72	13.07	3.3	48.75	17.36	Central KZ
EA-SI-29	Kairan-1	Structure 2	XVIII-XVI BC	2nd plnx	-18.27	13.58	3.0	37.29	14.53	Central KZ
EA-SI-30	Kairan-1	Structure 4	XVIII-XVI BC	1st plnx	-18.39	13.78	3.2	37.21	13.66	Central KZ
EA-SI-31	Kairan-1	Structure 5, Bur. 1	XVIII-XVI BC	2nd plnx	-17.86	14.05	3.3	38.08	13.65	Central KZ
EA-SI-32	Kairan-1	Structure 7-6	XVIII-XVI BC	2nd plnx	-18.11	14.08	3.1	41.99	15.78	Central KZ
EA-SI-33	Kairan-1	Structure 7A, box 1	XVIII-XVI BC	2nd plnx	-17.24	15.48	3.2	37.55	13.94	Central KZ
EA-SI-34	Kairan-1	Structure 7A, box 2	XVIII-	metatarsal	-17.42	15.10	3.2	37.32	13.49	Central KZ

			XVI BC							
EA-SI-35	Kairan-1	Structure 9, box 1(10)	XVIII-XVI BC	2nd plnx	-17.73	14.90	3.3	44.19	15.77	Central KZ
EA-SI-36	Kairan-1	Structure 10	XVIII-XVI BC	2nd plnx	-17.70	14.59	3.4	36.47	12.41	Central KZ
EA-SI-38	Kairan-1	Structure 11, box 1, bur. 1	XVIII-XVI BC	long bone	-18.61	13.37	3.2	32.66	12.07	Central KZ
EA-SI-39	Kairan-1	Structure 11, box 2, bur. 1 (northern)	XVIII-XVI BC	2nd plnx	-18.17	13.35	3.1	36.51	13.70	Central KZ
EA-SI-40	Kairan-1	Structure 11, box 2	XVIII-XVI BC	1st plnx	-18.56	13.65	3.2	28.38	10.24	Central KZ
EA-SI-41	Kairan-1	Structure 11, box 2, bur. 2 (southern)	XVIII-XVI BC	scapula	-18.26	13.41	3.1	37.46	14.40	Central KZ
EA-SI-42	Kairan-1	Structure 11, box 3	XVIII-XVI BC	metacarpal	-17.78	15.66	3.1	37.96	14.36	Central KZ
EA-SI-43	Kairan-1	Structure 13, Northern skeleton	XVIII-XVI BC	rib	-18.64	13.70	3.4	37.09	12.87	Central KZ
EA-SI-44	Kairan-1	Structure 12, box 2	XVIII-XVI BC	2nd plnx	-18.68	15.31	3.1	39.60	14.91	Central KZ
EA-SI-46	Kairan-1	Structure 14, box 2 (northern)	XVIII-XVI BC	2nd plnx	-18.56	12.68	3.1	40.36	15.28	Central KZ
EA-SI-80	Karatugai	Burial 1,2	FBA-EIA	cervical vertebra	-18.47	11.98	3.4	29.93	10.11	Central KZ
EA-SI-81	Karatugai	Enclosure 11	FBA-EIA	metacarpal	-17.66	14.04	3.4	27.35	9.46	Central KZ
EA-SI-82	Karatugai	Burial 5	FBA-EIA	cervical vertebra	-18.49	12.01	3.3	46.68	16.56	Central KZ
EA-SI-83	Karatugai	Burial 8	FBA-EIA	cervical vertebra	-19.36	10.29	3.3	53.24	19.22	Central KZ
EA-SI-84	Karatugai	Burial 12	FBA-EIA	1st plnx	-19.35	10.39	3.0	42.63	16.55	Central KZ
EA-SI-85	Karazhartas	Enclosure 1, burial outside of the enclosure	XV-XIII BC	2nd plnx	-15.15	13.38	3.4	40.30	13.81	Central KZ
EA-SI-86	Karazhartas	Enclosure 5	XV-XIII BC	humerus	-17.27	13.25	3.3	30.73	10.95	Central KZ
EA-SI-87	Karazhartas	Enclosure 7	XV-XIII	2nd plnx	-17.22	13.36	3.3	40.99	14.65	Central KZ

			BC							
EA-SI-88	Karazhartas	Enclosure 8	XV-XIII BC	1st plnx	-17.27	13.50	3.5	40.61	13.61	Central KZ
EA-SI-89	Karazhartas	Enclosure 9, child burial	XV-XIII BC	radius	-16.93	14.39	3.4	30	10.22	Central KZ
EA-SI-95	Kudryavaya Sopka	Burial 2	FBA-EIA	axis	-18.28	14.95	3.4	29.87	10.23	Central KZ
BTC1-567	PPK Saba	2018, Kurgan group 3, kurgan 4 burial	IA	1st plnx	-17.88	14.31	3.0	77.35	29.96	Central KZ
EA-SI-98	Senkibai-2	Kurgan 2, inserted EIA burial	FBA-EIA	metatarsus	-18.94	14.01	3.2	47.78	17.21	Central KZ
EA-SI-96	Shantimes	Enclosure 18	VIII-VI BC	metacarpal	-19.29	11.85	3.4	31.09	10.77	Central KZ
BTC-10	Tankara	Burial 30	XVII-XV BC	1st plnx	-18.47	13.46	3.3	37.63	13.32	Central KZ
BTC-15	Tankara	Burial 12	XVII-XV BC	metapodia	-18.37	14.15	3.2	37.76	13.71	Central KZ
BTC-16	Tankara	Construction 11, burial 2	XVII-XV BC	vertebra	-18.96	13.19	3.5	31.74	10.52	Central KZ
BTC-17	Tankara	Burial 4-2	XVII-XV BC	vertebra	-18.40	13.50	3.4	37.94	12.96	Central KZ
BTC-18	Tankara	Burial 4-1	XVII-XV BC	vertebra	-18.14	13.27	3.4	41.60	14.38	Central KZ
EA-SI-25	Tersakkan	Kurgan 3, skeleton 2 (central)	II BC-I AD	metatarsus	-18.14	12.72	3.5	32.90	11.04	Central KZ
EA-SI-28	Tersakkan	Kurgan 3, skeleton 1 (northern)	II BC-I AD	metacarpus	-17.98	13.49	3.6	42.57	13.91	Central KZ
EA-SI-23	Tersakkan	Kurgan 1 (with moustache)	VIII-VI BC	metacarpus	-18.39	14.76	3.4	32.57	11.19	Central KZ
EA-SI-24_1	Tersakkan	Kurgan 2, bones from the filling	VIII-IV BC	metacarpus	-17.97	15.27	3.5	29.21	9.50	Central KZ
EA-SI-20	Tersakkan-2	Object 1, burial 1	XVIII AD	humerus	-19.10	11.73	3.2	37.36	13.79	Central KZ
EA-SI-21	Tersakkan-2	Object 1, burial 3	XVIII AD	humerus	-19.68	12.72	3.2	40.15	14.57	Central KZ
EA-SI-22	Tersakkan-2	Object 1, burial 7	XVIII	thoracic	-18.61	13.82	3.3	40.1	14.2	Central KZ

			AD	vertebra						
EA-SI-66	Zhanteli-12	Burial	Medieval	1st plnx	-18.96	12.90	3.3	48.86	17.56	Central KZ
EA-SI-93	Zhartas	Enclosure 2	VI-III BC	metatarsus	-18.21	14.27	3.3	38.11	13.61	Central KZ
EA-SI-61	Zheken	Kurgan 3	IA	rib	-17.82	14.42	3.0	42.54	16.75	Central KZ
EA-SI-62	Zheken	Burial 1	XVIII AD	scapula	-18.54	15.50	3.1	40.21	15.26	Central KZ
EA-SI-63	Zheken	Burial 2	XVIII AD	rib	-17.41	15.62	3.0	38.22	14.67	Central KZ
EA-SI-64	Zheken	Burial 6	XVIII AD	clovicle	-18.98	14.29	3.1	43.70	16.47	Central KZ
EA-SI-60	Zheken	Object 1	IX-XI AD	metacarpus	-18.18	14.99	3.5	38.98	13.06	Central KZ
LT-KZ-1*	Akbeit	Kurgan 6	IX-VI BC	rib fragment	-17.95	14.54	3.3			Central KZ
LT-KZ-23*	Baike 2	Kurgan «s usami» 3	VIII-V BC	clovicle fragment	-19.08	14.83	3.3			Central KZ
LT-KZ-19*	Bakybulak	Kurgan 9	IX-VI BC	skull fragment	-18.35	13.61	3.5			Central KZ
LT-KZ-24*	Karakemer	Kurgan 3	VIII-V BC	rib fragment	-17.88	14.90	3.3			Central KZ
LT-KZ-3*	Karashoky	Kurgan 6	IX-V BC	rib fragment	-18.01	15.12	3.3			Central KZ
LT-KZ-2*	Karashoky	Kurgan 7	IX-V BC	clovicle fragment	-16.14	14.59	3.3			Central KZ
LT-KZ-4*	Karashoky	Kurgan 9	IX-V BC	vertebra	-17.76	15.05	3.3			Central KZ
LT-KZ-21*	Kyzylshilik	Kurgan 5	VIII-V BC	clovicle fragment	-22.10	13.51	3.3			Central KZ
LT-KZ-18*	Myrzhyk 6	Kurgan 3	VIII-V BC	skull fragment	-16.79	15.24	3.4			Central KZ
LT-KZ-20*	Tandaily	Kurgan 1	VIII-V BC	bone fragment	-19.47	13.58	3.3			Central KZ
LT-KZ-25*	Tegiszhol	Construction 27, burial 2	IA	clovicle fragment	-17.79	14.59	3.4			Central KZ

EA-SI-01	Taksai-1	K. 4, Bur. 1	IA	skull	-18.47	14.20	3.3	38.1	13.4	Western KZ
EA-SI-04	Taksai-1	K. 6, Bur. 2	IA	scapula	-18.46	14.51	3.3	40.85	14.49	Western KZ
EA-SI-05	Taksai-1	K. 6, Bur. 1	IA	fibula	-18.09	13.04	3.2	37.17	13.63	Western KZ
EA-SI-02	Taksai-2	K. 2, Pit 1, Bur. 2	IA	metatarsus	-18.60	13.77	3.1	38.19	14.66	Western KZ
EA-SI-03	Taksai-2	K. 2, Pit 1	IA	rib	-18.75	13.15	3.2	31.54	11.42	Western KZ
EA-SI-07	Taksai-2	K. 2, Bur. 1	IA	skull	-13.36	16.46	3.4	38.48	13.37	Western KZ
EA-SI-08	Taksai-2	K. 2, Pit 1	IA	clovicle	-18.82	12.85	3.1	37.87	14.19	Western KZ
EA-SI-09	Taksai-2	K. 2, central pit	IA	ulna	-18.98	12.74	3.4	39.97	13.91	Western KZ
EA-SI-11	Taksai-2	K. 2, pit 9	IA	metacarpus	-16.71	11.91	3.3	40.56	14.40	Western KZ
EA-SI-12	Taksai-2	K. 2, pit 5	IA	rib	-15.35	17.90	3.2	38.93	14.14	Western KZ
EA-SI-13	Taksai-2	K. 2, Bur. 2	IA	ulna	-17.66	12.87	3.3	38.08	13.67	Western KZ
EA-SI-14	Taksai-2	K. 2, Pit 7	IA	skull	-18.81	12.30	3.3	35.90	12.89	Western KZ
EA-SI-16	Taksai-2	K. 2, Pit 8, Bur. 1, skull 2	IA	skull	-18.23	12.17	3.3	41.68	14.79	Western KZ
EA-SI-17	Taskala, ind zone	K. 3	BA	ulna	-18.48	14.12	3.1	38.66	14.65	Western KZ
EA-SI-18	Taskala, ind zone	K. 5, Pit 4, Bur. 3	BA	fibula	-18.84	12.44	3.3	32.47	11.39	Western KZ
EA-SI-19	Taskala, ind zone	K. 4, Pit 1	BA	atlas	-18.33	14.45	3.2	34.61	12.87	Western KZ
BTC1-568	Tortoba	2013, Object 6	IA	metapodia	-18.30	14.11	3.0	29.01	11.13	Western KZ
BTC1-569	Tortoba	2017, Kurgan 1, eastern burial, southern part	IA	rib	-17.45	14.10	3.0	54.13	20.74	Western KZ
BTC1-571	Tortoba	2013, Object 8	IA	1st plnx	-17.42	16.25	3.0	59.79	23.24	Western KZ
BTC1-573	Tortoba	2016, Kurgan 1, burial 1	IA	metapodia	-18.10	13.40	3.0	40.44	15.57	Western KZ
EA-SI-124	Balandy	Balandy cemetery	IV-III BC	skull	-18.33	11.14	3.5	38.66	12.86	Syr-Darya and Otrar

BTC-47	Burgulyuk	kurgan 16	FBA-EIA	rib	-15.79	10.28	3.4	34.22	11.62	Syr-Darya and Otrar
BTC-46	Burgulyuk-2	kurgan 2	FBA-EIA	rib	-15.48	12.80	3.4	42.86	14.83	Syr-Darya and Otrar
BTC-51	Burgulyuk-2	kurgan 9	FBA-EIA	skull	-14.31	11.15	3.4	42.08	14.51	Syr-Darya and Otrar
EA-SI-113	Chirik Rabat	Object 1, burial 2	IV-III BC	skull	-16.30	14.81	3.5	37.91	12.56	Syr-Darya and Otrar
EA-SI-114	Chirik Rabat	Object 1, burial 3	IV-III BC	rib	-18.05	14.88	3.2	43.47	15.93	Syr-Darya and Otrar
EA-SI-115	Chirik Rabat	Object 1, burial 4, western sector	IV-III BC	skull	-17.08	14.38	3.4	37.26	12.98	Syr-Darya and Otrar
EA-SI-116	Chirik Rabat	Object 1, burial 1(?), western sector	IV-III BC	metatarsal	-16.34	12.97	3.3	36.20	12.83	Syr-Darya and Otrar
EA-SI-117	Chirik Rabat	Object 1, burial 2(?), western sector	IV-III BC	skull	-22.48	15.22	3.3	43.74	15.60	Syr-Darya and Otrar
EA-SI-120	Chirik Rabat	Kurgan 49, burial 1	IV-III BC	bone fragm.	-16.78	13.47	3.44			Syr-Darya and Otrar
EA-SI-121	Chirik Rabat	Kurgan 49, burial 2	IV-III BC	skull	-16.93	14.49	3.3	45.21	16.03	Syr-Darya and Otrar
EA-SI-122	Chirik Rabat	Kurgan 50, burial 1	IV-III BC	skull	-15.69	15.21	3.3	49.18	17.36	Syr-Darya and Otrar
EA-SI-123	Chirik Rabat	Kurgan 50, burial 2	IV-III BC	skull	-16.53	14.94	3.5	35.94	11.92	Syr-Darya and Otrar
EA-SI-125	Chirik Rabat	Kurgan 1	IV-III BC	ulna	-16.38	14.53	3.3	32.65	11.43	Syr-Darya and Otrar
BTC-23	Kaitpas	Kurgan 2, skeleton 2	FBA-EIA	mandible	-16.10	13.94	3.4	34.45	11.89	Syr-Darya and Otrar
BTC-44	Kaitpas	kurgan 2, skeleton 2	FBA-EIA	vertebra	-16.58	13.55	3.2	48.21	17.43	Syr-Darya and Otrar
BTC-42	Kaitpas	kurgan 2, skeleton 1	FBA-EIA	vertebra	-14.23	13.36	3.2	40.23	14.51	Syr-Darya and Otrar
BTC-33	Karauyltobe		Medieval	vertebra	-18.71	9.35	3.5	34.05	11.45	Syr-Darya and Otrar
BTC-45	Madani	Hankurgan, skeleton 1	Medieval	vertebra	-16.95	10.84	3.3	40.80	14.46	Syr-Darya and Otrar
BTC-48	Madani	Hankurgan, skeleton 3	Medieval	vertebra	-15.35	9.56	3.3	38.90	13.78	Syr-Darya and Otrar
BTC-49	Madani	Hankurgan, skeleton 4	Medieval	vertebra	-19.02	10.68	3.1	51.98	19.49	Syr-Darya and Otrar

BTC-50	Madani	Hankurgan, skeleton 2	Medieval	vertebra	-17.77	10.85	3.4	25.45	8.82	Syr-Darya and Otrar
BTC-52	Madani	Hankurgan, skeleton 5	Medieval	vertebra	-18.18	10.30	3.2	49.06	17.83	Syr-Darya and Otrar
EA-SI-47	Aktogai	Structure 1, kurgan 2	BA	tarsal	-17.31	14.63	3.1	37.36	14.03	South-east KZ
EA-SI-48	Aktogai	Structure 3, burial	BA	metacarpus	-17.52	12.75	3.1	39.01	14.54	South-east KZ
EA-SI-51	Aktogai	Object 7, structure 7	XIV-XII BC	long bone fragm.	-16.56	14.62	3.3	33.84	11.99	South-east KZ
EA-SI-52	Aktogai	Object 7, kurgan 4	XIV-XII BC	tibia	-16.34	14.46	3.3	46.41	16.55	South-east KZ
EA-SI-53	Aktogai	Object 7, kurgan 2, box 2, burial 1 (southern)	XIV-XII BC	2nd plnx	-17.12	11.16	3.1	38.17	14.46	South-east KZ
EA-SI-54	Aktogai	Object 7, kurgan 2, box 2, burial 2 (northern)	XVI-XV BC	metatarsus	-16.32	11.36	3.3	32.64	11.53	South-east KZ
EA-SI-56	Aktogai	Object 10	BA	thoracic vertebra	-17.73	16.04	3.4	21.40	7.45	South-east KZ
EA-SI-57	Aktogai	Object 6	BA	2nd plnx	-17.53	11.91	3.2	45.42	16.57	South-east KZ
EA-SI-49	Aktogai	Structure 4, kurgan 2	VI-IV BC	metacarpus	-17.62	12.09	3.2	31.63	11.57	South-east KZ
EA-SI-55	Aktogai	Object 7, kurgan 3, burial 1 (southern)	IV-III BC	metatarsus	-16.55	15.33	3.2	42.36	15.65	South-east KZ
BTC-29	Alatau	box n 40	FBA-EIA	skull	-17.29	8.92	3.3	41.35	14.56	South-east KZ
BTC-31	Alatau-1		FBA-EIA	bone fragm.	-16.75	10.81	3.2	57.88	21.00	South-east KZ
BTC-32	Butakty	T1, burial 29	Medieval	skull	-11.66	14.01	3.3	44.70	15.86	South-east KZ
BTC-28	Butakty-1		Medieval	bone fragm.	-15.22	10.73	3.2	50.90	18.64	South-east KZ
BTC-34	Kamenka		FBA-EIA	tibia	-16.87	10.47	3.3	42.11	14.80	South-east KZ
BTC-41	Kargalinka-2		Medieval	skull	-14.90	9.49	3.2	48.75	17.73	South-east KZ
BTC-37	Kargaly-1	burial 3	FBA-EIA	bone fragm.	-13.30	11.60	3.2	37.55	13.60	South-east KZ
BTC-30	Kargaly-108	sq. A-12/B	FBA-EIA	skul	-13.74	12.19	3.3	49.44	17.70	South-east KZ

EA-SI-67	Karkara	Kurgan 1, sector D, object 9	VI-V BC	humerus	-15.91	10.09	3.3	39.29	14.10	South-east KZ
EA-SI-68	Karkara	Object 15	VI-V BC	rib	-17.83	11.23	3.4	29.07	9.98	South-east KZ
BTC1-557	Katartobe	Group 1, kurgan 2, burial 2	IA	metapodia	-18.42	12.08	3.0	30.01	11.59	South-east KZ
BTC1-558	Katartobe	2017, Kurgan 10A	IA	1st plnx	-18.05	10.98	3.1	43.54	16.55	South-east KZ
BTC1-559	Katartobe	2015, Kurgan 1-1, burial	IA	metapodia	-17.32	11.92	3.0	35.02	13.63	South-east KZ
BTC1-561	Katartobe	2015, Kurgan 1, burial 51	IA	2nd plnx	-17.39	15.46	3.1	31.80	12.03	South-east KZ
BTC-40	Kyzyl-Bulak-4	kurgan 2	Medieval	vertebra	-19.50	9.45	3.2	59.73	21.87	South-east KZ
EA-SI-65	Nurly	Object 4, kurgan 7	II BC-I AD	metacarpus	-14.72	13.65	3.1	34.04	12.71	South-east KZ
BTC-35	Oi-Dzhailau-8		FBA-EIA	bone fragm.	-16.62	10.30	3.5	32.41	10.92	South-east KZ
BTC-36	Shokpar	kurgan 3, burial 1, central burial	FBA-EIA	skull	-16.05	13.48	3.3	37.03	13.22	South-east KZ
EA-SI-129	Turgen-2	House 4, sq. D7, child burial	XV-XIII BC	bone fragm.	-19.15	10.27	3.4	43.22	14.68	South-east KZ
EA-SI-128	Turgen-2	Kurgan 12, sq. D5, Bur. 3	III-I BC	bone fragm.	-18.36	10.09	3.4	48.78	16.97	South-east KZ
LT-KZ-9*	Shatyrkul	Kurgan 3, burial 7	EIA	1st phalanx	-15.03	13.73	3.4			South-east KZ
LT-KZ-5*	Shatyrkul	Kurgan 3, burial 9	EIA	bone fragment	-12.80	13.27	3.4			South-east KZ
LT-KZ-7*	Shatyrkul	Kurgan 4, burial 10	EIA	1st phalanx	-13.85	13.05	3.3			South-east KZ
LT-KZ-15*	Shatyrkul	Kurgan 4, burial 11	EIA	1st phalanx	-14.99	14.76	3.4			South-east KZ
LT-KZ-6*	Shatyrkul	Kurgan 11, burial 1	EIA	1st phalanx	-15.60	14.42	3.3			South-east KZ
LT-KZ-13*	Shatyrkul	Kurgan 11, burial 2	EIA	vertebra	-15.73	15.71	3.3			South-east KZ
LT-KZ-	Shatyrkul	Kurgan 11, burial 4	EIA	bone	-14.05	13.82	3.4			South-east KZ

8*				fragment						
LT-KZ-11*	Shatyrkul	Kurgan 12, burial 2	EIA	bone fragment	-14.16	14.11	3.4			South-east KZ
LT-KZ-14*	Shatyrkul	Kurgan 12, burial 5(1)	EIA	vertebra	-15.14	15.01	3.5			South-east KZ
LT-KZ-16*	Shatyrkul	Kurgan 12, burial 5(2)	EIA	bone fragment	-12.24	12.81	3.4			South-east KZ
LT-KZ-12*	Shatyrkul	Kurgan 12, burial 6	EIA	bone fragment	-15.50	14.19	3.5			South-east KZ
LT-KZ-10*	Shatyrkul	Kurgan 12, burial 9	EIA	1st phalanx	-15.71	12.91	3.4			South-east KZ
LT-KZ-17*	Shatyrkul	Burial 4	EIA	1st phalanx	-15.79	13.67	3.4			South-east KZ
LT-KZ-26*	Turgen	Kurgan 5, burial 1	EIA	bone fragment	-17.73	13.35	3.4			South-east KZ
LT-KZ-38*	Turgen	Kurgan 12, burial 1	EIA	vertebra	-16.88	13.00	3.3			South-east KZ
LT-KZ-27*	Turgen	Kurgan 12, burial 2	EIA	vertebra	-16.35	13.76	3.5			South-east KZ
LT-KZ-28*	Turgen	Kurgan 13, burial 2	EIA	bone fragment	-20.51	13.44	3.4			South-east KZ
LT-KZ-29*	Turgen	Kurgan 17, burial 1	EIA	vertebra	-17.25	13.46	3.4			South-east KZ
LT-KZ-30*	Turgen	Kurgan 17, burial 2	EIA	vertebra	-16.10	12.57	3.5			South-east KZ
LT-KZ-31*	Turgen	Kurgan 17, burial 4	EIA	vertebra	-15.97	11.93	3.6			South-east KZ
LT-KZ-33*	Turgen	Kurgan 18, burial 2	EIA	bone fragment	-15.86	12.48	3.3			South-east KZ
LT-KZ-32*	Turgen	Kurgan 19, burial 2	EIA	skull fragment	-16.38	12.30	3.4			South-east KZ
LT-KZ-34*	Turgen	Kurgan 19, burial 3	EIA	1st phalanx	-16.12	12.13	3.3			South-east KZ
LT-KZ-36*	Turgen	Kurgan 19, burial 4	EIA	vertebra	-16.10	12.60	3.3			South-east KZ
LT-KZ-	Turgen	Kurgan 25, burial 1	EIA	vertebra	-16.03	13.50	3.4			South-east KZ

37*										
LT-KZ-35*	Turgen	Kurgan 26, burial 1	EIA	1st phalanx	-15.40	11.59	3.3			South-east KZ

Table 3: Animal stable isotope values from Kazakhstan (samples marked with * were published earlier in Ananyevskaya et al. (2018)). This table does not include data from Ashutasty.

Sample ID	**Site**	**Period**	**Specie**	**δ^{13}C‰**	**δ^{15}N‰**	**C/N atomic**	**C%**	**N%**	**Region**
EA-SI-180	Shagalaly	Late BA	caprine	-19,89	3,90	3.3	49,11	17,34	Northern KZ
EA-SI-181	Shagalaly	Late BA	horse	-20,39	4,11	3.4	47,94	16,55	Northern KZ
EA-SI-182	Shagalaly	Late BA	red deer	-20,58	5,10	3.3	47,51	17,06	Northern KZ
EA-SI-183	Shagalaly	Late BA	horse	-19,96	4,88	3.3	32,20	11,38	Northern KZ
EA-SI-184	Shagalaly	Late BA	cattle	-20,61	4,41	3.4	46,62	16,23	Northern KZ
EA-SI-185	Shagalaly	Late BA	caprine	-19,75	4,70	3.3	50,17	17,70	Northern KZ
EA-SI-187	Shagalaly	Late BA	horse	-20,74	3,07	3.3	47,92	16,72	Northern KZ
EA-SI-188	Shagalaly	Late BA	caprine	-19,62	4,64	3.3	49,09	17,50	Northern KZ
EA-SI-189	Shagalaly	Late BA	cattle	-19,28	5,95	3.3	48,22	16,99	Northern KZ
EA-SI-190	Shagalaly	Late BA	caprine	-18,34	9,68	3.3	48,49	17,41	Northern KZ
EA-SI-191	Shagalaly-5	Late BA	caprine	-20,22	5,07	3.3	46,56	16,39	Northern KZ
EA-SI-198	Koshkarbai-1	Late BA	caprine	-20,49	4,13	3.2	44,10	16,09	Northern KZ
EA-SI-192	Shondykorasy-2	IA	caprine	-20,17	5,87	3.3	43,36	15,44	Northern KZ
EA-SI-194	Ostrogorka	IA	horse	-21,51	4,46	3.4	37,61	13,08	Northern KZ

EA-SI-193	Syganak	Medieval	dog	-20,09	9,58	3.6	41,48	13,46	Northern KZ
LT-KZ-56*	Tobolskyi	Final BA	horse	-21,28	4,31	3.3			Northern KZ
LT-KZ-57*	Tobolskyi	Final BA	caprine	-19,72	9,15	3.6			Northern KZ
LT-KZ-83*	Karatobe	II BC — II AD	caprine	-19,04	10,33	3.3			Eastern KZ
EA-SI-179	Karazhartas	IA	caprine	-17,48	8,37	3.4	46,00	15,74	Central KZ
EA-SI-199	Taldysai	BA	caprine	-19,99	5,06	3.3	45,79	16,13	Central KZ
EA-SI-200	Taldysai	BA	horse	-19,12	8,92	3.3	43,15	15,18	Central KZ
EA-SI-202	Taldysai	BA	caprine	-19,07	8,54	3.2	47,05	17,02	Central KZ
EA-SI-205	Taldysai	BA	cattle	-19,08	8,98	3.3	45,54	16,05	Central KZ
EA-SI-208	Taldysai	BA	caprine	-18,81	9,66	3.2	46,78	16,93	Central KZ
EA-SI-209	Taldysai	BA	cattle	-19,66	10,70	3.3	46,36	16,26	Central KZ
BTC-11	Tankara	BA	caprine	-19,91	6,32	3.4	37,47	12,84	Central KZ
EA-SI-178	Zhartas	IA	caprine	-17,70	9,78	3.4	39,97	13,84	Central KZ
LT-KZ-74*	Abylai	VIII-V BC	caprine	-19,40	8,69	3.4			Central KZ
LT-KZ-75*	Abylai	VIII-V BC	horse	-21,23	7,07	3.5			Central KZ
LT-KZ-60*	Akbeit	IX-VI BC	cattle	-19,85	7,97	3.6			Central KZ
LT-KZ-62*	Akbeit	IX-VI BC	caprine	-18,64	10,54	3.2			Central KZ
LT-KZ-63*	Akbeit	IX-VI BC	caprine	-19,94	7,83	3.5			Central KZ
LT-KZ-64*	Akbeit	IX-VI BC	caprine	-18,95	10,20	3.3			Central KZ

LT-KZ-65*	Akbeit	IX-VI BC	horse	-20,82	5,31	3.5			Central KZ
LT-KZ-66*	Akbeit	IX-VI BC	caprine	-20,36	6,74	3.3			Central KZ
LT-KZ-79*	Dongal	Fin BA	cattle	-20,17	8,27	3.5			Central KZ
LT-KZ-76*	Karashoky	IX-V BC	caprine	-19,16	8,21	3.3			Central KZ
LT-KZ-77*	Karashoky	IX-V BC	caprine	-19,66	9,04	3.3			Central KZ
LT-KZ-80*	Kent	Fin BA	cattle	-20,25	7,03	3.4			Central KZ
LT-KZ-81*	Kent	Fin BA	animal bone	-19,77	7,59	3.4			Central KZ
LT-KZ-82*	Kent	Fin BA	cattle	-19,77	10,05	3.4			Central KZ
LT-KZ-67*	Kyzylsuir 2	VII-VI BC	cattle	-20,51	6,91	3.3			Central KZ
LT-KZ-68*	Kyzylsuir 2	VII-VI BC	cattle	-19,46	7,80	3.3			Central KZ
LT-KZ-69*	Kyzylsuir 2	VII-VI BC	cattle	-20,00	9,50	3.3			Central KZ
LT-KZ-70*	Kyzylsuir 2	VII-VI BC	cattle	-20,32	8,27	3.3			Central KZ
LT-KZ-71*	Kyzylsuir 2	VII-VI BC	cattle	-19,91	8,57	3.3			Central KZ
LT-KZ-73*	Kyzylsuir 2	VII-VI BC	cattle	-20,15	7,84	3.3			Central KZ
LT-KZ-78*	Okule 5	VII BC	caprine	-20,92	7,38	3.4			Central KZ
EA-SI-132	Taksai-1	IA	horse	-19,57	5,85	3.2	44,31	16,10	Western KZ
EA-SI-133	Taksai-2	IA	horse	-19,96	6,28	3.3	46,98	16,61	Western KZ

EA-SI-134	Taksai-2	IA	horse	-19,83	7,18	3.3	43,60	15,29	Western KZ
EA-SI-135	Taksai-2	IA	horse	-20,19	5,83	3.2	48,77	17,85	Western KZ
EA-SI-136	Taksai-2	IA	horse	-20,18	6,00	3.3	45,74	16,27	Western KZ
EA-SI-137	Taksai-2	IA	horse	-19,75	8,23	3.4	45,28	15,55	Western KZ
EA-SI-138	Taksai-2	IA	cattle	-19,72	7,68	3.3	45,69	16,07	Western KZ
EA-SI-139	Taksai-2	IA	cattle	-19,25	7,90	3.3	47,79	16,77	Western KZ
EA-SI-140	Taksai-2	IA	caprine	-18,73	7,70	3.2	47,34	17,13	Western KZ
EA-SI-141	Taksai-2	IA	caprine	-19,46	6,77	3.3	44,23	15,88	Western KZ
EA-SI-142	Taksai-2	IA	caprine	-20,31	5,58	3.3	46,76	16,42	Western KZ
EA-SI-143	Taksai-2	IA	caprine	-20,62	5,82	3.5	43,70	14,78	Western KZ
EA-SI-146	Taksai-2	IA	caprine	-20,83	5,98	3.3	40,43	14,28	Western KZ
EA-SI-147	Taksai-3	IA	horse	-20,75	5,10	3.5	44,23	14,80	Western KZ
EA-SI-149	Taksai-3	IA	horse	-21,02	5,57	3.5	41,04	13,61	Western KZ
EA-SI-150	Taksai-3	IA	caprine	-19,47	6,54	3.3	46,49	16,39	Western KZ
EA-SI-151	Taksai-3	IA	caprine	-19,12	7,66	3.3	44,69	15,82	Western KZ
EA-SI-167	Babish-Mulla-7	IA	cattle	-16,81	8,62	3.2	46,12	16,98	Syr-Darya and Otrar
EA-SI-168	Babish-Mulla-7	IA	caprine	-17,96	9,76	3.3	44,94	16,06	Syr-Darya and Otrar
EA-SI-170	Babish-Mulla-7	IA	caprine	-17,04	8,56	3.3	45,13	16,06	Syr-Darya and Otrar
EA-SI-172	Babish-Mulla-7	IA	caprine	-15,68	11,03	3.3	46,75	16,64	Syr-Darya and Otrar
EA-SI-173	Chirik Rabat	IA	cattle	-12,20	10,16	3.3	42,12	14,84	Syr-Darya and Otrar
EA-SI-152	Kyzylbulak-4	BA	cattle	-19,70	3,40	3.3	43,71	15,25	South-east KZ
EA-SI-153	Kyzylbulak-4	IA	cattle	-19,61	7,95	3.3	44,32	15,54	South-east KZ

EA-SI-154	Kyzylbulak-4	BA	cattle	-17,47	6,01	3.6	39,14	12,77	South-east KZ
EA-SI-212	Serektas	BA	caprine	-18,99	6,38	3.3	40,28	14,37	South-east KZ
EA-SI-213	Serektas	BA	caprine	-18,49	7,30	3.4	34,91	11,84	South-east KZ
EA-SI-214	Serektas	BA	cattle	-18,33	8,89	3.4	38,00	13,19	South-east KZ
EA-SI-215	Serektas	BA	horse	-18,78	8,63	3.4	41,16	14,03	South-east KZ
EA-SI-216	Serektas	BA	horse	-19,41	7,93	3.3	45,71	15,95	South-east KZ
EA-SI-217	Serektas-2	BA	horse	-19,29	7,60	3.4	47,92	16,66	South-east KZ
EA-SI-219	Serektas-2	BA	horse	-17,59	11,74	3.3	46,50	16,33	South-east KZ
EA-SI-220	Serektas-2	BA	cattle	-17,85	8,52	3.3	46,26	16,49	South-east KZ
EA-SI-221	Serektas-2	BA	caprine	-16,33	7,63	3.3	46,37	16,73	South-east KZ
EA-SI-222	Serektas-2	BA	caprine	-17,87	4,92	3.5	37,94	12,84	South-east KZ
EA-SI-223	Serektas-2	BA	caprine	-18,25	8,92	3.3	42,60	14,89	South-east KZ
EA-SI-224	Serektas-2	BA	caprine	-18,28	9,73	3.3	38,57	13,62	South-east KZ
EA-SI-225	Serektas-2	BA	caprine	-17,36	8,79	3.3	47,63	16,95	South-east KZ
EA-SI-226	Serektas-2	BA	cattle	-17,92	9,54	3.4	45,08	15,70	South-east KZ
EA-SI-228	Serektas-2	BA	horse	-18,10	9,25	3.4	39,39	13,47	South-east KZ
EA-SI-155	Turgen-2	BA	cattle	-20,61	5,02	3.3	46,88	16,49	South-east KZ
EA-SI-156	Turgen-2	BA	cattle	-18,99	6,34	3.2	46,21	16,66	South-east KZ
EA-SI-159	Turgen-2	BA	cattle	-20,02	5,87	3.3	47,49	17,05	South-east KZ
EA-SI-161	Turgen-2	BA	horse	-20,12	5,77	3.3	45,58	16,32	South-east KZ
EA-SI-162	Turgen-2	BA	caprine	-19,01	5,46	3.4	49,96	17,08	South-east KZ
EA-SI-163	Turgen-2	BA	caprine	-19,97	5,24	3.3	47,13	16,84	South-east KZ

EA-SI-164	Turgen-2	BA	caprine	-19,71	5,35	3.3	46,73	16,48	South-east KZ
EA-SI-165	Turgen-2	BA	caprine	-18,82	7,03	3.4	46,20	15,96	South-east KZ
EA-SI-166	Turgen-2	BA	caprine	-19,83	4,97	3.3	50,12	17,65	South-east KZ

Appendix 4: Previously published stable isotope data used in the statistical analyses (dates marked by * indicate relative dating by archaeological affiliation)

Table 1: Previously published human stable isotope data

Sample ID	**Site**	**Context**	**Date/Period**	$\delta^{13}C$ ‰	$\delta^{15}N$ ‰	**C/N atomic**	**Source**
CGG_2_016125 DA127	Aktas		AD 252-304 cal.	-15,5	12,0	3.1	de Barros Damgaard et al. 2018
CGG_2_016124 DA126	Almaly	Kurgan 1, Object 1	AD 901-920 cal.	-14,8	12,6	3.1	de Barros Damgaard et al. 2018
CGG_2_019168 DA224	Besynshitobe	Excavation 1, layer 3, grave 3	AD 264-273 cal.	-19,4	12,6	3.2	de Barros Damgaard et al. 2018
CGG_2_015474 DA17	Birlik	Kurgan 12	800-773 cal. BC	-18,3	12,4	3.2	de Barros Damgaard et al. 2018
CGG_2_019095 DA204	Butakty-1	Grave 34	AD 897-925 cal.	-12,6	12,3	3.2	de Barros Damgaard et al. 2018
CGG_2_016122 DA124	Esik		AD 654-589 cal.	-15,9	11,2	3.2	de Barros Damgaard et al. 2018
CGG_2_015429 DA27	Halvai	Kurgan 3, 3A	AD 349-368 cal.	-18,2	13,6	3.2	de Barros Damgaard et al. 2018
CGG_2_016126 DA128	Janaturmus	Object 1	AD 1230-1230 cal.	-17,3	14,8	3.1	de Barros Damgaard et al. 2018
CGG_2_015471 DA14	Karashoky-1	Kurgan 8	753-681 cal. BC	-18,5	15,6	3.2	de Barros Damgaard et al. 2018
CGG_2_015472 DA15	Karashoky-6	Kurgan 1	755-680 cal. BC	-17,7	15,8	3.2	de Barros Damgaard et al. 2018

CGG_2_019115 DA221	Kargaly-1	Grave 9	790-747 cal. BC	-13,0	15,0	3.2	de Barros Damgaard et al. 2018
CGG_2_016123 DA125	Kok-Mardan		AD 140-160 cal.	-16,1	11,9	3.2	de Barros Damgaard et al. 2018
CGG_2_016119 DA121	Kok-Mardan	Kurgan7, Object 7	AD 264-273 cal.	-17,8	12,7	3.2	de Barros Damgaard et al. 2018
CGG_2_019104 DA206	Konyr-Tobe	Kurgan 1, grave 19	AD 133-254 cal.	-15,8	12,6	3.2	de Barros Damgaard et al. 2018
CGG_2_015449 DA11	Kurgan Borli		766-729 cal. BC	-16,7	13,7	3.2	de Barros Damgaard et al. 2018
CGG_2_016127 DA129	Kyzylasker	Object 1	427-422 cal. BC	-14,4	12,8	3.2	de Barros Damgaard et al. 2018
CGG_2_015425 DA23	Lisakovsk	Kipchak burial	AD 1045-1095 cal.	-18,1	13,3	3.2	de Barros Damgaard et al. 2018
CGG_2_015432 DA30	Naurzum	Kurgan 3	47 BC - AD 24	-17,5	14,6	3.2	de Barros Damgaard et al. 2018
CGG_2_015473 DA16	Nazar-2	Kurgan 1	750-683 cal. BC	-18,0	14,8	3.2	de Barros Damgaard et al. 2018
CGG_2_016128 DA130	Ornek	Object 1, Kurgan 2	357-284 cal. BC	-14,6	15,2	3.2	de Barros Damgaard et al. 2018
CGG_2_015338 DA18	Shidertinskoye-2	Burial 1	753-681 cal. BC	-18,1	12,1	3.2	de Barros Damgaard et al. 2018
CGG_2_015470 DA13	Taldy-2	Kurgan 5	752-682 cal. BC	-16,8	14,5	3.2	de Barros Damgaard et al. 2018
CGG_2_019126 DA223	Turgen-2		403-374 cal. BC	-13,9	12,4	3.2	de Barros Damgaard et al. 2018
CGG_2_019092	Turgen-2	Kurgan 10, grave 2	171-88 cal. BC	-16,3	13,5	3.2	de Barros Damgaard et al. 2018
KA-5 A0937	Kamennyi Ambar	Kurgan 4, pit 3	MBA*	-17,9	14,2	3.5	Hanks et al. 2018
KA-5 A0939	Kamennyi Ambar	Kurgan 4, pit 1	MBA*	-18,2	12,2	3.5	Hanks et al. 2018
KA-5 A0940	Kamennyi Ambar	Kurgan 4, mound	MBA*	-18,3	13,1	3.5	Hanks et al. 2018

KA-5 A0941	Kamennyi Ambar	Kurgan 4, mound	MBA*	-18,2	13,5	3.4	Hanks et al. 2018
KA-5 A0942	Kamennyi Ambar	Kurgan 4, mound	MBA*	-18,3	12,6	3.4	Hanks et al. 2018
KA-5 A0945	Kamennyi Ambar	Kurgan 4, pit 9	MBA*	-18,2	12,2	3.1	Hanks et al. 2018
KA-5 A0946	Kamennyi Ambar	Kurgan 4, pit 11	MBA*	-18,6	12,9	3.5	Hanks et al. 2018
KA-5 A0947	Kamennyi Ambar	Kurgan 4, pit 9	MBA*	-19,4	10,6	3.5	Hanks et al. 2018
KA-5 A0948	Kamennyi Ambar	Kurgan 4, pit 9	MBA*	-19	11,4	3.4	Hanks et al. 2018
KA-5 A0949	Kamennyi Ambar	Kurgan 4, pit 11	MBA*	-17,7	13,4	3.5	Hanks et al. 2018
KA-5 A0950	Kamennyi Ambar	Kurgan 4, pit 2	MBA*	-17,8	13,4	3.0	Hanks et al. 2018
KA-5 A0951	Kamennyi Ambar	Kurgan 4, pit 2	MBA*	-18	13,9	3.4	Hanks et al. 2018
KA-5 A0952	Kamennyi Ambar	Kurgan 4, pit 2	MBA*	-18,1	14	3.5	Hanks et al. 2018
KA-5 A0953	Kamennyi Ambar	Kurgan 4, pit 2	MBA*	-17,9	13,9	3.5	Hanks et al. 2018
KA-5 A0954	Kamennyi Ambar	Kurgan 4, pit 2	MBA*	-18	15,6	3.5	Hanks et al. 2018
KA-5 A0955	Kamennyi Ambar	Kurgan 4, pit 2	MBA*	-17,8	14,4	3.5	Hanks et al. 2018
KA-5 A0956	Kamennyi Ambar	Kurgan 4, pit 5	MBA*	-17,9	14,5	3.5	Hanks et al. 2018
KA-5 A0957	Kamennyi Ambar	Kurgan 4, pit 5	MBA*	-17,6	13,9	3.4	Hanks et al. 2018
KA-5 A0960	Kamennyi Ambar	Kurgan 4, pit 5	MBA*	-18	13	3.5	Hanks et al. 2018
KA-5 A0962	Kamennyi Ambar	Kurgan 2, pit 4	MBA*	-17,8	15,1	3.6	Hanks et al. 2018
KA-5 A0963	Kamennyi Ambar	Kurgan 2, pit 4	MBA*	-17,6	15,6	3.5	Hanks et al. 2018
KA-5 A0964	Kamennyi Ambar	Kurgan 2, pit 4	MBA*	-17,9	13,2	3.5	Hanks et al. 2018
KA-5 A0965	Kamennyi Ambar	Kurgan 2, pit 4	MBA*	-17,5	14,6	3.5	Hanks et al. 2018
KA-5 A0966	Kamennyi Ambar	Kurgan 2, pit 4	MBA*	-17,2	15,6	3.5	Hanks et al. 2018
KA-5 A0967	Kamennyi Ambar	Kurgan 2, pit 4	MBA*	-19	12,3	3.1	Hanks et al. 2018

KA-5 A0968	Kamennyi Ambar	Kurgan 2, pit 10	MBA*	-17,9	13,1	3.1	Hanks et al. 2018
KA-5 A0969	Kamennyi Ambar	Kurgan 2, pit 10	MBA*	-17,9	11,9	3.4	Hanks et al. 2018
KA-5 A0970	Kamennyi Ambar	Kurgan 2, pit 10	MBA*	-18,3	10,8	3.5	Hanks et al. 2018
KA-5 A0971	Kamennyi Ambar	Kurgan 2, pit 8	MBA*	-19,1	11,6	3.5	Hanks et al. 2018
KA-5 A0972	Kamennyi Ambar	Kurgan 2, Tr.5	MBA*	-18,2	15,6	3.1	Hanks et al. 2018
KA-5 A0973	Kamennyi Ambar	Kurgan 2, Tr.1	MBA*	-17,9	14,1	3.1	Hanks et al. 2018
KA-5 A0975	Kamennyi Ambar	Kurgan 2, pit 11	MBA*	-18	12,8	3.2	Hanks et al. 2018
KA-5 A0976	Kamennyi Ambar	Kurgan 2, pit 11	MBA*	-18	12,6	3.4	Hanks et al. 2018
KA-5 A0977	Kamennyi Ambar	Kurgan 2, pit 11	MBA*	-16,8	14,8	3.4	Hanks et al. 2018
KA-5 A0978	Kamennyi Ambar	Kurgan 2, pit 16	MBA*	-17,5	14,5	3.1	Hanks et al. 2018
KA-5 A0979	Kamennyi Ambar	Kurgan 2, pit 17	MBA*	-18,2	12,3	3.1	Hanks et al. 2018
KA-5 A0980	Kamennyi Ambar	Kurgan 2, pit 17	MBA*	-18,1	12,4	3.4	Hanks et al. 2018
KA-5 A0981	Kamennyi Ambar	Kurgan 2, pit 3	MBA*	-18,4	12,2	3.5	Hanks et al. 2018
KA-5 A0982	Kamennyi Ambar	Kurgan 2, pit 15	MBA*	-17,8	13,6	3.5	Hanks et al. 2018
KA-5 A0983	Kamennyi Ambar	Kurgan 2, pit 12	MBA*	-17,9	13,4	3.5	Hanks et al. 2018
KA-5 A0984	Kamennyi Ambar	Kurgan 2, pit 12	MBA*	-17,4	14,4	3.3	Hanks et al. 2018
KA-5 A0985	Kamennyi Ambar	Kurgan 2, pit 12	MBA*	-19,7	11,3	3.1	Hanks et al. 2018
KA-5 A0986	Kamennyi Ambar	Kurgan 2, pit 12	MBA*	-19,4	14,8	3.5	Hanks et al. 2018
KA-5 A0988	Kamennyi Ambar	Kurgan 2, pit 14	MBA*	-18	13,8	3.4	Hanks et al. 2018
KA-5 A0989	Kamennyi Ambar	Kurgan 2, pit 7	MBA*	-18,5	12,5	3.5	Hanks et al. 2018
KA-5 A0990	Kamennyi Ambar	Kurgan 2, pit 7	MBA*	-18,3	11,9	3.4	Hanks et al. 2018
KA-5 A0991	Kamennyi Ambar	Kurgan 2, pit 7	MBA*	-18,5	12,2	3.5	Hanks et al. 2018

KA-5 A0992	Kamennyi Ambar	Kurgan 2, pit 7	MBA*	-18,2	12,1	3.1	Hanks et al. 2018
KA-5 A0993	Kamennyi Ambar	Kurgan 2, pit 7	MBA*	-18,3	12,9	3.4	Hanks et al. 2018
KA-5 A0994	Kamennyi Ambar	Kurgan 2, pit 7	MBA*	-18,7	11,7	3.4	Hanks et al. 2018
KA-5 A0995	Kamennyi Ambar	Kurgan 2, pit 6	MBA*	-18,4	12,6	3.2	Hanks et al. 2018
KA-5 A0996	Kamennyi Ambar	Kurgan 2, pit 6	MBA*	-18,5	11,5	3.4	Hanks et al. 2018
KA-5 A0997	Kamennyi Ambar	Kurgan 2, pit 6	MBA*	-18	12,9	3.1	Hanks et al. 2018
KA-5 A1000	Kamennyi Ambar	Kurgan 2, pit 6	MBA*	-17,9	14,9	3.5	Hanks et al. 2018
KA-5 A1002	Kamennyi Ambar	Kurgan 2, pit 6	MBA*	-17,7	14,8	3.1	Hanks et al. 2018
KA-5 A1005	Kamennyi Ambar	Kurgan 2, pit 9	MBA*	-17,7	13,4	3.4	Hanks et al. 2018
KA-5 A1006	Kamennyi Ambar	Kurgan 2, pit 9	MBA*	-17,7	14,2	3.4	Hanks et al. 2018
KA-5 A1008	Kamennyi Ambar	Kurgan 2, pit 8	MBA*	-18,2	14,2	3.1	Hanks et al. 2018
KA-5 A1009	Kamennyi Ambar	Kurgan 2, pit 8	MBA*	-18,3	11,7	3.1	Hanks et al. 2018
KA-5 A1010	Kamennyi Ambar	Kurgan 2, pit 8	MBA*	-17,8	13,3	3.3	Hanks et al. 2018
KA-5 A1011	Kamennyi Ambar	Kurgan 2, pit 13	MBA*	-18,2	12,3	3.2	Hanks et al. 2018
KA-5 A1012	Kamennyi Ambar	Kurgan 2, pit 5	MBA*	-18,8	11,2	3.1	Hanks et al. 2018
KA-5 A1013	Kamennyi Ambar	Kurgan 2, pit 5	MBA*	-19	10,6	3.1	Hanks et al. 2018
KA-5 A1014	Kamennyi Ambar	Kurgan 2, pit 5	MBA*	-18,3	12,8	3.1	Hanks et al. 2018
KA-5 A1015	Kamennyi Ambar	Kurgan 2, pit 5	MBA*	-19,1	11,2	3.2	Hanks et al. 2018
KA-5 A1016	Kamennyi Ambar	Kurgan 2, pit 5	MBA*	-19	11	3.2	Hanks et al. 2018
KA-5 A1017	Kamennyi Ambar	Kurgan 2, pit 5	MBA*	-19,3	11,3	3.2	Hanks et al. 2018
KA-5 A1018	Kamennyi Ambar	Kurgan 2, pit 5	MBA*	-19,1	11,1	3.2	Hanks et al. 2018
KA-5 A1024	Kamennyi Ambar	Kurgan 4, pit 4	MBA*	-17,8	12,9	3.2	Hanks et al. 2018

6966	Karatal	Karatal BR-1	X-XI AD*	-18,0	13,9	3.1	Hermes et al. 2018
6965	Karatal	Karatal BR-2	X-XI AD*	-18,1	12,7	2.9	Hermes et al. 2018
5164	Karatal	KZ-BR5	VIII-X AD*	-16,2	12,4	3.1	Hermes et al. 2018
KZ087	Akimbek	kurgan 5, grave 1	BA*	-18,5	15,5	3.3	Lightfoot et al. 2015
KZ065	Akimbek	kurgan 2, grave 1	BA*	-18,4	12,9	3.2	Lightfoot et al. 2015
KZ064	Akimbek	kurgan 1, grave 1	BA*	-18,2	13,3	3.2	Lightfoot et al. 2015
KZ063	Akimbek	kurgan 1	BA*	-18,1	14,1	3.2	Lightfoot et al. 2015
KZ062	Akimbek	grave 4	BA*	-18,4	14,4	3.2	Lightfoot et al. 2015
KZ076	Aschisu		BA*	-17,8	13,6	3.2	Lightfoot et al. 2015
KZ059	Aschisu	kurgan 2, grave 1	EBA-MBA*	-18,4	12,5	3.2	Lightfoot et al. 2015
KZ058	Aschisu	kurgan 1, grave 1	EBA-MBA*	-18,8	11,7	3.2	Lightfoot et al. 2015
KZ057	Aschisu	kurgan 5, grave 2	EBA-MBA*	-18,4	12,8	3.2	Lightfoot et al. 2015
KZ056	Aschisu	kurgan 2, grave 1	EBA-MBA*	-19,1	11,5	3.2	Lightfoot et al. 2015
KZ055	Aschisu	kurgan 1, grave1	EBA-MBA*	-18,6	11,7	3.2	Lightfoot et al. 2015
KZ054	Aschisu	kurgan 1, grave 2	EBA-MBA*	-18,7	11,9	3.2	Lightfoot et al. 2015
KZ052	Aschisu	kurgan 1, grave 1	EBA-MBA*	-17,2	14,2	3.3	Lightfoot et al. 2015
KZ050	Aschisu	kurgan 5, grave 1	EBA-MBA*	-18,9	12,4	3.2	Lightfoot et al. 2015
KZ051	Ayapbergen	kurgan 1, grave 2	EBA-MBA*	-18,5	12,3	3.2	Lightfoot et al. 2015
KZ044	Daryinskyi	grave 7	XIX-XVIII BC*	-17,7	14,2	3.2	Lightfoot et al. 2015
KZ043	Daryinskyi	grave 5	XIX-XVIII BC*	-18,1	14,2	3.2	Lightfoot et al. 2015
KZ042	Daryinskyi	grave 9	XIX-XVIII BC*	-18	14,3	3.2	Lightfoot et al. 2015
KZ102	Kairakty		EBA-MBA*	-19	11,6	3.2	Lightfoot et al. 2015

KZ100	Karatugai	kurgan 8	FBA-EIA*	-18,8	12,7	3.2	Lightfoot et al. 2015
KZ099	Karatugai	kurgan 6	FBA-EIA*	-18,1	14,3	3.2	Lightfoot et al. 2015
KZ098	Karatugai	kurgan 10	FBA-EIA*	-17,8	13,9	3.2	Lightfoot et al. 2015
KZ097	Karatugai	kurgan 1	FBA-EIA*	-17,7	14	3.2	Lightfoot et al. 2015
KZ096	Karatugai	kurgan 5	FBA-EIA*	-18,4	12,8	3.3	Lightfoot et al. 2015
KZ104	Kent	Settlement	FBA-EIA*	-16	13,5	3.3	Lightfoot et al. 2015
KZ061	Kopa-1	grave 1	EBA-MBA*	-18,3	12,5	3.3	Lightfoot et al. 2015
KZ085	Kudryavaya Sopka-1	kurgan 1, grave 1	FBA-EIA*	-18,4	15,7	3.3	Lightfoot et al. 2015
KZ075	Kudryavaya Sopka-1	kurgan 1, grave 2	FBA-EIA*	-18,1	15,3	3.2	Lightfoot et al. 2015
KZ092	Kyzyl	kurgan 8	FBA-EIA*	-16,8	13	3.2	Lightfoot et al. 2015
KZ084	Kyzylkol	kurgan 1, grave 1	EBA-MBA*	-18,4	14,4	3.3	Lightfoot et al. 2015
KZ083	Kyzylkol	kurgan 1, grave 2	EBA-MBA*	-19,2	13,2	3.3	Lightfoot et al. 2015
KZ082	Kyzylkol	kurgan 1, grave 3	EBA-MBA*	-18,9	13	3.3	Lightfoot et al. 2015
KZ081	Kyzylkol	kurgan 1, grave 4	EBA-MBA*	-18,8	13,4	3.2	Lightfoot et al. 2015
KZ080	Kyzylkol	kurgan 1, grave 5	EBA-MBA*	-18,4	15,1	3.3	Lightfoot et al. 2015
KZ079	Kyzylkol	kurgan 1, grave 6	EBA-MBA*	-18,9	13,1	3.4	Lightfoot et al. 2015
KZ078	Kyzylkol	kurgan 1, grave 8	EBA-MBA*	-18,3	13,8	3.2	Lightfoot et al. 2015
KZ077	Kyzylkol	kurgan 1, grave 9	EBA-MBA*	-18,2	14	3.2	Lightfoot et al. 2015
KZ027	Nurataldy-1		EBA*	-18,6	14,3	3.3	Lightfoot et al. 2015
KZ090	Tashik	kurgan 5, grave 1	XIX-XVIII BC*	-18,3	12,5	3.3	Lightfoot et al. 2015
KZ089	Tashik	kurgan 17, grave 1	XIX-XVIII BC*	-18	12,9	3.3	Lightfoot et al. 2015
KZ088	Tashik	kurgan 12	XIX-XVIII BC*	-18,7	12,9	3.2	Lightfoot et al. 2015

KZ073	Tashik	kurgan 10, grave 5	XIX-XVIII BC*	-18,2	13,1	3.2	Lightfoot et al. 2015
KZ072	Tashik	kurgan 7, grave 1	XIX-XVIII BC*	-18,7	12,6	3.2	Lightfoot et al. 2015
KZ071	Tashik	kurgan 10, grave 5	XIX-XVIII BC*	-18,2	14,9	3.3	Lightfoot et al. 2015
KZ070	Tashik	kurgan 10, grave 1	XIX-XVIII BC*	-18,3	14	3.2	Lightfoot et al. 2015
KZ069	Tashik	kurgan 10, grave 5	XIX-XVIII BC*	-18,1	14,7	3.2	Lightfoot et al. 2015
KZ068	Tashik	kurgan 7	XIX-XVIII BC*	-18,9	12,7	3.3	Lightfoot et al. 2015
KZ067	Tashik	kurgan 10, grave 4	XIX-XVIII BC*	-18,2	13,6	3.3	Lightfoot et al. 2015
KZ049	Tashik	kurgan 3, grave 1	XIX-XVIII BC*	-18,5	13	3.2	Lightfoot et al. 2015
KZ048	Tashik	kurgan 8, grave 4	XIX-XVIII BC*	-18,5	13,3	3.2	Lightfoot et al. 2015
KZ047	Tashik	kurgan 8, grave 2	XIX-XVIII BC*	-18,6	13,8	3.3	Lightfoot et al. 2015
KZ046	Tashik	kurgan 8, grave 4	XIX-XVIII BC*	-18,7	13,1	3.3	Lightfoot et al. 2015
KZ045	Tashik	kurgan 3, grave 2	XIX-XVIII BC*	-18,7	12,6	3.2	Lightfoot et al. 2015
KZ066	Tasyrbai	kurgan 13	BA*	-18,6	11,4	3.3	Lightfoot et al. 2015
KZ053	Tasyrbai	kurgan 10, grave 1	LBA*	-15,7	17,7	3.2	Lightfoot et al. 2015
KZ103	Tegiszhol	kurgan 10, grave 1	LBA	-18,9	13	3.2	Lightfoot et al. 2015
KZ026	Tegiszhol	kurgan 1	BA*	-18,3	12,8	3.1	Lightfoot et al. 2015
KZ025	Tegiszhol	kurgan 3	BA*	-16,4	13	3.1	Lightfoot et al. 2015
KZ024	Tegiszhol	kurgan 4	BA*	-18,1	12,9	3.2	Lightfoot et al. 2015
KZ023	Tegiszhol	kurgan 5	BA*	-17,7	13,7	3.2	Lightfoot et al. 2015
KZ021	Tegiszhol	kurgan 21	BA*	-18,3	14,1	3.2	Lightfoot et al. 2015
KZ020	Tegiszhol	kurgan 31, grave 2	BA*	-18,6	12,9	3.2	Lightfoot et al. 2015
KZ019	Tegiszhol	kurgan 17	BA*	-17,9	13,2	3.2	Lightfoot et al. 2015

KZ018	Tegiszhol	kurgan 18	BA*	-18,1	15,5	3.2	Lightfoot et al. 2015
KZ017	Tegiszhol	kurgan 19	BA*	-19,1	11,8	3.3	Lightfoot et al. 2015
KZ016	Tegiszhol	kurgan 20	BA*	-18,9	12,6	3.2	Lightfoot et al. 2015
KZ015	Tegiszhol	kurgan 24	BA*	-18,4	12,1	3.2	Lightfoot et al. 2015
KZ013	Tegiszhol	kurgan 9, grave 4	BA*	-18,1	12,9	3.2	Lightfoot et al. 2015
KZ012	Tegiszhol	kurgan 9, grave 3	BA*	-18,4	12,9	3.2	Lightfoot et al. 2015
KZ011	Tegiszhol	kurgan 9, grave 2	BA*	-18,1	12,7	3.2	Lightfoot et al. 2015
KZ010	Tegiszhol	kurgan 9, grave 1	BA*	-18,6	11,9	3.2	Lightfoot et al. 2015
KZ009	Tegiszhol	kurgan 9	BA*	-17,4	13,3	3.1	Lightfoot et al. 2015
KZ008	Tegiszhol	kurgan 31, grave 1	BA*	-18,3	12,8	3.2	Lightfoot et al. 2015
KZ007	Tegiszhol	kurgan 32, grave 1	BA*	-18,5	12,1	3.2	Lightfoot et al. 2015
KZ005	Tegiszhol	kurgan 29	BA*	-18,3	13,7	3.2	Lightfoot et al. 2015
KZ004	Tegiszhol	kurgan 26, grave 3	BA*	-18,1	12,7	3.2	Lightfoot et al. 2015
KZ003	Tegiszhol	kurgan 8	BA*	-18,5	12,7	3.2	Lightfoot et al. 2015
KZ002	Tegiszhol	kurgan 7, grave 1	BA*	-18,3	13,4	3.2	Lightfoot et al. 2015
KZ001	Tegiszhol	kurgan 26	BA*	-17,9	13,3	3.2	Lightfoot et al. 2015
KZ095	Tegiszhol	kurgan 27, grave 1	IA*	-18,2	14,1	3.3	Lightfoot et al. 2015
KZ014	Tegiszhol	kurgan 27, grave 1	IA*	-17,3	14,4	3.2	Lightfoot et al. 2015
KZ094	Temirkash	kurgan 9	FBA*	-17,6	13,3	3.2	Lightfoot et al. 2015
KZ093	Temirkash	kurgan 4	FBA*	-18,8	12,7	3.2	Lightfoot et al. 2015
KZ101	Zhartas		IA*	-18,6	14,5	3.2	Lightfoot et al. 2015
GM_167	Akbidaik		FBA-EIA*	-18,2	13,5	3.1	Motuzaite Matuzeviciute et al. 2015

GM_039	Alatau-1	Kurgan 1/grave 3	IA*	-15,9	11,6	3.3	Motuzaite Matuzeviciute et al. 2015
GM_038	Alatau-1	Kurgan 1/grave 2	IA*	-17,3	10,0	3.2	Motuzaite Matuzeviciute et al. 2015
GM_037	Alatau-1	Kurgan 1/grave 1	IA*	-16,2	10,9	3.1	Motuzaite Matuzeviciute et al. 2015
GM_149	Bozshakol-2	Kurgan 3	BA*	-18,4	13,8	3.6	Motuzaite Matuzeviciute et al. 2015
GM_112	Bozshakol-2	grave 1	BA*	-18,9	11,5	3.1	Motuzaite Matuzeviciute et al. 2015
GM_018	Butakty-1	Grave 23	X-XII AD*	-12,1	11,7	3.2	Motuzaite Matuzeviciute et al. 2015
GM_017	Butakty-1	Grave 35/1	X-XII AD*	-11,2	12,2	3.1	Motuzaite Matuzeviciute et al. 2015
GM_016	Butakty-1	Kurgan 35/2	X-XII AD*	-11,2	12,1	3.4	Motuzaite Matuzeviciute et al. 2015
GM_014	Butakty-1	Kurgan 1/grave 1	X-XII AD*	-15,3	10,7	3.2	Motuzaite Matuzeviciute et al. 2015
GM_003	Butakty-1		X-XII AD*	-15,7	11,2	3.1	Motuzaite Matuzeviciute et al. 2015
GM_ 015	Butakty-1	Grave 16	X-XII AD*	-10,7	11,3	3.2	Motuzaite Matuzeviciute et al. 2015
GM_132	Kainarbulak-1		FBA-EIA*	-12,6	13,1	3.1	Motuzaite Matuzeviciute et al. 2015
GM_128	Kainarbulak-1	Kurgan 3/grave 2	FBA-EIA*	-13,9	11,1	3.1	Motuzaite Matuzeviciute et al. 2015
GM_127	Kainarbulak-1	Kurgan 3/grave 2	FBA-EIA*	-14,5	12,0	3.1	Motuzaite Matuzeviciute et al. 2015
GM_126	Kainarbulak-1	Kurgan 8	FBA-EIA*	-13,1	11,5	3.2	Motuzaite Matuzeviciute et al. 2015
GM_125B	Kainarbulak-1	Kurgan13/grave 1	FBA-EIA*	-11,1	10,5	3.3	Motuzaite Matuzeviciute et al. 2015

GM_125A	Kainarbulak-1	Kurgan13/grave 2	FBA-EIA*	-11,8	10,4	3.3	Motuzaite Matuzeviciute et al. 2015
GM_123	Kainarbulak-1	Kurgan 6	FBA-EIA*	-12,7	12,4	3.1	Motuzaite Matuzeviciute et al. 2015
GM_121	Kainarbulak-1	Kurgan 4	FBA-EIA*	-15,4	14,7	3.4	Motuzaite Matuzeviciute et al. 2015
GM_120	Kainarbulak-1	Kurgan 11/grave 2	FBA-EIA*	-13	13,6	3.1	Motuzaite Matuzeviciute et al. 2015
GM_119	Kainarbulak-1	Kurgan 5	FBA-EIA*	-11,3	12,5	3.2	Motuzaite Matuzeviciute et al. 2015
GM_118	Kainarbulak-1	Kurgan 6/grave 3?	FBA-EIA*	-14,2	13,4	3.3	Motuzaite Matuzeviciute et al. 2015
GM_117	Kainarbulak-1	Kurgan 11/grave 1	FBA-EIA*	-12,7	12,0	3.2	Motuzaite Matuzeviciute et al. 2015
GM_116	Kainarbulak-1	Kurgan 7/grave 2	FBA-EIA*	-11,2	12,9	3.3	Motuzaite Matuzeviciute et al. 2015
GM_115	Kainarbulak-1	Kurgan 7/grave 1	FBA-EIA*	-11,9	13,7	3.2	Motuzaite Matuzeviciute et al. 2015
GM_135	Kainarbulak-2	Kurgan 3	FBA-EIA*	-10,9	11,7	3.3	Motuzaite Matuzeviciute et al. 2015
GM_130	Kainarbulak-2	Kurgan 11/grave 2	FBA-EIA*	-10,5	10,4	3.3	Motuzaite Matuzeviciute et al. 2015
GM_129	Kainarbulak-2	Kurgan 11/grave 1	FBA-EIA*	-13	10,1	3.3	Motuzaite Matuzeviciute et al. 2015
GM_042	Kamenka	Kurgan 5/grave 2	FBA-EIA*	-15,3	9,7	3.2	Motuzaite Matuzeviciute et al. 2015
GM_041	Kamenka	Kurgan 12	FBA-EIA*	-15,6	12,3	3.2	Motuzaite Matuzeviciute et al. 2015
GM_040	Kamenka	Kurgan 5/grave 1	FBA-EIA	-16	10,3	3.3	Motuzaite Matuzeviciute et al. 2015
GM_F78	Karatuma	Kurgan 45	IA*	-16,5	11,3	3.3	Motuzaite Matuzeviciute et al. 2015

GM_158	Karatuma	Kurgan 59	IA*	-15,2	8,8	3.5	Motuzaite Matuzeviciute et al. 2015
GM_157	Karatuma	Kurgan49	IA*	-16,4	10,6	3.4	Motuzaite Matuzeviciute et al. 2015
GM_156	Karatuma	Kurgan47	IA*	-15,7	11,4	3.3	Motuzaite Matuzeviciute et al. 2015
GM_155	Karatuma	Kurgan 59	IA*	-13,5	11,9	3.4	Motuzaite Matuzeviciute et al. 2015
GM_148	Karatuma	Kurgan 64	IA*	-15,1	12,5	3.3	Motuzaite Matuzeviciute et al. 2015
GM_109	Karatuma		IA*	-17	9,0	3.3	Motuzaite Matuzeviciute et al. 2015
GM_099	Karatuma	Kurgan 8	IA*	-15,8	11,8	3.1	Motuzaite Matuzeviciute et al. 2015
GM_098	Karatuma	Kurgan 150	IA*	-13,8	13,2	3.1	Motuzaite Matuzeviciute et al. 2015
GM_095	Karatuma	Kurgan 107	IA*	-15,2	13,3	3.2	Motuzaite Matuzeviciute et al. 2015
GM_092	Karatuma	Kurgan 92	IA*	-15,1	12,3	3.2	Motuzaite Matuzeviciute et al. 2015
GM_090	Karatuma	Kurgan 163	IA*	-16,8	12,9	3.4	Motuzaite Matuzeviciute et al. 2015
GM_087	Karatuma	Kurgan 21	IA*	-16,3	10,7	3.2	Motuzaite Matuzeviciute et al. 2015
GM_086	Karatuma	Kurgan 20/g1	IA*	-16,1	13,4	3.2	Motuzaite Matuzeviciute et al. 2015
GM_083	Karatuma	Kurgan 21	IA*	-15,8	12,7	3.1	Motuzaite Matuzeviciute et al. 2015
GM_082	Karatuma	Kurgan 26	IA*	-15,9	12,3	3.1	Motuzaite Matuzeviciute et al. 2015
GM_082	Karatuma	Kurgan 26	IA*	-16,8	13,7	3.3	Motuzaite Matuzeviciute et al. 2015

GM_080	Karatuma	Kurgan 34	IA*	-16	12,2	3.1	Motuzaite Matuzeviciute et al. 2015
GM_079	Karatuma	Kurgan 52	IA*	-15,4	12,7	3.1	Motuzaite Matuzeviciute et al. 2015
GM_077B	Karatuma	Kurgan 7	IA*	-14	12,6	3.3	Motuzaite Matuzeviciute et al. 2015
GM_077A	Karatuma	Kurgan 65	IA*	-14,8	13,5	3.3	Motuzaite Matuzeviciute et al. 2015
GM_077	Karatuma	Kurgan 26	IA*	-16,5	12,5	3.1	Motuzaite Matuzeviciute et al. 2015
GM_076	Karatuma	Kurgan 112	IA*	-14,7	13,6	3.2	Motuzaite Matuzeviciute et al. 2015
GM_075	Karatuma	Kurgan 20/grave 1	IA*	-16,9	10,7	3.2	Motuzaite Matuzeviciute et al. 2015
GM_074	Karatuma	Kurgan 35	IA*	-12,9	17,2	3.3	Motuzaite Matuzeviciute et al. 2015
GM_072	Karatuma	Kurgan 59	IA*	-13,2	12,4	3.1	Motuzaite Matuzeviciute et al. 2015
GM_070	Karatuma	Kurgan 26	IA*	-16,2	12,1	3.3	Motuzaite Matuzeviciute et al. 2015
GM_068	Karatuma	Kurgan 11	IA*	-14,4	13,0	3.3	Motuzaite Matuzeviciute et al. 2015
GM_065	Karatuma	Kurgan 165/grave 2	IA*	-16,2	12,1	3.2	Motuzaite Matuzeviciute et al. 2015
GM_063	Karatuma	Kurgan 112	IA*	-15	13,5	3.2	Motuzaite Matuzeviciute et al. 2015
GM_062	Karatuma	Kurgan 35	IA*	-14,9	9,0	3.3	Motuzaite Matuzeviciute et al. 2015
GM_059	Karatuma	Kurgan 62	IA*	-14,5	12,4	3.1	Motuzaite Matuzeviciute et al. 2015
GM_058	Karatuma	Kurgan 36	IA*	-16	12,0	3.2	Motuzaite Matuzeviciute et al. 2015

GM_055	Karatuma	Kurgan 80/grave 2	IA*	-15,2	11,1	3.1	Motuzaite Matuzeviciute et al. 2015
GM_054	Karatuma	Kurgan 80/grave 2	IA*	-15,5	14,2	3.1	Motuzaite Matuzeviciute et al. 2015
GM_053	Karatuma	Kurgan 90	IA*	-16,3	12,1	3.2	Motuzaite Matuzeviciute et al. 2015
GM_051	Karatuma	Kurgan 10	IA*	-16	11,8	3.2	Motuzaite Matuzeviciute et al. 2015
GM_050	Karatuma	Kurgan 19/grave 2	IA*	-15,1	14,8	3.3	Motuzaite Matuzeviciute et al. 2015
GM_049	Karatuma	Kurgan 55	IA*	-15	13,4	3.2	Motuzaite Matuzeviciute et al. 2015
GM_164	Karatumsk	grave 70	BA*	-19,6	13,9	3.4	Motuzaite Matuzeviciute et al. 2015
GM_047	Kargaly-1		FBA-EIA*	-15,5	12,5	3.4	Motuzaite Matuzeviciute et al. 2015
GM_046	Kargaly-1	Kurgan 1/12	FBA-EIA*	-13,6	12,4	3.3	Motuzaite Matuzeviciute et al. 2015
GM_045	Kargaly-1	Kurgan 2/14	FBA-EIA*	-15,0	12,0	3.2	Motuzaite Matuzeviciute et al. 2015
GM_044	Kargaly-1		FBA-EIA*	-14,2	10,4	3.4	Motuzaite Matuzeviciute et al. 2015
GM_43	Khatau-1	Konstruction 12/grave 1	IA*	-15	15,9	3.2	Motuzaite Matuzeviciute et al. 2015
GM_147	Konyr-Tobe-1	Kurgan 1/grave 17	V-VII AD*	-16,8	12,1	3.1	Motuzaite Matuzeviciute et al. 2015
GM_146	Konyr-Tobe-1	Kurgan1/ grave 13	V-VII AD*	-18,2	10,7	3.1	Motuzaite Matuzeviciute et al. 2015
GM_145	Konyr-Tobe-1		V-VII AD*	-19,1	12,1	3.1	Motuzaite Matuzeviciute et al. 2015
GM_144	Konyr-Tobe-1	Kurgan 1/grave 6	V-VII AD*	-17,4	11,1	3.3	Motuzaite Matuzeviciute et al. 2015

GM_143	Konyr-Tobe-1		V-VII AD*	-18,7	12,8	3.1	Motuzaite Matuzeviciute et al. 2015
GM_142	Konyr-Tobe-1	Kurgan 1/grave16	V-VII AD*	-12,4	12,9	3.3	Motuzaite Matuzeviciute et al. 2015
GM_141	Konyr-Tobe-1	Kurgan 1/grave 15	V-VII AD*	-13,8	11,5	3.1	Motuzaite Matuzeviciute et al. 2015
GM_140	Konyr-Tobe-1	Kurgan 1/grave 14	V-VII AD*	-18,6	11,9	3.1	Motuzaite Matuzeviciute et al. 2015
GM_139	Konyr-Tobe-1	Kurgan 1/grave 17	V-VII AD*	-15,3	12,7	3.3	Motuzaite Matuzeviciute et al. 2015
GM_113	Kyrik-Oba-2	K3/g1	FBA-EIA*	-17,7	13,2	3.4	Motuzaite Matuzeviciute et al. 2015
KZ25	Novoilinovka		BA*	-19,2	11,3	3.2	Motuzaite Matuzeviciute et al. 2015
KZ24	Novoilinovka	Kurgan 2/2	BA*	-18,8	11,2	3.1	Motuzaite Matuzeviciute et al. 2015
KZ23	Novoilinovka	Kurgan 1/grave 2/1	BA*	-18,9	11,1	3.1	Motuzaite Matuzeviciute et al. 2015
KZ22	Novoilinovka	Kurgan 2/grave 2/1	BA*	-18,9	11,1	3.1	Motuzaite Matuzeviciute et al. 2015
KZ21	Novoilinovka	Kurgan 2/ garve 2/2	BA*	-18,7	11,2	3.1	Motuzaite Matuzeviciute et al. 2015
KZ20	Novoilinovka	Kurgan 2/grave 2	BA*	-19,1	11,4	3.2	Motuzaite Matuzeviciute et al. 2015
KZ19	Novoilinovka	Kurgan 2/grave 2	BA*	-19,1	10,8	3.1	Motuzaite Matuzeviciute et al. 2015
KZ18	Novoilinovka	Kurgans 3/grave 3	BA*	-18,6	11,4	3.1	Motuzaite Matuzeviciute et al. 2015
GM_035	Oi-Dzailau-7	Kurgan 9/grave 8	LBA*	-14,8	14,5	3.2	Motuzaite Matuzeviciute et al. 2015
GM_034	Oi-Dzailau-7	Grave 2/construction 3	LBA*	-14,4	13,2	3.2	Motuzaite Matuzeviciute et al. 2015

GM_033	Oi-Dzailau-7	Kurgan 1	LBA*	-16,2	13,1	3.2	Motuzaite Matuzeviciute et al. 2015
GM_029	Oi-Dzailau-7	Grave 1/construction 2	LBA*	-18,5	13,8	3.2	Motuzaite Matuzeviciute et al. 2015
GM_028	Oi-Dzailau-7	Grave 5/construction 2	LBA*	-18,0	12,8	3.4	Motuzaite Matuzeviciute et al. 2015
GM_027	Oi-Dzailau-7	Grave 1/construction 2	LBA*	-14,1	14,3	3.3	Motuzaite Matuzeviciute et al. 2015
GM_026	Oi-Dzailau-7	Grave 4/construction 3	LBA*	-13,7	14,6	3.3	Motuzaite Matuzeviciute et al. 2015
GM_025	Oi-Dzailau-7	Grave 5/construction 3	LBA*	-16,9	13,9	3.2	Motuzaite Matuzeviciute et al. 2015
GM_024	Oi-Dzailau-7	Grave 1/construction 3	LBA*	-13,3	14,7	3.2	Motuzaite Matuzeviciute et al. 2015
GM_022	Oi-Dzailau-7	Grave 7	LBA*	-16,8	13,7	3.5	Motuzaite Matuzeviciute et al. 2015
GM_020	Oi-Dzailau-7	Kurgan 3/grave 2	LBA*	-14,5	13,4	3.1	Motuzaite Matuzeviciute et al. 2015
GM_168	Ormandy Bulak	Kurgan	BA*	-19	10,9	3.4	Motuzaite Matuzeviciute et al. 2015
GM_131	Shymkent	Kurgan 9	IA*	-11,3	10,7	3.3	Motuzaite Matuzeviciute et al. 2015
GM_005	Temirlanovka	Kurgan 33/grave 1	II-IV AD*	-13,2	13,2	3.2	Motuzaite Matuzeviciute et al. 2015
GM_004	Temirlanovka	Kurgan 33/grave 2	II-IV AD*	-14,6	14,0	3.2	Motuzaite Matuzeviciute et al. 2015
GM_002	Temirlanovka	Kurgan 26	II-IV AD*	-12,6	12,0	3.2	Motuzaite Matuzeviciute et al. 2015
GM_001	Temirlanovka	Kurgan 20	II-IV AD*	-13,7	13,2	3.3	Motuzaite Matuzeviciute et al. 2015
GM_013	Turgen-2	Kurgan 7/grave 1	II-VI AD*	-17,3	11,0	3.2	Motuzaite Matuzeviciute et al. 2015

GM_012	Turgen-2	Kurgan 8	II-VI AD*	-15,2	11,4	3.1	Motuzaite Matuzeviciute et al. 2015
GM_010	Turgen-2		II-VI AD*	-18,1	10,4	3.1	Motuzaite Matuzeviciute et al. 2015
GM_009	Turgen-2	Kurgan 10/grave 3	II-VI AD*	-15,1	11,9	3.5	Motuzaite Matuzeviciute et al. 2015
GM_008	Turgen-2	Kurgan 10/grave 2	II-VI AD*	-15,5	11,7	3.4	Motuzaite Matuzeviciute et al. 2015
GM_007	Turgen-2	Kurgan 10/grave 1	II-VI AD*	-16,7	11,7	3.4	Motuzaite Matuzeviciute et al. 2015
GM_006	Turgen-2	Kurgan 9	II-VI AD*	-15,6	11,8	3.5	Motuzaite Matuzeviciute et al. 2015
GM_166	Zhambyl	Kurgan 5	FBA-EIA*	-18,8	13	3.1	Motuzaite Matuzeviciute et al. 2015
Al_30	Firsovo-11	grave 16	166-26 BC	-15,3	11,5	3.2	Motuzaite Matuzeviciute et al. 2016
Al_44	Firsovo-14	grave 14	MBA*	-19,3	10,5	3.2	Motuzaite Matuzeviciute et al. 2016
Al_43	Firsovo-14	grave 7 (2)	MBA*	-19,1	11,3	3.2	Motuzaite Matuzeviciute et al. 2016
Al_42	Firsovo-14	grave 7(1)	MBA*	-19,4	10,9	3.2	Motuzaite Matuzeviciute et al. 2016
Al_41	Firsovo-14	grave 25	MBA*	-19,8	11,4	3.2	Motuzaite Matuzeviciute et al. 2016
Al_40	Firsovo-14	grave 40	1684-1512 BC	-19,9	10,6	3.2	Motuzaite Matuzeviciute et al. 2016
K8 M2B Sk 2	Ai-Dai	Kurgan 8	FBA-EIA*	-15,3	11	3.5	Murphy et al. 2013
K8 M2B Sk 1	Ai-Dai	Kurgan 8	FBA-EIA*	-15,3	10,4	3.4	Murphy et al. 2013
K8 M2A Sk 3	Ai-Dai	Kurgan 8	FBA-EIA*	-16,6	10,6	3.6	Murphy et al. 2013
K8 M2A Sk 2	Ai-Dai	Kurgan 8	FBA-EIA*	-16,1	10,3	3.6	Murphy et al. 2013
K8 M2A Sk 1	Ai-Dai	Kurgan 8	FBA-EIA*	-16,2	10,2	3.3	Murphy et al. 2013

K6 M2 Sk2	Ai-Dai	Kurgan 6	FBA-EIA*	-16,6	11,2	3.4	Murphy et al. 2013
K5 M1 Sk8	Ai-Dai	Kurgan 5	FBA-EIA*	-15,5	10,8	3.6	Murphy et al. 2013
K4 Sk1	Ai-Dai	Kurgan 4	FBA-EIA*	-15,2	11,2	3.4	Murphy et al. 2013
K4 M3 Sk7	Ai-Dai	Kurgan 4	FBA-EIA*	-15,6	10,2	3.3	Murphy et al. 2013
K4 M3 Sk5	Ai-Dai	Kurgan 4	FBA-EIA*	-14,2	10,4	3.4	Murphy et al. 2013
K4 M3 Sk4	Ai-Dai	Kurgan 4	FBA-EIA*	-12,8	9,9	3.6	Murphy et al. 2013
K4 M3 Sk 2	Ai-Dai	Kurgan 4	FBA-EIA*	-14,7	10,2	3.4	Murphy et al. 2013
K3 M1 Sk4	Ai-Dai	Kurgan 3	FBA-EIA*	-14,6	10,2	3.3	Murphy et al. 2013
K3 M1 Sk2	Ai-Dai	Kurgan 3	FBA-EIA*	-15,2	11	3.3	Murphy et al. 2013
K3 M1 Sk R	Ai-Dai	Kurgan 3	FBA-EIA*	-13,8	11,5	3.6	Murphy et al. 2013
K2 M1 Sk 4	Ai-Dai	Kurgan 2	FBA-EIA*	-15	11,8	3.3	Murphy et al. 2013
K1 M1 Sk1	Ai-Dai	Kurgan 1	FBA-EIA*	-14,4	10,2	3.4	Murphy et al. 2013
XXV. 16. Sk1	Aymyrlyg		IA*	-15,1	13,1	3.6	Murphy et al. 2013
XXIII. 8	Aymyrlyg		IA*	-15	13,2	3.4	Murphy et al. 2013
XXIII. 4	Aymyrlyg		IA*	-17,5	13,8	3.6	Murphy et al. 2013
XXIII. 11. Sk3	Aymyrlyg		IA*	-17,2	12,9	3.6	Murphy et al. 2013
XXIII. 11. Sk1	Aymyrlyg		IA*	-14,9	13,1	3.5	Murphy et al. 2013
XXI. 4, Sk4	Aymyrlyg		IA*	-14,1	13	3.5	Murphy et al. 2013
XX. 9. Sk4	Aymyrlyg		IA*	-17,2	14	3.4	Murphy et al. 2013
XX. 8. Sk. 2	Aymyrlyg		IA*	-15,5	13,3	3.4	Murphy et al. 2013
XX. 7.Sk1	Aymyrlyg		IA*	-13,9	12,3	3.3	Murphy et al. 2013
XX. 7. Sk5	Aymyrlyg		IA*	-13,2	11,8	3.4	Murphy et al. 2013

XX. 7. Sk2	Aymyrlyg		IA*	-13,9	12,9	3.6	Murphy et al. 2013
XX. 10. Sk4	Aymyrlyg		IA*	-16,8	13,6	3.6	Murphy et al. 2013
XX. 10. Sk2	Aymyrlyg		IA*	-16,2	13,9	3.6	Murphy et al. 2013
XIII. 17. Sk1	Aymyrlyg		IA*	-14,7	13,5	3.6	Murphy et al. 2013
VIII. 54. Sk5	Aymyrlyg		IA*	-13,6	13	3.6	Murphy et al. 2013
VIII. 17. Sk2	Aymyrlyg		IA*	-15,7	13,8	3.3	Murphy et al. 2013
VII. 8. Sk1	Aymyrlyg		IA*	-15,3	14	3.3	Murphy et al. 2013
VI. 16. Sk4	Aymyrlyg		IA*	-15,2	12,8	3.3	Murphy et al. 2013
No context	Aymyrlyg		IA*	-16,1	13,4	3.4	Murphy et al. 2013
D. 7. Sk1 (i)	Aymyrlyg		IA*	-14,2	13	3.4	Murphy et al. 2013
??XXIII	Aymyrlyg		IA*	-16,2	13,2	3.4	Murphy et al. 2013
14248	Kamennyi Ambar-5		BA*	-17,6	14,4		Privat 2004
14247	Kamennyi Ambar-5		BA*	-17,2	14,7		Privat 2004
14245	Kamennyi Ambar-5		BA*	-17,1	13,6		Privat 2004
14244	Kamennyi Ambar-5		BA*	-17,4	15,1		Privat 2004
14243	Kamennyi Ambar-5		BA*	-17,5	15,1		Privat 2004
14242	Kamennyi Ambar-5		BA*	-17,2	13,1		Privat 2004
14237	Kulevchi-6		BA*	-19,1	13,1		Privat 2004
14236	Kulevchi-6		BA*	-18,6	12,7		Privat 2004
14235	Kulevchi-6		BA*	-18,5	12,7		Privat 2004

14234	Peschanka-1		BA*	-19,6	11,1		Privat 2004
14233	Peschanka-1		BA*	-19	11,2		Privat 2004
14254	Sintashta		BA*	-18	13,3		Privat 2004
14223	Ust'e		BA*	-18,6	12		Privat 2004
14222	Ust'e		BA*	-18,2	10,5		Privat 2004
14221	Ust'e		BA*	-18,9	10,4		Privat 2004
BKAR 9	Bolshekaragansky		BA*	-18,3	11,5	3.2	Privat 2004
BKAR 8	Bolshekaragansky		BA*	-18,2	11,2	3.2	Privat 2004
BKAR 7	Bolshekaragansky		BA*	-18,9	10,5	3.2	Privat 2004
BKAR 6	Bolshekaragansky		BA*	-18,3	11,6	3.2	Privat 2004
BKAR 5	Bolshekaragansky		BA*	-19,2	10,3	3.3	Privat 2004
BKAR 4	Bolshekaragansky		BA*	-19,3	10,5	3.3	Privat 2004
BKAR 3	Bolshekaragansky		BA*	-18,9	10,3	3.2	Privat 2004
BKAR 2	Bolshekaragansky		BA*	-19,1	9,7	3.2	Privat 2004
BKAR 14	Bolshekaragansky		BA*	-19,2	10,8	3.2	Privat 2004
BKAR 13	Bolshekaragansky		BA*	-19,3	11,2	3.2	Privat 2004
BKAR 12	Bolshekaragansky		BA*	-18,9	11,7	3.2	Privat 2004
BKAR 11	Bolshekaragansky		BA*	-19,1	10,6	3.2	Privat 2004
BKAR 10	Bolshekaragansky		BA*	-19,2	9,5	3.2	Privat 2004
BKAR 1	Bolshekaragansky		BA*	-18	11,8	3.2	Privat 2004
GAY 7	Gayovsky-1		IA*	-20,3	12	3.2	Privat 2004
GAY 6	Gayovsky-1		IA*	-20,3	11	3.2	Privat 2004

GAY 5	Gayovsky-1		IA*	-20,6	12,4	3.3	Privat 2004
GAY 4	Gayovsky-1		IA*	-20	11,4	3.3	Privat 2004
GAY 3	Gayovsky-1		IA*	-21,5	12,8	3.3	Privat 2004
GAY 1	Gayovsky-1		IA*	-20,7	12,7	3.3	Privat 2004
ISI 6	Isiney-1		BA*	-18,8	11,6	3.2	Privat 2004
ISI 5	Isiney-1		BA*	-20,3	11,4	3.2	Privat 2004
ISI 4	Isiney-1		BA*	-18,4	11,9	3.2	Privat 2004
ISI 3	Isiney-1		BA*	-19,1	10,5	3.2	Privat 2004
ISI 2	Isiney-1		BA*	-18,8	11,3	3.2	Privat 2004
ISI 1	Isiney-1		BA*	-18,8	11,6	3.3	Privat 2004
KZ 3a	Kizil		FBA-EIA*	-19	10,2	3.3	Privat 2004
KUR 9	Kurtuguz-1		IA*	-20,3	14,3	3.3	Privat 2004
KUR 8	Kurtuguz-1		IA*	-21,4	13	3.3	Privat 2004
KUR 7	Kurtuguz-1		IA*	-21,6	13	3.3	Privat 2004
KUR 6	Kurtuguz-1		IA*	-17,5	12,6	3.3	Privat 2004
KUR 5	Kurtuguz-1		IA*	-19,8	12,7	3.2	Privat 2004
KUR 4	Kurtuguz-1		IA*	-17,9	12,9	3.2	Privat 2004
KUR 10	Kurtuguz-1		IA*	-18,1	11,7	3.3	Privat 2004
MUR 7	Murzino-1		IV BC-II AD*	-21	12,4	3.2	Privat 2004
MUR 6	Murzino-1		IV BC-II AD*	-20,9	14,9	3.2	Privat 2004
MUR 5	Murzino-1		IV BC-II AD*	-22,8	13,4	3.3	Privat 2004
MUR 4	Murzino-1		IV BC-II AD*	-20,4	13	3.4	Privat 2004

MUR 2	Murzino-1		IV BC-II AD*	-21,1	12,1	3.3	Privat 2004
MUR 1	Murzino-1		IV BC-II AD*	-20,5	12,5	3.3	Privat 2004
POB 8	Pobeda		IA*	-18,8	12,6	3.2	Privat 2004
POB 7	Pobeda		IA*	-18,8	12,4	3.2	Privat 2004
POB 6	Pobeda		IA*	-18,7	13,1	3.2	Privat 2004
POB 5	Pobeda		IA*	-18,4	13	3.2	Privat 2004
POB 4	Pobeda		IA*	-18,3	12,6	3.2	Privat 2004
POB 2	Pobeda		IA*	-17,9	13,8	3.2	Privat 2004
POB 1	Pobeda		IA*	-18	13	3.2	Privat 2004
SEB 96 K2a	Sebystei		IA*	-18,1	13,2	3.3	Privat 2004
SEB 96 K1b	Sebystei		IA*	-18,1	11,7	3.2	Privat 2004
SHA 5	Shaidurikha		IA*	-20	12,4	3.3	Privat 2004
SHA 4	Shaidurikha		IA*	-19,1	12,1	3.2	Privat 2004
SHA 3	Shaidurikha		IA*	-20,6	12	3.2	Privat 2004
SHA 2	Shaidurikha		IA*	-19,9	12,8	3.2	Privat 2004
SHA 1	Shaidurikha		IA*	-19,9	11,9	3.5	Privat 2004
SKA 3	Skaty-1		IA*	-20,2	11,1	3.2	Privat 2004
SKA 2	Skaty-1		IA*	-19,6	10,8	3.2	Privat 2004
SOLII 3	Solonchanka-2		IA*	-18,2	13,3	3.1	Privat 2004
SOLII 1	Solonchanka-2		IA*	-18,1	14,6	3.2	Privat 2004
STA 1	Staraya Mel'nitsa		IA*	-18,1	14,6	3.2	Privat 2004
VAR 1	Varnenskiye		IA*	-19,1	10,9	3.2	Privat 2004
UBA-28351	Akbeit	Kurgan 7	FBA-EIA*	-17,3	15,4	3.2	Svyatko and Beisenov 2017

UBA-23672	Akbeit	Kurgan 1	829-546 cal. BC	-15,7	16,2	3.3	Svyatko and Beisenov 2017
UBA-23670	Akbeit	Kurgan 2	781-517 cal. BC	-17,7	15	3.3	Svyatko and Beisenov 2017
UBA-28344	Bakybulak	Kurgan 14	FBA-EIA*	-19,1	14,5	3.1	Svyatko and Beisenov 2017
UBA-28366	Bakybulak	Kurgan 2	FBA-EIA*	-18,2	15	3.2	Svyatko and Beisenov 2017
UBA-23666	Bakybulak	Kurgan 15	807-558 cal. BC	-17,1	15,8	3.2	Svyatko and Beisenov 2017
UBA-28345	Bektauata	Kurgan 1	FBA-EIA*	-17,2	16,6	3.2	Svyatko and Beisenov 2017
UBA-28353	Birlik	Kurgan 29	FBA-EIA*	-17,5	14	3.2	Svyatko and Beisenov 2017
UBA-28352	Birlik	Kurgan 15	FBA-EIA*	-18,6	14,1	3.2	Svyatko and Beisenov 2017
UBA-24918	Complex «37 voinov»	Kurgan 11	750-407 cal. BC	-18,4	15,5	3.1	Svyatko and Beisenov 2017
UBA-23671	Karashoky	Kurgan 8	894-790 cal. BC	-17,6	15,4	3.3	Svyatko and Beisenov 2017
UBA-23674	Karashoky	Kurgan 1	791-542 cal. BC	-16	16,9	3.2	Svyatko and Beisenov 2017
UBA-23668	Karashoky-6	Kurgan 1	FBA-EIA*	-17,7	15,1	3.2	Svyatko and Beisenov 2017
UBA-23664	Koitas		791-636 cal. BC	-14,1	14,3	3.2	Svyatko and Beisenov 2017
UBA-24917	Kosoba	Kurgan 2	772-431 cal. BC	-18,5	13,6	3.1	Svyatko and Beisenov 2017
UBA-25474	Kyzyl	Kurgan 3, left burial	786-490 cal. BC	-18,9	13,7	3.1	Svyatko and Beisenov 2017
UBA-28346	Kyzylkoi	Kurgan 1	FBA-EIA*	-18	15,9	3.3	Svyatko and Beisenov 2017
UBA-28350	Kyzylshilik	Kurgan 8	FBA-EIA*	-19,2	14	3.2	Svyatko and Beisenov 2017
UBA-24916	Kyzylshilik	Kurgan 2	747-403 cal. BC	-18,2	13,1	3.1	Svyatko and Beisenov 2017
UBA-23669	Nazar-2	Kurgan 2	773-435 cal. BC	-18,4	14,1	3.2	Svyatko and Beisenov 2017
UBA-23665	Nazar-2	Kurgan 1	788-540 cal. BC	-18,7	13,9	3.2	Svyatko and Beisenov 2017
UBA-28343	Nurken-2	Kurgan 1, lower skeleton	FBA-EIA*	-17,3	14,5	3.2	Svyatko and Beisenov 2017
UBA-23673	Taisoigan	Kurgan 3	509-377 cal. BC	-18,2	13,3	3.2	Svyatko and Beisenov 2017
UBA-23667	Taldy-2	Kurgan 2	807-540 cal. BC	-14,5	15,2	3.3	Svyatko and Beisenov 2017

UBA-28347	Tandaily-2	Kurgan 2	FBA-EIA*	-18,7	13,3	3.2	Svyatko and Beisenov 2017
UBA-28349	Zhamantas		FBA-EIA*	-18,9	13,7	3.2	Svyatko and Beisenov 2017
PSUAMS-2496	Ak-Moustafa	Kurgan 2, Al-1	1869-1665 cal. BC	-18,2	15,1	3.3	Narasimhan et al. 2018
PSUAMS-2608	Aktogai	KZ-AKT-008, Object 7, Kurgan 4	1615-1509 cal. BC	-16,9	15,5	3.3	Narasimhan et al. 2018
PSUAMS-2607	Aktogai	KZ-AKT-002,Object 7, Kurgan 7	1618-1513 cal. BC	-17,5	14,9	3.3	Narasimhan et al. 2018
PSUAMS-2511	Aktogai	KZ-AKT-003	1640-1527 cal. BC	-16,3	14,8	3.3	Narasimhan et al. 2018
PSUAMS-2124	Aktogai	KZ-AKT-001	1691-1528 cal. BC	-17,0	15,8	3.1	Narasimhan et al. 2018
PSUAMS-2071	Dali, Byan Zherek	DL-OP2-B, #41	2850-2495 cal. BC	-17,8	13,0	3.3	Narasimhan et al. 2018
PSUAMS-3099	Kairan	KZ-KAR-012	1931-1772 cal. BC	-18,1	15,6	3.2	Narasimhan et al. 2018
PSUAMS-2991	Kairan	KZ-KAN-004	1729-1563 cal. BC	-17,2	15,7	3.2	Narasimhan et al. 2018
PSUAMS-2961	Kairan	KZ-KAN-002 + KZ-KAY-002	1767-1658 cal. BC	-18,4	15,3	3.3	Narasimhan et al. 2018
PSUAMS-2939	Kairan	KZ-KAR005, ogr. N11, grave N3	1745-1636 cal. BC	-18,0	15,3	3.2	Narasimhan et al. 2018
PSUAMS-2913	Kairan	KZ-KAR009	1754-1642 cal. BC	-17,2	16,1	3.3	Narasimhan et al. 2018
PSUAMS-2913	Kairan	KZ-KAN005	1767-1658 cal. BC	-18,1	13,9	3.3	Narasimhan et al. 2018
PSUAMS-2546	Kairan	KZ-KAR-006	1745-1636 cal. BC	-17,5	14,9	3.2	Narasimhan et al. 2018
PSUAMS-2545	Kairan	KZ-KAN-006	1743-1631 cal. BC	-17,5	14,6	3.2	Narasimhan et al. 2018
PSUAMS-2543	Kairan	KZ-KAR-010	1746-1630 cal. BC	-18,1	15,3	3.3	Narasimhan et al. 2018

PSUAMS-2611	Karagash-2	KZ-KAR-003, KV. 1V, Grave 2, 1994	1728-1546 cal. BC	-18,3	14,3	3.3	Narasimhan et al. 2018
PSUAMS-2123	Karagash-2	KZ-KAR-004	1861-1639 cal. BC	-18,8	13,9	3.3	Narasimhan et al. 2018
PSUAMS-2122	Karagash-2	KZ-KAR-002	1881-1695 cal. BC	-18,1	13,9	3.1	Narasimhan et al. 2018
PSUAMS-2962	Kazakh Mys	KZ-KAZ-003	1640-1527 cal. BC	-16,4	16,1	3.3	Narasimhan et al. 2018
PSUAMS-2915	Kazakh Mys	KZ-KAZ-004	1736-1621 cal. BC	-16,0	12,8	3.2	Narasimhan et al. 2018
PSUAMS-2612	Kazakh Mys	KZ-KAZ-006, Object 3, Og. 1, 2015	1610-1454 cal. BC	-17,9	14,7	3.3	Narasimhan et al. 2018
PSUAMS-2544	Kazakh Mys	KZ-KAZ-005	1611-1503 cal. BC	-14,1	13,5	3.2	Narasimhan et al. 2018
PSUAMS-2963	Kyzyl-Bulak-1	KZ-KUZ-002	1741-1627 cal. BC	-16,5	12,6	3.3	Narasimhan et al. 2018
PSUAMS-2613	Kyzyl-Bulak-1	KZ-KUZ-001, Og. 46	1618-1513 cal. BC	-18,8	10,8	3.2	Narasimhan et al. 2018
PSUAMS-2942	Lisakovsk	TOMSK_4387, inv. 4387	1767-1658 cal. BC	-18,7	11,9	3.2	Narasimhan et al. 2018
PSUAMS-2921	Lisakovsk	TOMSK_4114	1862-1664 cal. BC	-18,4	11,5	3.2	Narasimhan et al. 2018
PSUAMS-2980	Maitan	TOMSK_4337, inv. 4337	1872-1684 cal. BC	-17,9	14,4	3.2	Narasimhan et al. 2018
PSUAMS-2929	Maitan	TOMSK_4352	1872-1684 cal. BC	-18,5	13,2	3.2	Narasimhan et al. 2018
PSUAMS-2928	Maitan	TOMSK_4351	1882-1748 cal. BC	-18,9	11,6	3.2	Narasimhan et al. 2018
PSUAMS-2927	Maitan	TOMSK_4350	1749-1642 cal. Bc	-18,6	13,3	3.2	Narasimhan et al. 2018
PSUAMS-2926	Maitan	TOMSK_4347	1876-1688 cal. BC	-18,7	12,6	3.2	Narasimhan et al. 2018
PSUAMS-2925	Maitan	TOMSK_4346	1745-1636 cal.	-18,5	12,9	3.2	Narasimhan et al. 2018

			BC				
PSUAMS-2924	Maitan	TOMSK_4344	1876-1691 cal. BC	-18,3	13,5	3.2	Narasimhan et al. 2018
PSUAMS-2923	Maitan	TOMSK_4341	1862-1664 cal. BC	-18,3	13,4	3.2	Narasimhan et al. 2018
PSUAMS-2922	Maitan	TOMSK_4335	1877-1693 cal. BC	-19,6	12,1	3.2	Narasimhan et al. 2018
PSUAMS-3115	Oi-Dzhailau	BI No 22, Grave 4	1872-1684 cal. BC	-18,3	13,3	3.2	Narasimhan et al. 2018
PSUAMS-2964	Oi-Dzhailau	KZ-DJA-001 + KZ-DJA-002	1596-1439 cal. BC	-14,6	13,3	3.2	Narasimhan et al. 2018
PSUAMS-2548	Oi-Dzhailau	KZ-DJA-006	1609-1450 cal. BC	-17,0	14,1	3.3	Narasimhan et al. 2018
PSUAMS-2547	Oi-Dzhailau	KZ-DJA-004	1527-1439 cal. BC	-16,0	13,6	3.3	Narasimhan et al. 2018
PSUAMS-2492	Oi-Dzhailau	BI No 20, Grave 24, Section D-4	1734-1617 cal. BC	-17,1	14,5	3.2	Narasimhan et al. 2018
PSUAMS-2981	Satan	TOMSK_4371, inv. 4371	1876-1688 cal. BC	-18,3	13,4	3.2	Narasimhan et al. 2018
PSUAMS-2614	Taldysai	KZ-UKZ-002, Grave (?) 1, KV E7	1379-1196 cal. BC	-19,1	12,3	3.3	Narasimhan et al. 2018
PSUAMS-2502	Zevakinskiy	CII-47	1609-1443 cal. BC	-21,6	14,8	3.3	Narasimhan et al. 2018
PSUAMS-2079	Zevakinskiy	CII-52	2132-1940 cal. BC	-18,2	12,9	3.3	Narasimhan et al. 2018
PSUAMS-2540	Zevakinskiy	CII (VIII-VII BC) No51	1111-941 cal. BC	-15,7	13,5	3.2	Narasimhan et al. 2018
PSUAMS-2507	Zevakinskiy	CII No 44	1126-1000 cal. BC	-19,1	14,0	3.2	Narasimhan et al. 2018
PSUAMS-2506	Zevakinskiy	CII No 43	1191-1010 cal. BC	-16,5	13,1	3.2	Narasimhan et al. 2018
PSUAMS-2080	Zevakinskiy	CII-56	1025-901 cal. BC	-12,8	10,7	3.2	Narasimhan et al. 2018

BS575	Bestamak		MBA*	-18,9	11,2	3.5	Ventresca Miller et al. 2014
BS566	Bestamak		MBA*	-18,7	11,9	3.6	Ventresca Miller et al. 2014
BS558	Bestamak		MBA*	-18,3	14,0	3.6	Ventresca Miller et al. 2014
BS550	Bestamak		MBA*	-19,4	12,0	3.5	Ventresca Miller et al. 2014
BS547	Bestamak		MBA*	-19,3	12,1	3.5	Ventresca Miller et al. 2014
BS545	Bestamak		MBA*	-18,7	11,5	3.4	Ventresca Miller et al. 2014
BS542	Bestamak		MBA*	-19,0	11,1	3.6	Ventresca Miller et al. 2014
BS540	Bestamak		MBA*	-17,6	14,1	3.5	Ventresca Miller et al. 2014
BS538	Bestamak		MBA*	-19,2	11,1	3.4	Ventresca Miller et al. 2014
BS534	Bestamak		MBA*	-19,0	9,5	3.5	Ventresca Miller et al. 2014
BS532	Bestamak		MBA*	-19,5	11,0	3.5	Ventresca Miller et al. 2014
BS531	Bestamak		MBA*	-18,6	12,5	3.4	Ventresca Miller et al. 2014
BS523	Bestamak		MBA*	-18,8	12,6	3.5	Ventresca Miller et al. 2014
BS520	Bestamak		MBA*	-19,2	11,3	3.4	Ventresca Miller et al. 2014
BS518	Bestamak		MBA*	-18,8	12,0	3.5	Ventresca Miller et al. 2014
BS515	Bestamak		MBA*	-19,6	11,3	3.5	Ventresca Miller et al. 2014
BS513	Bestamak		MBA*	-19,4	12,2	3.5	Ventresca Miller et al. 2014
BS512	Bestamak		MBA*	-19,4	11,4	3.5	Ventresca Miller et al. 2014
BS508	Bestamak		MBA*	-19,2	11,1	3.5	Ventresca Miller et al. 2014
BS507	Bestamak		MBA*	-19,2	11,6	3.4	Ventresca Miller et al. 2014
B3501	Bestamak		MBA*	-19,4	11,6	3.5	Ventresca Miller et al. 2014
L3184	Lisakovsk		LBA*	-18,7	11,9	3.3	Ventresca Miller et al. 2014
L3178	Lisakovsk		LBA*	-19,7	10,0	3.5	Ventresca Miller et al. 2014

L3173	Lisakovsk		LBA*	-18,8	12,0	3.4	Ventresca Miller et al. 2014
L3170	Lisakovsk		LBA*	-19,1	12,0	3.4	Ventresca Miller et al. 2014
L3168	Lisakovsk		LBA*	-19,0	11,7	3.3	Ventresca Miller et al. 2014
L3167	Lisakovsk		LBA*	-18,3	12,2	3.3	Ventresca Miller et al. 2014
L3165	Lisakovsk		LBA*	-18,8	11,3	3.5	Ventresca Miller et al. 2014
L3161	Lisakovsk		LBA*	-18,6	10,9	3.4	Ventresca Miller et al. 2014
L3160	Lisakovsk		LBA*	-18,5	12,5	3.4	Ventresca Miller et al. 2014
L3155	Lisakovsk		LBA*	-17,6	13,1	3.0	Ventresca Miller et al. 2014
L3150	Lisakovsk		LBA*	-19,0	11,9	3.4	Ventresca Miller et al. 2014
L3142	Lisakovsk		LBA*	-19,0	11,3	3.4	Ventresca Miller et al. 2014
L3139	Lisakovsk		LBA*	-19,0	12,5	3.4	Ventresca Miller et al. 2014
L3137	Lisakovsk		LBA*	-17,5	14,4	3.3	Ventresca Miller et al. 2014
L3130	Lisakovsk		LBA*	-18,9	12,8	3.4	Ventresca Miller et al. 2014
L3112	Lisakovsk		LBA*	-18,8	13,5	3.4	Ventresca Miller et al. 2014
L3110	Lisakovsk		LBA*	-19,3	11,2	3.4	Ventresca Miller et al. 2014
L3105	Lisakovsk		LBA*	-19,0	12,0	3.4	Ventresca Miller et al. 2014
L3102	Lisakovsk		LBA*	-18,7	12,4	3.3	Ventresca Miller et al. 2014
L3093	Lisakovsk		LBA*	-19,4	11,5	3.3	Ventresca Miller et al. 2014
L3081	Lisakovsk		LBA*	-18,9	12,1	3.3	Ventresca Miller et al. 2014
L3071	Lisakovsk		LBA*	-18,6	13,9	3.3	Ventresca Miller et al. 2014
L3070	Lisakovsk		LBA*	-18,7	12,1	3.3	Ventresca Miller et al. 2014
L3036	Lisakovsk		LBA*	-18,6	12,0	3.3	Ventresca Miller et al. 2014
L3016	Lisakovsk		LBA*	-18,9	9,9	3.4	Ventresca Miller et al. 2014

L3013	Lisakovsk		LBA*	-18,9	12,5	3.5	Ventresca Miller et al. 2014
L3004	Lisakovsk		LBA*	-19,0	11,6	3.3	Ventresca Miller et al. 2014
L3001	Lisakovsk		LBA*	-18,8	11,5	3.4	Ventresca Miller et al. 2014

Table 2: Previously published animal stable isotope data

Sample ID	**Site**	**Period**	**Specie**	$\delta^{13}C$ ‰	$\delta^{15}N$ ‰	**C/N atomic**	**Publication**
KA-5002	Kamennyi Ambar V	BA*	caprine	−18.2	7,8	3.1	Hanks et al. 2018
KA-5005	Kamennyi Ambar V	BA*	caprine	−18.4	9,8	3.2	Hanks et al. 2018
KA-5007	Kamennyi Ambar V	BA	caprine	−18.5	6,1	3.2	Hanks et al. 2018
KA-5001	Kamennyi Ambar V	BA*	cattle	−19.7	6,2	3.1	Hanks et al. 2018
KA-5003	Kamennyi Ambar V	BA*	cattle	−18.6	8,7	3.2	Hanks et al. 2018
KA-5008	Kamennyi Ambar V	BA*	cattle	−19.5	6,5	3.2	Hanks et al. 2018
KA-5006	Kamennyi Ambar V	BA*	horse	−20.6	4,9	3.1	Hanks et al. 2018
KA-5009	Kamennyi Ambar V	BA*	horse	−20.8	3,1	3.1	Hanks et al. 2018
KA-5010	Kamennyi Ambar V	BA*	horse	−20.0	4,1	2.9	Hanks et al. 2018
KZF48	Aschisu	BA*	herbivore	-18,6	7,9	3.2	Lightfoot et al. 2015'
KZF49	Aschisu	BA*	herbivore	-18,4	8	3.2	Lightfoot et al. 2015'
KZF50	Aschisu	BA*	herbivore	-18,2	12,7	3.2	Lightfoot et al. 2015'
KZF51	Aschisu	BA*	herbivore	-19,8	6,2	3.2	Lightfoot et al. 2015'
KZF52	Aschisu	BA*	herbivore	-20	6,7	3.2	Lightfoot et al. 2015'
KZF45	Kapamyzau	BA*	herbivore	-20,7	3,4	3,2	Lightfoot et al. 2015'
KZF53	Kudryavaya Sopka-1	FBA-EIA*	herbivore	-18,7	9,9	3,3	Lightfoot et al. 2015'

KZF72	Nurataldy	BA*	herbivore	-19	8,5	3,2	Lightfoot et al. 2015'
KZF46	Tashik	BA*	herbivore	-18,6	13,3	3.2	Lightfoot et al. 2015'
KZF47	Tashik	BA*	herbivore	-18,6	13,2	3.2	Lightfoot et al. 2015'
KZF54	Tashik	BA*	herbivore	-19	7	3.2	Lightfoot et al. 2015'
KZF55	Tashik	BA*	herbivore	-18,9	7,6	3.2	Lightfoot et al. 2015'
KZF56	Tashik	BA*	herbivore	-17,9	8,5	3.3	Lightfoot et al. 2015'
KZF57	Tashik	BA*	herbivore	-20,3	5,6	3.3	Lightfoot et al. 2015'
KZF58	Tashik	BA*	herbivore	-20,2	5,7	3.2	Lightfoot et al. 2015'
KZF60	Tashik	BA*	herbivore	-20,1	6	3.2	Lightfoot et al. 2015'
KZF61	Tashik	BA*	herbivore	-19	7,7	3.2	Lightfoot et al. 2015'
KZF62	Tashik	BA*	herbivore	-18,7	7,9	3.2	Lightfoot et al. 2015'
KZF63	Tashik	BA*	herbivore	-19,2	7,4	3.4	Lightfoot et al. 2015'
KZF64	Tashik	BA*	herbivore	-19	7,6	3.3	Lightfoot et al. 2015'
KZF65	Tashik	BA*	herbivore	-19,1	7,4	3.4	Lightfoot et al. 2015'
KZF66	Tashik	BA*	herbivore	-19,1	7,2	3.3	Lightfoot et al. 2015'
KZF67	Tashik	BA*	herbivore	-19,8	7,6	3.3	Lightfoot et al. 2015'
KZF68	Tashik	BA*	herbivore	-19,4	8,3	3.2	Lightfoot et al. 2015'
KZF70	Tashik	BA*	herbivore	-19,4	7,5	3.4	Lightfoot et al. 2015'
KZF71	Tashik	BA*	herbivore	-18,7	8	3.2	Lightfoot et al. 2015'
KZF02	Tegiszhol	BA*	herbivore	-19,5	7,8	3.1	Lightfoot et al. 2015'
KZF03	Tegiszhol	BA*	herbivore	-18,9	7,6	3.2	Lightfoot et al. 2015'
KZF04	Tegiszhol	BA*	herbivore	-19,1	7,9	3.2	Lightfoot et al. 2015'
KZF05	Temirkash	BA*	herbivore	-18,8	8,7	3.1	Lightfoot et al. 2015'

KZF06	Temirkash	BA*	herbivore	-20,4	4,8	3.2	Lightfoot et al. 2015'
KZF06B	Temirkash	BA*	herbivore	-19,2	7,7	3.2	Lightfoot et al. 2015'
KZF07	Temirkash	BA*	herbivore	-18,6	8,6	3.2	Lightfoot et al. 2015'
KZF09	Temirkash	BA*	herbivore	-20,4	5,9	3.2	Lightfoot et al. 2015'
KZF10	Temirkash	BA*	herbivore	-18,6	7,8	3.1	Lightfoot et al. 2015'
KZF11	Temirkash	BA*	herbivore	-18,9	8,8	3.2	Lightfoot et al. 2015'
KZF13	Temirkash	BA*	herbivore	-19,7	6,2	3.3	Lightfoot et al. 2015'
KZF14	Temirkash	BA*	herbivore	-19,3	8,2	3.2	Lightfoot et al. 2015'
KZF14B	Temirkash	BA*	herbivore	-18,8	6,9	3.2	Lightfoot et al. 2015'
KZF15	Temirkash	BA*	herbivore	-19,6	7,6	3.1	Lightfoot et al. 2015'
KZF16	Temirkash	BA*	herbivore	-19,1	6,3	3.1	Lightfoot et al. 2015'
KZF17	Temirkash	BA*	herbivore	-18,8	6,3	3.2	Lightfoot et al. 2015'
KZF18	Temirkash	BA*	herbivore	-19,4	8,3	3.2	Lightfoot et al. 2015'
KZF19	Temirkash	BA*	herbivore	-18,4	7,5	3.1	Lightfoot et al. 2015'
KZF20	Temirkash	BA*	herbivore	-18,8	7,1	3.2	Lightfoot et al. 2015'
KZF21	Temirkash	BA*	herbivore	-20,6	5,7	3.2	Lightfoot et al. 2015'
KZF22	Temirkash	BA*	herbivore	-19,4	6,9	3.2	Lightfoot et al. 2015'
KZF23	Temirkash	BA*	herbivore	-18,8	6,1	3.2	Lightfoot et al. 2015'
KZF24	Temirkash	BA*	herbivore	-20,3	6,1	3.2	Lightfoot et al. 2015'
KZF25	Temirkash	BA*	herbivore	-20,2	5,8	3.1	Lightfoot et al. 2015'
KZF26	Temirkash	BA*	herbivore	-19,7	8,7	3.1	Lightfoot et al. 2015'
KZF27	Temirkash	BA*	herbivore	-19,6	8,4	3.2	Lightfoot et al. 2015'
KZF28	Temirkash	BA*	herbivore	-18,8	7,7	3.1	Lightfoot et al. 2015'

KZF29	Temirkash	BA*	Herbivore	-18,7	8,2	3.1	Lightfoot et al. 2015'
KZF30	Temirkash	BA*	herbivore	-20,6	6,3	3.2	Lightfoot et al. 2015'
KZF31	Temirkash	BA*	herbivore	-18,8	7,7	3.1	Lightfoot et al. 2015'
KZF32	Temirkash	BA*	herbivore	-19,7	7,1	3.2	Lightfoot et al. 2015'
KZF33	Temirkash	BA*	herbivore	-18,3	7,7	3.1	Lightfoot et al. 2015'
KZF34	Temirkash	BA*	herbivore	-19,1	7,3	3.1	Lightfoot et al. 2015'
KZF35	Temirkash	BA*	herbivore	-19	8,8	3.1	Lightfoot et al. 2015'
KZF37	Temirkash	BA*	herbivore	-18,4	6,7	3.2	Lightfoot et al. 2015'
KZF38	Temirkash	BA*	herbivore	-18,7	5,3	3.2	Lightfoot et al. 2015'
KZF39	Temirkash	BA*	herbivore	-19,1	6	3.2	Lightfoot et al. 2015'
KZF40	Temirkash	BA*	herbivore	-20,6	6	3.2	Lightfoot et al. 2015'
KZF41	Temirkash	BA*	herbivore	-19,1	7,7	3.2	Lightfoot et al. 2015'
KZF43B	Temirkash	BA*	herbivore	-19,3	7,3	3.2	Lightfoot et al. 2015'
KZF43	Temirkash	BA*	herbivore	-19,5	5,5	3.2	Lightfoot et al. 2015'
KZF44	Temirkash	BA*	herbivore	-17,9	7,1	3.2	Lightfoot et al. 2015'
GM_F06	Kirik Oba 2	BA*	horse	-20,2	5,9	3.2	Motuzaite Matuzeviciute et al. 2016'
GM_F07	Kyrik Oba-2	BA*	horse	-20	6,3	3.1	Motuzaite Matuzeviciute et al. 2016'
GM_F09	Bozshakol-6	BA*	caprine	-19,0	8,0	3.5	Motuzaite Matuzeviciute et al. 2015'
GM_F43	Bozshakol-6	BA*	caprine	-18,4	5,6	3.2	Motuzaite Matuzeviciute et al. 2015'
GM_F44	Bozshakol-6	BA*	caprine	-18,8	7,5	3.1	Motuzaite Matuzeviciute et al. 2015'
GM_F45	Bozshakol-6	BA*	caprine	-19,1	8,5	3.4	Motuzaite Matuzeviciute et al. 2015'

GM_F46	Bozshakol-6	BA*	caprine	-17,6	7,1	3.2	Motuzaite Matuzeviciute et al. 2015'
GM_F48	Bozshakol-6	BA*	caprine	-19,3	5,4	3.2	Motuzaite Matuzeviciute et al. 2015'
GM_F49	Bozshakol-6	BA*	caprine	-18,7	8,3	3.2	Motuzaite Matuzeviciute et al. 2015'
GM_F50	Bozshakol-6	BA*	caprine	-19,1	11,5	3.1	Motuzaite Matuzeviciute et al. 2015'
GM_F51	Bozshakol-6	BA*	caprine	-18,3	6,2	3.2	Motuzaite Matuzeviciute et al. 2015'
GM_F8	Bozshakol-6	BA*	caprine	-19,2	7,2	3.4	Motuzaite Matuzeviciute et al. 2015'
GM_F75	Bozshakol-6	BA*	horse	-20,2	6,7	3.5	Motuzaite Matuzeviciute et al. 2015'
GM_F74	Bozshakol-6	BA*	horse	-20,3	6,2	3.2	Motuzaite Matuzeviciute et al. 2015'
GM_F73	Bozshakol-6	BA*	horse	-20,7	4,2	3.5	Motuzaite Matuzeviciute et al. 2015'
GM_F71	Bozshakol-6	BA*	horse	-20,3	5,4	3.4	Motuzaite Matuzeviciute et al. 2015'
GM_F69	Bozshakol-6	BA*	horse	-20,5	6,8	3.5	Motuzaite Matuzeviciute et al. 2015'
GM_F67	Bozshakol-6	BA*	horse	-20,3	6,0	3.2	Motuzaite Matuzeviciute et al. 2015'
GM_F66	Bozshakol-6	BA*	horse	-20,5	6,0	3.4	Motuzaite Matuzeviciute et al. 2015'
GM_F10	Bozshakol-6	BA*	horse	-19,3	6,5	3.4	Motuzaite Matuzeviciute et al. 2015'
GM_F68	Bozshakol-6	BA*	horse	-19,8	6,9	3.5	Motuzaite Matuzeviciute et al. 2015'
GM_F47	Bozshakol-6	BA*	caprine	-18,8	8,0	3.2	Motuzaite Matuzeviciute et al. 2015'

GM_F04	Butakty	Medieval*	caprine	-18,4	7,4	3.2	Motuzaite Matuzeviciute et al. 2015'
GM_F26	Kainar Bulak-1	FBA-EIA*	horse	-20,7	4,5	3.3	Motuzaite Matuzeviciute et al. 2015'
GM_F17	Kainar Bulak-1	FBA-EIA*	horse	-18,0	8,5	3.5	Motuzaite Matuzeviciute et al. 2015'
GM_F16	Kainar Bulak-1	FBA-EIA*	horse	-20,1	6,1	3.1	Motuzaite Matuzeviciute et al. 2015'
GM_F15	Kainar Bulak-1	FBA-EIA*	horse	-18,9	7,9	3.5	Motuzaite Matuzeviciute et al. 2015'
GM_F22	Kainar Bulak-1 '	FBA-EIA*	caprine	-19,3	9,3	3.1	Motuzaite Matuzeviciute et al. 2015'
GM_F23	Kainar Bulak-1 '	FBA-EIA*	caprine	-19,1	7,1	3.1	Motuzaite Matuzeviciute et al. 2015'
GM_F25	Kainar Bulak-1 '	FBA-EIA*	caprine	-18,7	7,1	3.1	Motuzaite Matuzeviciute et al. 2015'
GM_F27	Kainar Bulak-1 '	FBA-EIA*	caprine	-19,5	7,0	3.2	Motuzaite Matuzeviciute et al. 2015'
GM_F28	Kainar Bulak-1 '	FBA-EIA*	caprine	-19,7	7,7	3.1	Motuzaite Matuzeviciute et al. 2015'
GM_F30	Kainar Bulak-1 '	FBA-EIA*	caprine	-20,4	5,5	3.4	Motuzaite Matuzeviciute et al. 2015'
GM_F32	Kainar Bulak-1 '	FBA-EIA*	caprine	-19,1	6,9	3.4	Motuzaite Matuzeviciute et al. 2015'
GM_F32	Kainar Bulak-1 '	FBA-EIA*	caprine	-19,0	9,7	3.5	Motuzaite Matuzeviciute et al. 2015'
GM_F33	Kainar Bulak-1 '	FBA-EIA*	caprine	-19,2	7,6	3.3	Motuzaite Matuzeviciute et al. 2015'
GM_F34	Kainar Bulak-1 '	FBA-EIA*	caprine	-18,4	8,9	3.1	Motuzaite Matuzeviciute et al. 2015'
GM_FF35	Kainar Bulak-1 '	FBA-EIA*	caprine	-18,5	7,6	3.1	Motuzaite Matuzeviciute et al. 2015'

GM_F18	Kanar Bulak-1	FBA-EIA*	cattle	-19,7	7,0	3.6	Motuzaite Matuzeviciute et al. 2015'
GM_F24	Kanar Bulak-1	FBA-EIA*	cattle	-19,0	8,6	3.4	Motuzaite Matuzeviciute et al. 2015'
GM_F29	Kanar Bulak-1	FBA-EIA*	cattle	-18,1	7,9	3.4	Motuzaite Matuzeviciute et al. 2015'
GM_F31	Kanar Bulak-1	FBA-EIA*	cattle	-18,1	8,8	3.4	Motuzaite Matuzeviciute et al. 2015'
GM_F76	Karatuma	IA*	caprine	-16,7	10,7	3.3	Motuzaite Matuzeviciute et al. 2015'
GM_F77	Karatuma	IA*	caprine	-16,8	10,7	3.3	Motuzaite Matuzeviciute et al. 2015'
GM_F78	Karatuma	IA*	cattle	-17	9,9	3.3	Motuzaite Matuzeviciute et al. 2015'
GM_F105	Kenelkel-18	BA*	caprine	-19,7	5,1	3.2	Motuzaite Matuzeviciute et al. 2015'
GM_F103	Kenelkel-18	IA*	cattle	-20,0	5,2	3.2	Motuzaite Matuzeviciute et al. 2015'
GM_136	Konyr-Tebe-1	medieval*	caprine	-18,1	6,3	3.1	Motuzaite Matuzeviciute et al. 2015'
GM_F35	Konyr-Tebe-1	medieval*	caprine	-19	11,8	3.4	Motuzaite Matuzeviciute et al. 2015'
GM_F36	Konyr-Tebe-1	medieval*	caprine	-18,5	7,7	3.3	Motuzaite Matuzeviciute et al. 2015'
GM_F37	Konyr-Tebe-1	medieval*	caprine	-18,3	7,7	3.1	Motuzaite Matuzeviciute et al. 2015'
GM_F38	Konyr-Tebe-1	medieval*	caprine	-18,4	7,8	3.3	Motuzaite Matuzeviciute et al. 2015'
GM_F39	Konyr-Tebe-1	medieval*	caprine	-18,5	7,6	3.3	Motuzaite Matuzeviciute et al. 2015'
GM_F40	Konyr-Tebe-1	medieval*	caprine	-18,4	7,7	3.3	Motuzaite Matuzeviciute et al. 2015'

GM_F41	Konyr-Tebe-1	medieval*	caprine	-18,5	8	3.1	Motuzaite Matuzeviciute et al. 2015'
GM_F42	Konyr-Tebe-1	medieval*	caprine	-18,1	7,9	3.4	Motuzaite Matuzeviciute et al. 2015'
GM_F82	Kyzyl-Bulak	BA*	caprine	-19	9,6	3.3	Motuzaite Matuzeviciute et al. 2015'
GM_F79	Lisakovsk	BA*	caprine	-19,0	7,8	3.2	Motuzaite Matuzeviciute et al. 2015'
GM_F80	Lisakovsk	BA*	caprine	-19,8	5,3	3.2	Motuzaite Matuzeviciute et al. 2015'
GM_F82	Lisakovsk	BA*	caprine	-19,1	6,1	3.1	Motuzaite Matuzeviciute et al. 2015'
GM_F83	Lisakovsk	BA*	caprine	-19,2	6,1	3.2	Motuzaite Matuzeviciute et al. 2015'
GM_F84	Lisakovsk	BA*	caprine	-18,8	6,2	3.5	Motuzaite Matuzeviciute et al. 2015'
GM_F85	Lisakovsk	BA*	caprine	-19,5	6,0	3.2	Motuzaite Matuzeviciute et al. 2015'
GM_F86	Lisakovsk	BA*	caprine	-19,5	6,0	3.2	Motuzaite Matuzeviciute et al. 2015'
GM_F101	Lisakovsk	BA*	cattle	-19,8	5,4	3.5	Motuzaite Matuzeviciute et al. 2015'
GM_F102	Lisakovsk	BA*	cattle	-19,8	6,5	3.6	Motuzaite Matuzeviciute et al. 2015'
GM_F87	Lisakovsk	BA*	cattle	-19,8	5,8	3.6	Motuzaite Matuzeviciute et al. 2015'
GM_F89	Lisakovsk	BA*	cattle	-19,8	5,7	3.6	Motuzaite Matuzeviciute et al. 2015'
GM_F95	Lisakovsk	BA*	cattle	-19,4	5,6	3.5	Motuzaite Matuzeviciute et al. 2015'
GM_F96	Lisakovsk	BA*	cattle	-19,3	5,3	3.2	Motuzaite Matuzeviciute et al. 2015'
GM_F97	Lisakovsk	BA*	cattle	-19,7	6,6	3.2	Motuzaite Matuzeviciute et

							al. 2015'
GM_F99	Lisakovsk	BA*	cattle	-19,1	5,9	3.6	Motuzaite Matuzeviciute et al. 2015'
GM_F94	Lisakovsk	BA*	horse	-20,1	5,8	3.2	Motuzaite Matuzeviciute et al. 2015'
GM_F93	Lisakovsk	BA*	horse	-20,4	6,1	3.5	Motuzaite Matuzeviciute et al. 2015'
GM_F100	Lisakovsk	BA*	horse	-20,9	4,3	3.2	Motuzaite Matuzeviciute et al. 2015'
GM_F91	Lisakovsk	BA*	horse	-20,4	6,5	3.5	Motuzaite Matuzeviciute et al. 2015'
GM_F023	Oi-Dzailau VII	BA*	caprine	-19,4	7,6	3.3	Motuzaite Matuzeviciute et al. 2015'
GM_F21	Shimkent	IA*	caprine	-18,4	6,6	3.4	Motuzaite Matuzeviciute et al. 2015'
GM_F003	Temirlanovka	IA*	caprine	-18,9	9,6	3.2	Motuzaite Matuzeviciute et al. 2015'
GM_F11	Bozshakol-6	IA*	cattle	-19,2	6,3	3.1	Motuzaite Matuzeviciute et al. 2016'
GM_F11	Bozshakol-6	IA*	cattle	-19,4	7,6	3.2	Motuzaite Matuzeviciute et al. 2016'
GM_F12	Bozshakol-6	IA*	cattle	-19,7	6,1	3.6	Motuzaite Matuzeviciute et al. 2016'
GM_F13	Bozshakol-6	IA*	cattle	-19,1	8,8	3.1	Motuzaite Matuzeviciute et al. 2016'
GM_F14	Bozshakol-6	IA*	cattle	-19,4	7,0	3.4	Motuzaite Matuzeviciute et al. 2016'
GM_F52	Bozshakol-6	IA*	cattle	-19,6	5,8	3.1	Motuzaite Matuzeviciute et al. 2016'
GM_F53	Bozshakol-6	IA*	cattle	-19,2	7,7	3.2	Motuzaite Matuzeviciute et al. 2016'
GM_F54	Bozshakol-6	IA*	cattle	-19,4	7,8	3.2	Motuzaite Matuzeviciute et al. 2016'

GM_F55	Bozshakol-6	IA*	cattle	-18,7	6,8	3.1	Motuzaite Matuzeviciute et al. 2016'
GM_F56	Bozshakol-6	IA*	cattle	-18,6	7,2	3.5	Motuzaite Matuzeviciute et al. 2016'
GM_F57	Bozshakol-6	IA*	cattle	-19,2	7,4	3.2	Motuzaite Matuzeviciute et al. 2016'
GM_F58	Bozshakol-6	IA*	cattle	-19,2	7,3	3.6	Motuzaite Matuzeviciute et al. 2016'
GM_F59	Bozshakol-6	IA*	cattle	-19,1	8,0	3.2	Motuzaite Matuzeviciute et al. 2016'
GM_F60	Bozshakol-6	IA*	cattle	-18,8	7,1	3.5	Motuzaite Matuzeviciute et al. 2016'
GM_F61	Bozshakol-6	IA*	cattle	-19,1	7,9	3.2	Motuzaite Matuzeviciute et al. 2016'
GM_F62	Bozshakol-6	IA*	cattle	-19,3	8,4	3.1	Motuzaite Matuzeviciute et al. 2016'
KZ16F	Novoilinovka	BA*	caprine	-19,8	7,5	3.2	Motuzaite Matuzeviciute et al. 2016'
KZ20F	Novoilinovka	BA*	cattle	-19,6	5,7	3.4	Motuzaite Matuzeviciute et al. 2016'
KZ21F	Novoilinovka	BA*	cattle	-20,0	4,5	3.2	Motuzaite Matuzeviciute et al. 2016'
KZ09F	Novoilinovka	BA*	cattle	-19,4	6,9	3.2	Motuzaite Matuzeviciute et al. 2016'
KZ10F	Novoilinovka	BA*	cattle	-19,7	6,0	3.2	Motuzaite Matuzeviciute et al. 2016'
KZ11F	Novoilinovka	BA*	cattle	-19,5	8,5	3.2	Motuzaite Matuzeviciute et al. 2016'
Ai-Dai II K4 M2	Ai-Dai	FBA-EIA*	cattle	-20,8	6,3	3.6	Murphy et al. 2013'
Aymyrlyg XXXI M139	Aymyrlyg	FBA-EIA*	caprine	-19,1	7,1	3.5	Murphy et al. 2013'
Aymyrlyg M35	Aymyrlyg	FBA-EIA*	horse	-20,9	7,2	3.6	Murphy et al. 2013'

BAI 1	Baitovo	FBA-EIA*	cattle	-20	5,4	3.2	Privat 2004'
BAI 2	Baitovo	FBA-EIA*	cattle	-21,4	5,7	3.5	Privat 2004'
BAI 3	Baitovo	FBA-EIA*	cattle	-20,1	5,7	3.2	Privat 2004'
BAI 4	Baitovo	FBA-EIA*	cattle	-20,7	6,2	3.3	Privat 2004'
BAI 7	Baitovo	FBA-EIA*	horse	-21,3	5,6	3.2	Privat 2004'
BAI 8	Baitovo	FBA-EIA*	horse	-21,5	4,1	3.3	Privat 2004'
BAI 9	Baitovo	FBA-EIA*	horse	-21,7	4,5	3.4	Privat 2004'
BKAR 17	Bolshekaragansky	BA*	caprine	-18,5	6,4	3.3	Privat 2004'
BKAR 16	Bolshekaragansky	BA*	cattle	-19	6,9	3.2	Privat 2004'
BKAR 15	Bolshekaragansky	BA*	horse	-19,7	4,7	3.2	Privat 2004'
KAM 12	Kamennyi Ambar V	BA*	caprine	-18,4	7,1	3.2	Privat 2004'
KAM 10	Kamennyi Ambar V	BA*	caprine	-17,9	8,1	3.2	Privat 2004'
KAM 9	Kamennyi Ambar V	BA*	caprine	-17,1	9,4	3.2	Privat 2004'
KAM 8	Kamennyi Ambar V	BA*	caprine	-19	4,3	3.2	Privat 2004'
KAM 11	Kamennyi Ambar V	BA*	caprine	-17,3	8,8	3.2	Privat 2004'
KAM 13	Kamennyi Ambar V	BA*	caprine	-18,2	8,4	3.2	Privat 2004'
KAM 15	Kamennyi Ambar V	BA*	cattle	-19	5,5	3.2	Privat 2004'
KAM 14	Kamennyi Ambar V	BA*	cattle	-18,2	7,1	3.4	Privat 2004'
KAM 17	Kamennyi Ambar V	BA*	cattle	-19,1	5,4	3.2	Privat 2004'
KAM 16	Kamennyi Ambar V	BA*	cattle	-18,4	9,4	3.3	Privat 2004'
KAM 18	Kamennyi Ambar V	BA*	cattle	-18,6	6,1	3.2	Privat 2004'
KAM 5	Kamennyi Ambar V	BA*	horse	-19,8	5,4	3.2	Privat 2004'
KAM 7	Kamennyi Ambar V	BA*	horse	-20	4,4	3.2	Privat 2004'

KAM 6	Kamennyi Ambar V	BA*	horse	-20,1	6,3	3.2	Privat 2004'
KAM 4	Kamennyi Ambar V	BA*	horse	-19,9	6,5	3.1	Privat 2004'
KAM 3	Kamennyi Ambar V	BA*	horse	-19,5	5,2	3.2	Privat 2004'
KZ 2	Kizil	FBA-EIA*	horse	-20,3	2,4	3.3	Privat 2004'
KZ 1	Kizil	FBA-EIA*	horse	-19,4	5,4	3.2	Privat 2004'
MUR 9	Murzino I	IA*	cattle	-20,5	7,3	3.2	Privat 2004'
PAV 11	Pavlinova	IA*	caprine	-17,7	8,8	3.2	Privat 2004'
PAV 12	Pavlinova	IA*	caprine	-18,1	9,4	3.2	Privat 2004'
PAV 13	Pavlinova	IA*	caprine	-19,6	9,1	3.2	Privat 2004'
PAV 14	Pavlinova	IA*	caprine	-18,7	8,7	3.2	Privat 2004'
PAV 15	Pavlinova	IA*	caprine	-20,3	6,5	3.2	Privat 2004'
PAV 16	Pavlinova	IA*	caprine	-19,9	4,6	3.2	Privat 2004'
PAV 17	Pavlinova	IA*	caprine	-18,9	8,4	3.2	Privat 2004'
PAV 1	Pavlinova	IA*	cattle	-20,8	5,9	3.3	Privat 2004'
PAV 18	Pavlinova	IA*	cattle	-21,3	5,4	3.4	Privat 2004'
PAV 19	Pavlinova	IA*	cattle	-20,7	5,6	3.4	Privat 2004'
PAV 2	Pavlinova	IA*	cattle	-20,4	6,2	3.5	Privat 2004'
PAV 3	Pavlinova	IA*	cattle	-20,4	5,6	3.2	Privat 2004'
PAV 4	Pavlinova	IA*	cattle	-20,4	4	3.2	Privat 2004'
PAV 5	Pavlinova	IA*	cattle	-20,9	6,5	3.2	Privat 2004'
PAV 10	Pavlinova	IA*	horse	-21,1	4,1	3.2	Privat 2004'
PAV 20	Pavlinova	IA*	horse	-21,4	4,6	3.2	Privat 2004'
PAV 21	Pavlinova	IA*	horse	-20,1	7,5	3.3	Privat 2004'

PAV 6	Pavlinova	IA*	horse	-21,1	6,3	3.2	Privat 2004'
PAV 7	Pavlinova	IA*	horse	-20,7	4,3	3.2	Privat 2004'
PAV 8	Pavlinova	IA*	horse	-21	4,6	3.3	Privat 2004'
PAV 9	Pavlinova	IA*	horse	-20,3	4	3.3	Privat 2004'
SKA 1	Skaty-1	IA*	herbivore	-21,2	4,1	3.2	Privat 2004'
UBA-23677	Tagybaibulak	IA*	herbivore	-19,1	8,5	3.2	Svyatko and Beisenov 2017
UBA-23677	Tagybaibulak	IA*	herbivore	-19,1	8,5	3.2	Svyatko and Beisenov 2017
BES 2	Bestamak	BA*	caprine	-17,7	7,8	3.3	Ventresca Miller et al. 2014'
BES 3	Bestamak	BA*	cattle	-18,5	8,4	3.3	Ventresca Miller et al. 2014'
BES 1	Bestamak	BA*	horse	-20	6,2	3.3	Ventresca Miller et al. 2014'

Appendix 5: Statistical calculations of stable isotope data

Table 1: Summary of the human data

Site (n)	$\delta^{13}C$ ‰					$\delta^{15}N$‰				
	Min	Max	Mean	SD	Median	Min	Max	Mean	SD	Median
Group A: Trans-Urals/Northern KZ(227)	**-22,8**	**-16,8**	**-18,8**	**0,9**	**-18,7**	**9,5**	**15,6**	**12,4**	**1,3**	**12,2**
Bronze Age(171)	**-20,3**	**-16,8**	**-18,5**	**0,6**	**-18,6**	**9,5**	**15,6**	**12,3**	**1,4**	**12,1**
Bestamak(21)	-19,6	-17,6	-19	0,5	-19,2	9,5	14,1	11,8	1	11,6
Bolshekaraganskyi (Arkaim)(14)	-19,3	-18	-18,9	0,5	-19	9,5	11,8	10,8	0,7	10,7
Isiney I(6)	-20,3	-18,4	-19	0,7	-18,8	10,5	11,9	11,4	0,5	11,5
Kamennyi Ambar, 5(77)	-19,7	-16,8	-18,1	0,6	-18	10,5	15,6	13,1	1,4	13
Krivoe Ozero(1)	-18,7	-18,7				10,5	10,5			
Kulevchi-6(3)	-19,1	-18,5	-18,7			12,7	13,1	12,8		
Lisakovsk(30)	-19,7	-17,5	-18,8	0,4	-18,8	9,9	14,4	12	1,2	12
Novoilinovka(8)	-19,2	-18,6	-18,9	0,2	-18,9	10,8	11,4	11,2	0,2	11,2
Ormandy Bulak-1(1)	-19	-19				10,9	10,9			
Peschanka-1(2)	-19,6	-19	-19,3			11,1	11,2	11,2		
Shagalaly(4)	-19,3	-19,1	-19,2			10,6	11,3	11		
Shondykorasy-2(1)	-18,3	-18,3				13,9	13,9			
Sintashta(1)	-18	-18				13,3	13,3			
Ust'e(3)	-18,9	-18,2	-18,6			10,4	12	11		
FBA - EIA(2)	**-18,7**	**-18,2**				**12,3**	**13,5**			
Akbidaik(1)	-18,2	-18,2				13,5	13,5			
Nikel'(1)	-18,7	-18,7				12,3	12,3			
Iron Age(49)	**-22,8**	**-17,5**	**-19,5**	**1,2**	**-19,1**	**10,5**	**14,9**	**12,5**	**1**	**12,5**

Bestamak(5)	-19,1	-18	-18,8	0,5	-19	12,2	13,1	12,6	0,4	12,5
Gavovsky-1(6)	-21,5	-20	-20,6	0,5	-20,5	11	12,8	12,1	0,7	12,2
Halvai 3 & Karatomar(4)	-19,2	-18,7	-19			10,5	12,9	11,6		
Kurtuguz-1(7)	-21,6	-17,5	-19,5	1,7	-19,8	11,7	14,3	12,9	0,8	12,9
Murzino-1(6)	-22,8	-20,4	-21,1	0,9	-21	12,1	14,9	13,1	1	12,8
Pobeda(7)	-18,8	-17,9	-18,4	0,4	-18,4	12,4	13,8	12,9	0,5	13
Shagalaly, 4,5(3)	-21,4	-18,7	-19,7			11,1	12	11,5		
Shaidurihka(5)	-20,6	-19,1	-19,9	0,5	-19,9	11,9	12,8	12,2	0,4	12,1
Skaty-1(2)	-20,2	-19,6				10,8	11,1	11		
Solonchanka-2(2)	-18,2	-18,1				12,3	14,6			
Staraya Mel'nitca(1)	-18,1	-18,1				14,6	14,6			
Varnenskie(1)	-19,1	-19,1				10,9	10,9			
Medieval(5)	**-19,4**	**-17,9**	**-18,4**	**0,6**	**-18,2**	**13,3**	**14**	**13,6**	**0,3**	**13,6**
Budenovka-5(1)	-19,4	-19,4				13,5	13,5			
Halvai(2)	-18,2	-17,9				13,6	13,6			
Ostrogorka(1)	-18,2	-18,2				14	14			
Lisakovsk(1)	-18,1	-18,1				13,3	13,3			
Group B: Altai piedmonts(56)	**-21,6**	**-12,8**	**-16,1**	**2**	**-15,6**	**9,9**	**14,8**	**12,1**	**1,4**	**11,8**
Bronze Age(8)	**-21,6**	**-18,2**	**-19,6**			**10,5**	**14,8**	**12**		
Firsovo-14(5)	-19,3	-19,1	-19,5			10,5	11,4	11		
Karatumsk(1)	-19,6	-19,6				13,9	13,9			
Zevakinskyi stone fence(2)	-21,6	-18,2				12,9	14,8			
FBA - EIA(24)	**-19,1**	**-12,8**	**-15,4**	**1,5**	**-15,3**	**9,9**	**14**	**11**	**1,1**	**10,8**
Ai-Dai(17)	-16,6	-12,8	-15,1	1	-15,2	9,9	11,8	10,7	0,5	10,4
Kizil(1)	-19	-19				10,2	10,2			
Zevakinskyi (6)	-19,1	-12,8	-15,7			10,7	14	12,3		
Iron Age(24)	**-18,1**	**-13,2**	**-15,5**	**1,4**	**-15,3**	**11,5**	**14**	**13,1**	**0,7**	**13,2**
Aymyrlyg(21)	-17,5	-13,2	-15,3	1,3	-15,2	11,8	14	13,2	0,5	13,2
Firsovo-11(1)	-15,3	-15,3				11,5	11,5			

Sebystei(2)	-18,1	-18,1				11,7	13,2	12,5		
Group C: central KZ (213)	**-22,1**	**-14,1**	**-18,1**	**0,9**	**-18,3**	**10,3**	**17,7**	**13,8**	**1,2**	**13,7**
Bronze Age(129)	**-19,6**	**-15,2**	**-18,2**	**0,6**	**-18,3**	**11,4**	**17,7**	**13,5**	**1,1**	**13,4**
Akimbek(5)	-18,5	-18,1	-18,3	0,2	-18,4	12,9	15,5	14	1	14,1
Ak-Koitas-4,5(2)	-19,1	-18,2				12,8	13,1	12,9		
Ak-Moustafa(1)	-18,2	-18,2				15,1	15,1			
Aschisu(10)	-19,1	-17,2	-18,4	0,6	-18,5	11,5	14,2	12,6	1	12,5
Ayapbergen(1)	-18,5	-18,5				12,3	12,3			
Bozshakol-2(2)	-18,9	-18,4				11,5	13,8	12,7		
Daryinskyi(3)	-18,1	-17,7	-17,9			14,2	14,3	14,2		
Kairakty(1)	-19	-19				11,6	11,6			
Kairan(25)	-18,7	-17,2	-18	0,5	-18,1	12,7	16,1	14,5	0,9	14,6
Karagash-2(3)	-18,8	-18,1	-18,4			13,9	14,3	14		
Karazhartas(5)	-17,3	-15,2	-16,8	0,9	-17,2	13,3	14,4	13,6	0,5	13,4
Kopa-I(1)	-18,3	-18,3				12,5	12,5			
Kyzylkol(8)	-19,2	-18,2	-18,6	0,4	-18,6	13	15,1	13,8	0,7	13,6
Maitan(9)	-19,6	-17,9	-18,6	0,5	-18,5	11,6	14,4	13	0,8	13,2
Nurataldy-1(1)	-18,6	-18,6				14,3	14,3			
Satan(1)	-18,3	-18,3				13,4	13,4			
Taldysai(1)	-19,1	-19,1				12,3	12,3			
Tankara(5)	-19	-18,1	-18,5	0,3	-18,4	13,2	14,2	13,5	0,4	13,5
Tashik(15)	-18,9	-18	-18,4	0,3	-18,5	12,5	14,9	13,3	0,7	13,1
Tasyrbai(2)	-18,6	-15,7				11,4	17,7	14,6		
Tegiszhol(24)	-19,1	-16,4	-18,2	0,5	-18,3	11,8	15,5	13	0,8	12,9
Temirkash(2)	-18,8	-17,6				12,7	13,3	13		
Tersakkan(2)	-18,1	-18				12,7	13,5			
FBA - EIA(62)	**-22,1**	**-14,1**	**-17,9**	**1,3**	**-18,1**	**10,3**	**16,9**	**14,2**	**1,3**	**14,3**
Akbeit(4)	-18	-15,7	-17,2			14,5	16,2	15,3	0,7	15,2
Baike-2(1)	-19,1	-19,1				14,8	14,8			

Bakybulak(4)	-19,1	-17,1	-18,2			13,6	15,8	14,7	0,9	14,8
Bektauata(1)	-17,2	-17,2				16,6	16,6			
Birlik(3)	-18,6	-17,5	-18,1			12,4	14,1	13,5		
Bozshakol-5(1)	-14,7	-14,7				13,1	13,1			
Complex "37 Voinov"(1)	-18,4	-18,4				15,5	15,5			
Karakemer(1)	-17,9	-17,9				14,9	14,9			
Karashoky, 6(8)	-18,5	-16	-17,4	0,9	-17,7	14,6	16,9	15,5	0,7	15,3
Karatugai(10)	-19,4	-17,7	-18,4	0,6	-18,4	10,3	14,3	12,6	1,5	12,8
Kent(1)	-16	-16				13,5	13,5			
Koitas(1)	-14,1	-14,1				14,3	14,3			
Kosoba(1)	-18,5	-18,5				13,6	13,6			
Kudryavaya Sopka(3)	-18,4	-18,1	-18,3			15	15,7	15,3		
Kurgan Borli(1)	-16,7	-16,7				13,7	13,7			
Kyzyl(2)	-18,9	-16,8				13	13,7			
Kyzylkoi(1)	-18	-18				15,9	15,9			
Kyzylshilik(3)	-22,1	-18,2	-19,8			13,1	14	13,6		
Myrzhyk-6(1)	-16,8	-16,8				15,2	15,2			
Nazar-2(3)	-18,7	-18	-18,4			13,9	14,8	14,3		
Nurken-2(1)	-17,3	-17,3				14,5	14,5			
Senkibai-2(1)	-18,9	-18,9				14	14			
Shidertinskoye-2(1)	-18,1	-18,1				12,1	12,1			
Taldy-2(2)	-16,8	-14,5				14,5	15,2			
Tandaily, 2(2)	-19,5	-18,7				13,3	13,6			
Tersakkan(2)	-18,4	-18				14,8	15,3			
Zhamantas(1)	-18,9	-18,9				13,7	13,7			
Zhambyl(1)	-18,8	-18,8				13	13			
Iron Age(14)	**-19,3**	**-16**	**-17,9**	**0,8**	**-17,8**	**11,9**	**15,2**	**14,1**	**0,9**	**14,4**
Karatobe(3)	-17,8	-16	-17,2			13,3	15,2	14,4		
Kotyrkora(1)	-17,8	-17,8				13,2	13,2			

Naurzum(1)	-17,5	-17,5				14,6	14,6			
PPK Saba(1)	-17,9	-17,9				14,3	14,3			
Shantimes(1)	-19,3	-19,3				11,9	11,9			
Taisoigan(1)	-18,2	-18,2				13,3	13,3			
Tegiszhol(3)	-18,2	-17,3	-17,8			14,1	14,6	14,4		
Zhartas(2)	-18,6	-18,2				14,3	14,5	14,4		
Zheken(1)	-17,8	-17,8				14,4	14,4			
Medieval(8)	**-19,7**	**-17,4**	**-18,7**	**0,7**	**-18,8**	**11,7**	**15,6**	**14**	**1,4**	**14,1**
Tersakkan 2,3,4(3)	-19,7	-18,6	-19,1			11,7	13,8	12,8		
Zhanteli-12(1)	-19	-19				12,9	12,9			
Zheken(4)	-19	-17,4	-18,3			14,3	15,6	15,1		
Group D: western KZ (21)	**-19**	**-13,4**	**-17,9**	**1,3**	**-18,3**	**11,9**	**17,9**	**13,8**	**1,5**	**13,4**
Bronze Age(3)	**-18,8**	**-18,3**	**-18,6**			**12,4**	**14,5**	**13,7**		
Taskala(3)	-18,8	-18,3	-18,6			12,4	14,5	13,7		
FBA-EIA(1)	**-17,7**	**-17,7**				**13,2**	**13,2**			
Kyrik-Oba-2(1)	-17,7	-17,7				13,2	13,2			
Iron Age(17)	**-19**	**-13,4**	**-17,7**	**1,5**	**-18,2**	**11,9**	**17,9**	**13,9**	**1,6**	**13,4**
Taksai 1,2(13)	-19	-13,4	-17,7	1,7	-18,5	11,9	17,9	13,7	1,7	13
Tortoba(4)	-18,3	-17,4	-17,8			13,4	16,3	14,5		
Group E: oases of Syr Darya (58)	**-22,5**	**-10,5**	**-15,4**	**2,6**	**-15,7**	**9,4**	**15,2**	**12,4**	**1,5**	**12,6**
FBA-EIA(23)	**-16,6**	**-10,5**	**-13,3**	**1,8**	**-13**	**10,1**	**14,7**	**12,2**	**1,4**	**12,4**
Burgulyuk,2(3)	-15,8	-14,3	-15,2			10,3	12,8	11,4		
Kainarbulak-1,2(17)	-15,4	-10,5	-12,6	1,4	-12,7	10,1	14,7	12,1	1,3	12
Kaitpas(3)	-16,6	-14,2	-15,6			13,4	13,9	13,6		
Iron Age(16)	**-22,5**	**-11,3**	**-16,3**	**2,4**	**-16,4**	**10,7**	**15,2**	**13,9**	**1,2**	**14,4**
Balandy(1)	-18,3	-18,3				11,1	11,1			
Chirik Rabat(10)	-22,5	-15,7	-17,3	1,9	-16,7	13	15,2	14,5	0,7	14,7
Temirlanovka(4)	-14,6	-12,6	-13,5			12	14	13,1		

Shymkent(1)	-11,3	-11,3				10,7	10,7			
Medieval(19)	**-19,4**	**-12,4**	**-17,1**	**1,9**	**-17,8**	**9,4**	**12,9**	**11,5**	**1,1**	**11,9**
Besynshitobe(1)	-19,4	-19,4				12,6	12,6			
Karauyltobe(1)	-18,7	-18,7				9,4	9,4			
Kok-Mardan(2)	-17,8	-16,1				11,9	12,7			
Konyr-Tobe(10)	-19,1	-12,4	-16,6	2,3	-17,1	10,7	12,9	12	0,8	12,1
Madani(5)	-19	-15,4	-17,5	1,4	-17,8	9,6	10,9	10,5	0,5	10,7
Group F: southeast KZ (160)	**-19,5**	**-10,7**	**-15,7**	**1,6**	**-15,9**	**8,8**	**17,2**	**12,7**	**1,6**	**12,6**
Bronze Age(36)	**-19,2**	**-13,3**	**-16,5**	**1,5**	**-16,9**	**10,3**	**16,1**	**13,7**	**1,4**	**13,8**
Aktogai(12)	-17,7	-16,3	-17	0,5	-17	11,2	16	14	1,7	14,6
Dali, Byan Zherek(1)	-17,8	-17,8				13	13			
Kazakh Mys(4)	-17,9	-14,1	-16,1			12,8	16,1	14,3		
Kyzyl-Bulak-1(2)	-18,8	-16,5				10,8	12,6			
Oi-Dzhailau, 7(16)	-18,5	-13,3	-15,9	1,7	-16,1	12,8	14,7	13,8	0,6	13,8
Turgen-2 (1)	-19,2	-19,2				10,3	10,3			
FBA-EIA(15)	**-17,3**	**-13**	**-15,3**	**1,4**	**-15,5**	**8,9**	**15**	**11,5**	**1,6**	**11,6**
Alatau,1(2)	-17,3	-16,8				8,9	10,8			
Kamenka(4)	-16,9	-15,3	-15,9			9,7	12,3	10,7		
Kargaly-1,108(7)	-15,5	-13	-14	0,9	-13,7	10,4	15	12,3	1,4	12,2
Oi-Dzhailau-8(1)	-16,6	-16,6				10,3	10,3			
Shokpar(1)	-16,1	-16,1				13,5	13,5			
Iron Age(82)	**-18,4**	**-12,2**	**-15,5**	**1,3**	**-15,8**	**8,8**	**17,2**	**12,7**	**1,6**	**12,7**
Aktogai(2)	-17,6	-16,6				12,1	15,3			
Alatau-1(3)	-17,3	-15,9	-16,5			10	11,6	10,8		
Karatuma(39)	-17	-12,9	-15,4	1	-15,5	8,8	17,2	12,3	1,6	12,4
Karkara(2)	-17,8	-15,9	-16,9			10,1	11,2	10,7		
Katartobe(4)	-18,4	-17,3	-17,8			11,0	15,5	12,6		
Khatau-1(1)	-15	-15				15,9	15,9			
Kyzylasker(1)	-14,4	-14,4				12,8	12,8			

Nurly(1)	-14,7	-14,7				13,7	13,7			
Ornek(1)	-14,6	-14,6				15,2	15,2			
Shatyrkul(13)	-15,8	-12,2	-14,7	1,2	-15	12,8	15,7	14	0,9	13,8
Turgen-2(14)	-18,4	-15,4	-16,6	0,8	-16,3	10,1	13,8	12,5	1,0	12,3
Medieval(27)	**-19,5**	**-10,7**	**-15,2**	**2,3**	**-15,5**	**9,5**	**14,8**	**11,9**	**1,3**	**11,8**
Aktas(1)	-15,5	-15,5				12	12			
Almaly(1)	-14,8	-14,8				12,6	12,6			
Butakty,1(9)	-15,7	-10,7	-12,9	2	-12,1	10,7	14	11,8	1	11,7
Esik(1)	-15,9	-15,9				11,2	11,2			
Janaturmus(1)	-17,3	-17,3				14,8	14,8			
Karatal(3)	-18,1	-16,2	-17,4			12,4	13,9	13		
Kargalinka-2(1)	-14,9	-14,9				9,5	9,5			
Kyzylbulak-4(1)	-19,5	-19,5				9,5	9,5			
Turgen-2(7)	-18,1	-15,1	-16,2	1,2	-15,6	10,4	11,9	11,4	0,5	11,7

Table 2: Summary of the domestic herbivore data

Site (n)	**$\delta^{13}C$‰**					**$\delta^{15}N$‰**				
	Min	Max	Mean	SD	Median	Min	Max	Mean	SD	Median
Group A: Trans-Urals/Northern KZ(158)	**-21,7**	**-17,1**	**-19,6**	**0,9**	**-19,7**	**3,1**	**11,5**	**6,3**	**1,5**	**6,2**
Bronze Age(89)	**-20,9**	**-17,1**	**-19,5**	**0,8**	**-19,5**	**3,1**	**11,5**	**6,3**	**1,6**	**6,1**
Caprines(36)	-20,5	-17,1	-18,8	0,8	-18,8	3,9	11,5	6,9	1,8	7,1
Cattle(25)	-20,6	-18,2	-19,3	0,6	-19,4	4,4	9,4	6,4	1,3	6,0
Horse(28)	-20,9	-19,3	-20,2	0,4	-20,2	3,1	6,9	5,4	1,1	5,9
FBA - EIA(9)	**-21,7**	**-19,7**	**-20,9**	**0,7**	**-21,3**	**4,1**	**9,2**	**5,6**	**1,5**	**5,6**
Caprine(1)	-19,7	-19,7				9,2	9,2			
Cattle(4)	-21,4	-20	-20,6	0,7	-20,4	5,4	6,2	5,8	0,3	5,7
Horse(4)	-21,7	-21,3	-21,5	0,2	-21,4	4,1	5,6	4,6	0,7	4,4
Iron Age(42)	**-21,4**	**-17,7**	**-19,8**	**0,9**	**-19,8**	**4,0**	**9,4**	**6,5**	**1,5**	**6,5**
Caprine(9)	-20,3	-17,7	-19,3	1,0	-19,6	4,6	9,4	7,4	1,9	8,4
Cattle(25)	-21,3	-20,9	-19,7	0,8	-19,4	4,0	8,8	6,8	1,1	7,0
Horse(8)	-21,4	-20,1	-20,9	0,5	-21,1	4,0	7,5	4,9	1,3	4,5
Group B: Altai piedmonts(6)	**-20,9**	**-19,0**	**-19,9**	**0,9**	**-19,9**	**2,4**	**10,3**	**6,5**	**2,6**	**6,7**
FBA - EIA(5)	**-20,9**	**-19,1**	**-20,1**	**0,8**	**-20,3**	**2,4**	**7,1**	**5,7**	**2,0**	**6,3**
Caprine(1)	-19,1	-19,1				7,1	7,1			
Cattle(1)	-20,8	-20,8				6,3	6,3			
Horse(3)	-20,9	-19,4	-20,2			2,4	7,2	5,0		
Iron Age(1)	-19,0	-19,0				10,3	10,3			
Caprine(1)	-19,0	-19,0				10,3	10,3			

Group C: central KZ (101)	**-21,5**	**-17,5**	**-19,4**	**0,8**	**-19,2**	**3,4**	**13,3**	**7,7**	**1,6**	**7,7**
Bronze Age(74)	**-20,7**	**-17,9**	**-19,2**	**0,7**	**-19,1**	**3,4**	**13,3**	**7,5**	**1,7**	**7,6**
Caprine(4)	-20,0	-18,8	-19,5	0,6	-19,5	5,1	9,7	7,4	2,1	7,4
Cattle(2)	-19,7	-19,1				9,0	10,7			
Horse(1)	-19,1	-19,1				8,9	8,9			
FBA - EIA(22)	**-21,2**	**-17,5**	**-19,8**	**0,8**	**-19,9**	**5,3**	**10,5**	**8,3**	**1,3**	**8,2**
Caprine(8)	-20,4	-17,5	-19,2	0,9	-19,3	6,7	10,5	8,7	1,2	8,5
Cattle(10)	-20,5	-19,5	-20,0	0,3	-20,1	6,9	10,0	8,2	1,0	8,1
Horse(2)	-21,2	-20,8				5,3	7,1			
Iron Age(5)	**-21,5**	**-17,7**	**-19,7**	**1,5**	**-19,1**	**4,5**	**9,8**	**7,7**	**2,0**	**8,5**
Caprine(2)	-20,9	-17,7				7,4	9,8			
Horse(1)	-21,5	-21,5				4,5	4,5			
Group D: western KZ (17)	**-21,0**	**-18,7**	**-19,9**	**0,6**	**-19,8**	**5,1**	**8,2**	**6,6**	**1,0**	**6,3**
Iron Age(17)	-21,0	-18,7	-19,9	0,6	-19,8	5,1	8,2	6,6	1,0	6,3
Caprine(7)	-20,8	-18,7	-19,8	0,8	-19,5	5,6	7,7	6,6	0,9	6,5
Cattle(2)	-19,8	-19,3				7,7	7,9			
Horse(8)	-21,0	-19,6	-20,2	0,5	-20,1	5,1	8,2	6,3	1,0	5,9
Group E: oases of Syr Darya (33)	**-20,7**	**-12,2**	**-18,5**	**1,5**	**-18,5**	**4,5**	**11,8**	**8,0**	**1,5**	**7,8**
FBA-EIA(19)	**-20,7**	**-18,0**	**-19,1**	**0,8**	**-19,1**	**4,5**	**9,7**	**7,6**	**1,3**	**7,6**
Caprine(11)	-20,4	-18,4	-19,2	0,6	-19,1	5,5	9,7	7,7	1,2	7,6
Cattle(4)	-19,7	-18,1	-18,7	0,8	-18,5	7,0	8,8	8,1	0,8	8,2
Horse(4)	-20,7	-18,0	-19,4	1,2	-19,5	4,5	8,5	6,7	1,8	7,0
Iron Age(5)	**-18,0**	**-12,2**	**-16,0**	**2,2**	**-16,8**	**8,6**	**11,0**	**9,6**	**1,1**	**9,8**
Caprine(3)	-18,0	-15,7	-16,9			8,6	11,0	9,8		
Cattle(2)	-16,8	-12,2				8,6	10,2			
Medieval(9)	**-19,0**	**-18,1**	**-18,4**	**0,3**	**-18,4**	**6,3**	**11,8**	**8,1**	**1,5**	**7,7**

Caprine(9)	-19,0	-18,1	-18,4	0,3	-18,4	6,3	11,8	8,1	1,5	7,7
Group F: southeast KZ (35)	**-20,6**	**-16,3**	**-18,6**	**1,1**	**-18,8**	**3,4**	**11,7**	**7,6**	**2,0**	**7,6**
Bronze Age(28)	**-20,6**	**-16,3**	**-18,8**	**1,0**	**-18,9**	**3,4**	**11,7**	**7,3**	**1,9**	**7,4**
Caprine(14)	-20,0	-16,3	-18,7	1,0	-18,9	4,9	9,7	7,1	1,7	7,2
Cattle(8)	-20,6	-17,5	-18,9	1,2	-18,7	3,4	9,5	6,7	2,1	6,2
Horse(6)	-20,1	-17,6	-18,9	0,9	-19,0	5,8	11,7	8,5	2,0	8,3
Iron Age(6)	**-19,6**	**-16,7**	**-17,9**	**1,2**	**-17,7**	**6,6**	**10,7**	**9,2**	**1,6**	**9,8**
Caprine(4)	-18,9	-16,7	-17,7	1,1	-17,6	6,6	10,7	9,4	1,9	10,1
Cattle(2)	-19,6	-17,0				8,0	9,9			
Medieval(1)	**-18,4**	**-18,4**				**7,4**	**7,4**			
Caprine(1)	-18,4	-18,4				7,4	7,4			

Table 3. Bayesian bootstrap results: human data by geography

Group of values	$\delta^{13}C$‰ mean$_b$ Mean	2.50% CI	97.50% CI
Group A: Trans-Urals/northern KZ (n=227)	-18,83	-19,07	-18,68
Group B: Altai piedmonts (n=56)	-16,07	-16,61	-15,58
Group C: central KZ (n=212)	-18,13	-18,24	-18,0
Group D: western KZ (n=17)	-17,86	-18,36	-17,08
Group E: oases of Syr Darya (n=57)	-15,38	-16,05	-14,7
Group F: southeast KZ (n=156)	-15,66	-15,9	-15,41
Group of values	$\delta^{15}N$‰ mean$_b$ Mean	2.50% CI	97.50% CI
Group A: Trans-Urals/northern KZ(n=227)	12,37	12,2	12,54
Group B: Altai piedmonts (n=56)	12,06	11,7	12,42
Group C: central KZ (n=212)	13,76	13,61	13,93
Group D: western KZ (n=17)	13,66	13,07	14,48
Group E: oases of Syr Darya (n=57)	12,43	12,04	12,82
Group F: southeast KZ (n=156)	12,65	12,39	12,9

Table 4. Bayesian bootstrap results: human data by time period

Group A: Trans-Urals/northern KZ Time period	$\delta^{13}C$‰ mean$_b$ Mean	2.50% CI	97.50% CI
Bronze Age(n=171)	-18,54	-18,63	-18,44
Iron Age(n=49)	-19,53	-19,88	-19,22
Medieval(n=5)	-18,38	-18,91	-18,09
Time period	$\delta^{15}N$‰ mean$_b$ Mean	2.50% CI	97.50% CI
Bronze Age(n=171)	12,3	12,1	12,52
Iron Age(n=49)	12,48	12,22	12,76

Medieval(n=5)	13,6	13,43	13,78

Group B: Altai piedmonts	$\delta^{13}C$‰ $mean_b$		
Time period	Mean	2.50% CI	97.50% CI
Bronze Age(n=8)	-19,61	-20,27	-19,06
Final Bronze Age – Early Iron Age(n=24)	-15,42	-16,04	-14,88
Iron Age(n=24)	-15,54	-16,1	-15,02

	$\delta^{15}N$‰ $mean_b$		
Time period	Mean	2.50% CI	97.50% CI
Bronze Age(n=8)	12,04	11,21	13,12
Final Bronze Age – Early Iron Age(n=24)	11,04	10,69	11,51
Iron Age(n=24)	13,08	12,8	13,32

Group C: central KZ	$\delta^{13}C$‰ $mean_b$		
Time period	Mean	2.50% CI	97.50% CI
Bronze Age(n=129)	-18,23	-18,33	-18,12
Final Bronze Age – Early Iron Age(n=63)	-17,9	-18,19	-17,58
Iron Age(n=12)	-17,87	-18,26	-17,39
Medieval(n=8)	-18,69	-19,06	-18,23

	$\delta^{15}N$‰ $mean_b$		
Time period	Mean	2.50% CI	97.50% CI
Bronze Age(n=129)	13,51	13,33	13,7
Final Bronze Age – Early Iron Age(n=63)	14,21	13,88	14,51
Iron Age(n=12)	14,11	13,56	14,5
Medieval(n=8)	13,96	13,07	14,8

Group D: western KZ	$\delta^{13}C$‰ $mean_b$		
Time period	Mean	2.50% CI	97.50% CI
Iron Age(n=13)	-17,72	-18,36	-16,74

	$\delta^{15}N$‰ $mean_b$		

Time period	Mean	2.50% CI	97.50% CI
Iron Age(n=13)	13,69	12,95	14,71

Group E: oases of Syr Darya	$\delta^{13}C$‰ $mean_b$		
Time period	Mean	2.50% CI	97.50% CI
Final Bronze Age – Early Iron Age(n=23)	-13,32	-14,03	-12,61
Iron Age(n=15)	-16,32	-17,59	-15,24
Medieval(n=19)	-17,12	-17,85	-16,24

	$\delta^{15}N$‰ $mean_b$		
Time period	Mean	2.50% CI	97.50% CI
Final Bronze Age – Early Iron Age(n=23)	12,22	11,69	12,74
Iron Age(n=15)	13,89	13,27	14,42
Medieval(n=19)	11,54	11,06	12,0

Group F: southeast KZ	$\delta^{13}C$‰ $mean_b$		
Time period	Mean	2.50% CI	97.50% CI
Bronze Age(n=36)	-16,53	-16,96	-16,03
Final Bronze Age – Early Iron Age(n=15)	-15,26	-15,89	-14,58
Iron Age(n=78)	-15,52	-15,79	-15,23
Medieval(n=27)	-15,16	-15,97	-14,31

	$\delta^{15}N$‰ $mean_b$		
Time period	Mean	2.50% CI	97.50% CI
Bronze Age(n=36)	13,68	13,22	14,11
Final Bronze Age – Early Iron Age(n=15)	11,48	10,77	12,23
Iron Age(n=78)	12,67	12,31	13,03
Medieval(n=27)	11,87	11,42	12,36

Table 5. Bayesian bootstrap results: herbivore data by time period

Groups by time period	$\delta^{13}C$‰

Time period	$\delta^{13}C$‰ mean$_b$ Mean	2.50% CI	97.50% CI
Bronze Age(n=191)	-19,21	-19,32	-19,09
Final Bronze Age – Early Iron Age(n=55)	-19,74	-20,0	-19,5
Iron Age(n=76)	-19,45	-19,75	-19,1
Medieval(n=10)	-18,42	-18,58	-18,29

Time period	$\delta^{15}N$‰ mean$_b$ Mean	2.50% CI	97.50% CI
Bronze Age(n=191)	6,97	6,73	7,24
Final Bronze Age – Early Iron Age(n=55)	7,34	6,87	7,78
Iron Age(n=76)	7,0	6,61	7,4
Medieval(n=10)	8,0	7,41	8,97

Table 6. Bayesian bootstrap results: herbivore data by geography

Group A: Trans-Urals/northern Kazakhstan	$\delta^{13}C$‰ mean$_b$ Mean	2.50% CI	97.50% CI
All time periods(n=143)	-19,65	-19,78	-19,51
Bronze Age(n=90)	-19,41	-19,58	-19,23
Final Bronze Age – Early Iron Age(n=9)	-20,86	-21,25	-20,4
Iron Age(n=44)	-19,87	-20,13	-19,59

Group A: Trans-Urals/northern Kazakhstan	$\delta^{15}N$‰ mean$_b$ Mean	2.50% CI	97.50% CI
All time periods(n=143)	6,29	6,04	6,55
Final Bronze Age – Early Iron Age(n=90)	6,3	5,98	6,63
FBA - EIA(n=9)	5,63	4,9	6,7
Iron Age(n=44)	6,42	5,96	6,88

$\delta^{13}C$‰
mean$_b$

Group B: Altai piedmonts	Mean	2.50% CI	97.50% CI
All time periods(n=6)	-19,91	-20,49	-19,37
FBA - EIA(n=5)	-20,1	-20,62	-19,51

$\delta^{15}N$‰ $mean_b$

Group B: Altai piedmonts	Mean	2.50% CI	97.50% CI
All time periods(n=6)	6,4	4,56	8,18
FBA - EIA(n=5)	5,46	4,62	6,38

$\delta^{13}C$‰ $mean_b$

Group C: central KZ	Mean	2.50% CI	97.50% CI
All time periods(n=101)	-19,37	-19,53	-19,22
Bronze Age(n=74)	-19,24	-19,39	-19,1
Final Bronze Age – Early Iron Age(n=22)	-19,75	-20,06	-19,4
Iron Age(n=5)	-19,67	-20,75	-18,57

$\delta^{15}N$‰ $mean_b$

Group C: central KZ	Mean	2.50% CI	97.50% CI
All time periods(n=101)	7,68	7,39	8,0
Bronze Age(n=74)	7,5	7,15	7,9
Final Bronze Age – Early Iron Age(n=22)	8,25	7,75	8,76
Iron Age(n=5)	7,74	6,05	8,93

$\delta^{13}C$‰ $mean_b$

Group D: western KZ	Mean	2.50% CI	97.50% CI
Iron Age(n=17)	-19,92	-20,22	-19,64

$\delta^{15}N$‰ $mean_b$

Group D: western KZ	Mean	2.50% CI	97.50% CI
Iron Age(n=17)	6,58	6,16	7,02

$\delta^{13}C$‰ $mean_b$

Group E: oases of Syr Darya	Mean	2.50% CI	97.50% CI

All time periods(n=34)	-18,47	-18,88	-17,9
Final Bronze Age – Early Iron Age(n=20)	-19,12	-19,44	-18,82
Iron Age(n=5)	-15,93	-17,19	-14,05
Medieval(n=9)	-18,43	-18,61	-18,28

Group E: oases of Syr Darya	$\delta^{15}N‰$ mean$_b$ Mean	2.50% CI	97.50% CI
All time periods(n=34)	7,95	7,49	8,47
Final Bronze Age – Early Iron Age(n=20)	7,48	6,91	7,98
Iron Age(n=5)	9,64	8,92	10,4
Medieval(n=9)	8,05	7,39	9,12

Group F: southeast KZ	$\delta^{13}C‰$ mean$_b$ Mean	2.50% CI	97.50% CI
All time periods(n=35)	-18,6	-18,95	-18,26
Bronze Age(n=28)	-18,77	-19,13	-18,42
Iron Age(n=6)	-17,89	-18,72	-17,12

Group F: southeast KZ	$\delta^{15}N‰$ mean$_b$ Mean	2.50% CI	97.50% CI
All time periods(n=35)	7,61	6,96	8,25
Bronze Age(n=28)	7,26	6,57	7,94
Iron Age(n=6)	9,25	7,99	10,16

Table 7. Bayesian bootstrap results: herbivore data by species/time period

Bronze Age	$\delta^{13}C‰$ mean$_b$ Mean	2.50% CI	97.50% CI
Caprines(n=54)	-18,83	-19,04	-18,60
Cattle(n=35)	-19,23	-19,46	-18,97
Horse(n=35)	-19,93	-20,14	-19,68

$\delta^{15}N‰$
mean$_b$

Bronze Age	Mean	2.50% CI	97.50% CI
Caprines(n=54)	7,01	6,55	7,48
Cattle(n=35)	6,63	6,13	7,18
Horse(n=35)	6,07	5,53	6,67

$\delta^{13}C$‰ mean$_b$

Final Bronze Age – Early Iron Age	Mean	2.50% CI	97.50% CI
Caprines(n=21)	-19,21	-19,48	-18,91
Cattle(n=19)	-19,91	-20,23	-19,53
Horse(n=13)	-20,46	-20,94	-19,84

$\delta^{15}N$‰ mean$_b$

Final Bronze Age – Early Iron Age	Mean	2.50% CI	97.50% CI
Caprines(n=21)	8,1	7,58	8,65
Cattle(n=19)	7,58	7,0	8,1
Horse(n=13)	5,61	4,75	6,48

$\delta^{13}C$‰ mean$_b$

Iron Age	Mean	2.50% CI	97.50% CI
Caprines(n=26)	-18,89	-19,39	-18,34
Cattle(n=31)	-19,26	-19,71	-18,61
Horse(n=16)	-20,52	-20,81	-20,25

$\delta^{15}N$‰ mean$_b$

Iron Age	Mean	2.50% CI	97.50% CI
Caprines(n=26)	7,97	7,24	8,68
Cattle(n=31)	7,14	6,67	7,61
Horse(n=16)	5,62	5,06	6,26

$\delta^{13}C$‰ mean$_b$

Medieval	Mean	2.50% CI	97.50% CI
Caprines(n=10)	-18,42	-18,58	-18,29

$\delta^{15}N$‰ mean$_b$

Medieval	Mean	2.50% CI	97.50% CI

Caprines(n=10)	7,98	7,38	8,98

Table 8. Mann-Whitney U test results

No.	Humans/Group	$\delta^{13}C$ ‰ U	P-value (two-tailed)	$\delta^{15}N$ ‰ U	P-value (two-tailed)
	Comparison by geography - all time periods				
1	Trans-Urals/Northern KZ (n=227) vs. central KZ (n=212)	15279	< 0,0001	10330	< 0,0001
2	Central KZ (n=212) vs. western KZ (n=17)	1728	0,7808	1523	0,2907
3	Oases of Syr Darya (n=57) vs. southeast KZ (n=156)	4200	0,5373	4107	0,3953
	Comparison by time period				
4	Altai piedmonts: BA (n=8) vs. FBA-EIA (n=24)	3	< 0,0001	52	0,0549
5	Altai piedmonts: FBA-EIA (n=24) vs. Iron Age (24)	275	0,7943	55	< 0,0001
6	Central KZ: BA (n=129) vs. FBA-EIA (n=63)	3239	0,0327	2536	< 0,0001
7	Central KZ: FBA-EIA (n=63) vs. Iron Age (12)	337	0,5604	353	0,7239
8	Central KZ: Iron Age (n=12) vs. Medieval (n=8)	21	0,368	45	0,823
9	Oases of Syr Darya: Iron Age (n=15) vs. Medieval (n=19)	97	0,119	19	< 0,0001
10	Southeast KZ: FBA-EIA (n=15) vs. Iron Age (n=78)	530	0,5709	323	0,0054
11	Southeast KZ: Iron Age (n=78) vs. Medieval (n=27)	989,5	0,6239	685	0,0065

No.	Herbivores/Group	$\delta^{13}C$ ‰ U	P-value (two-tailed)	$\delta^{15}N$ ‰ U	P-value (two-tailed)
	Comparison by time period				
1	Bronze Age (n=191) vs. Final Bronze Age - Early Iron Age (n=55)	3684	< 0,0007	4247	0,0303
2	Final Bronze Age - Early Iron Age (n=55) vs. Iron Age (n=76)	1926	0,4464	1869	0,3032
3	Bronze Age (n=191) vs. Iron Age (n=76)	5847	0,013	6784	0,4061

Appendix 7: Results of FRUITS modelling for the selected sites

Group	$\delta^{13}C‰$			$\delta^{15}N‰$			
	mean	SD	[C]	mean	SD	[N]	**FRUITS results**
Southern Urals and northern Kazakhstan - Bronze Age sites							
1. BestamakBA (n=35)	**-18,9**	**0,5**		**11,6**	**1,0**		
Local contemp. herbivores (n=29)	-19,6	0,7	0,60	6,2	1,1	0,09	**0,21**
Freshwater fish (Chicha) (n=24)	-22,5	1,9	0,55	10,5	1,5	0,12	**0,40**
C3 plants (wheat, NKZ), (n=1)	-23,0		0,46	5,0		0,02	**0,27**
C4 plants (millet, WChin-NCaus), (n=2)	-10,4		0,47	8,0		0,02	**0,11**
2. Bolshekaraganskyi-Arkaim (n=14)	**-18,9**	**0,5**		**10,8**	**0,7**		
Local contemp. herbivores (n=19)	-18,8	0,9	0,60	6,6	1,6	0,09	**0,23**
Freshwater fish (Chicha) (n=24)	-22,5	1,9	0,55	10,5	1,5	0,12	**0,35**
C3 plants (wheat, NKZ), (n=1)	-23,0		0,46	5,0		0,02	**0,32**
C4 plants (millet, WChin-NCaus), (n=2)	-10,4		0,47	8,0		0,02	**0,10**
3. Kamennyi Ambar (n=19)	**-17,9**	**0,9**		**13,2**	**1,2**		
Local contemp. herbivores (n=19)	-18,8	0,9	0,60	6,6	1,6	0,09	**0,20**
Freshwater fish (Chicha) (n=24)	-22,5	1,9	0,55	10,5	1,5	0,12	**0,43**
C3 plants (wheat, NKZ), (n=1)	-23,0		0,46	5,0		0,02	**0,21**
C4 plants (millet, WChin-NCaus), (n=2)	-10,4		0,47	8,0		0,02	**0,17**
4. Lisakovsk (n=28)	**-18,8**	**0,4**		**12,0**	**1,0**		
Local contemp. herbivores (n=19)	-19,6	0,6	0,60	5,9	0,7	0,09	**0,19**
Freshwater fish (Chicha) (n=24)	-22,5	1,9	0,55	10,5	1,5	0,12	**0,43**
C3 plants (wheat, NKZ), (n=1)	-23,0		0,46	5,0		0,02	**0,26**

C4 plants (millet, WChin-NCaus), (n=2)	-10,4		0,47	8,0		0,02	**0,12**
Southern Urals and northern Kazakhstan - Iron Age sites							
1. BestamakIA (n=5)	**-18,8**	**0,5**		**12,1**	**0,9**		
Local BA herbivores (n=29)	-19,6	0,7	0,60	6,2	1,1	0,09	**0,20**
Freshwater fish (Chicha) (n=24)	-22,5	1,9	0,55	10,5	1,5	0,12	**0,43**
C3 plants (wheat, NKZ), (n=1)	-23,0		0,46	5,0		0,02	**0,24**
C4 plants (millet, WChin-NCaus), (n=2)	-10,4		0,47	8,0		0,02	**0,12**
2. Halvai 3 & Karatamar I (4)	**-19,0**	**0,2**		**11,6**	**1,0**		
Local BA herbivores (n=29)	-19,6	0,7	0,60	6,2	1,1	0,09	**0,22**
Freshwater fish (Chicha) (n=24)	-22,5	1,9	0,55	10,5	1,5	0,12	**0,42**
C3 plants (wheat, NKZ), (n=1)	-23,0		0,46	5,0		0,02	**0,24**
C4 plants (millet, WChin-NCaus), (n=2)	-10,4		0,47	8,0		0,02	**0,09**
3. Kurtuguz (n=7)	**-19,5**	**1,7**		**12,9**	**0,8**		
Local BA herbivores (n=18)	-19,0	1,1	0,60	6,4	1,9	0,09	**0,17**
Freshwater fish (Chicha) (n=24)	-22,5	1,9	0,55	10,5	1,5	0,12	**0,47**
C3 plants (wheat, NKZ), (n=1)	-23,0		0,46	5,0		0,02	**0,22**
C4 plants (millet, WChin-NCaus), (n=2)	-10,4		0,47	8,0		0,02	**0,13**
4. Shagalaly, IV, V (3)	**-19,7**	**1,5**		**11,5**	**0,5**		
Local BA and IA herbivores (n=11)	-19,9	0,7	0,60	5,0	1,7	0,09	**0,18**
Freshwater fish (Chicha) (n=24)	-22,5	1,9	0,55	10,5	1,5	0,12	**0,44**
C3 plants (wheat, NKZ), (n=1)	-23,0		0,46	5,0		0,02	**0,26**
C4 plants (millet, WChin-NCaus), (n=2)	-10,4		0,47	8,0		0,02	**0,12**
Altai piedmonts - Iron Age sites							
1. Ai-Dai (17)	**-15,1**	**1,0**		**10,7**	**0,5**		
Local IA and BA herbivores (n=9)	-19,6	0,8	0,60	6,6	0,5	0,09	**0,17**
Freshwater fish (Chicha) (n=24)	-22,5	1,9	0,55	10,5	1,5	0,12	**0,25**

C3 plants (wheat, NKZ), (n=1)	-23,0		0,46	5,0		0,02	**0,15**
C4 plants (millet, WChin-NCaus), (n=2)	-10,4		0,47	8,0		0,02	**0,42**
2. Aymyrlyg (21)	**-15,3**	**1,3**		**13,2**	**0,5**		
Local IA and BA herbivores (n=9)	-19,6	0,8	0,60	6,6	0,5	0,09	**0,06**
Freshwater fish (Chicha) (n=24)	-22,5	1,9	0,55	10,5	1,5	0,12	**0,45**
C3 plants (wheat, NKZ), (n=1)	-23,0		0,46	5,0		0,02	**0,09**
C4 plants (millet, WChin-NCaus), (n=2)	-10,4		0,47	8,0		0,02	**0,40**
Southern Siberia - Chicha (11)	**-19,5**	**0,6**		**14,5**	**1,0**		
Local contemp. herbivores (n=13)	-20,1	0,5	0,60	5,5	1,8	0,09	**0,11**
Freshwater fish (Chicha) (n=24)	-22,5	1,9	0,55	10,5	1,5	0,12	**0,57**
C3 plants (wheat, NKZ), (n=1)	-23,0		0,46	5,0		0,02	**0,21**
C4 plants (millet, WChin-NCaus), (n=2)	-10,4		0,47	8,0		0,02	**0,11**
Central Kazakhstan - Bronze Age sites							
1. Kairan 1 (n=16)	**-18,1**	**0,5**		**14,2**	**0,9**		
Local contemp. herbivores (n=9)	-19,4	0,8	0,60	8,3	2,0	0,09	**0,49**
Freshwater fish (Shauke) (n=4)	-23,5	0,9	0,55	9,2	0,5	0,12	**0,22**
C3 plants (wheat, NKZ), (n=1)	-23,0		0,46	5,0		0,02	**0,17**
C4 plants (millet, WChin-NCaus), (n=2)	-10,4		0,47	8,0		0,02	**0,12**
2. Karatugai (n=10)	**-18,4**	**0,6**		**12,6**	**1,5**		
Local contemp. herbivores (n=40)	-19,2	0,7	0,60	7,2	1,2	0,09	**0,25**
Freshwater fish (Shauke) (n=4)	-23,5	0,9	0,55	9,2	0,5	0,12	**0,38**
C3 plants (wheat, NKZ), (n=1)	-23,0		0,46	5,0		0,02	**0,22**
C4 plants (millet, WChin-NCaus), (n=2)	-10,4		0,47	8,0		0,02	**0,15**
3. Kent (n=1)	**-16,0**			**13,5**			
Local contemp. herbivores (n=9)	-19,4	0,8	0,60	8,3	2,0	0,09	**0,36**
Freshwater fish (Shauke) (n=4)	-23,5	0,9	0,55	9,2	0,5	0,12	**0,23**

C3 plants (wheat, NKZ), (n=1)	-23,0		0,46	5,0		0,02	**0,16**
C4 plants (millet, WChin-NCaus), (n=2)	-10,4		0,47	8,0		0,02	**0,25**
4. Kyzylkol (8)	**-18,6**	**0,4**		**13,8**	**0,7**		
Local contemp. herbivores (n=9)	-19,4	0,8	0,60	8,3	2,0	0,09	**0,46**
Freshwater fish (Shauke) (n=4)	-23,5	0,9	0,55	9,2	0,5	0,12	**0,26**
C3 plants (wheat, NKZ), (n=1)	-23,0		0,46	5,0		0,02	**0,19**
C4 plants (millet, WChin-NCaus), (n=2)	-10,4		0,47	8,0		0,02	**0,09**
5. Tegiszhol (n=24)	**-18,2**	**0,5**		**13,0**	**0,8**		
Local contemp. herbivores (n=40)	-19,2	0,7	0,60	7,2	1,2	0,09	**0,24**
Freshwater fish (Shauke) (n=4)	-23,5	0,9	0,55	9,2	0,5	0,12	**0,43**
C3 plants (wheat, NKZ), (n=1)	-23,0		0,46	5,0		0,02	**0,16**
C4 plants (millet, WChin-NCaus), (n=2)	-10,4		0,47	8,0		0,02	**0,17**
Central Kazakhstan - Iron Age sites							
1. Akbeit (n=4)	**-17,2**	**1,0**		**15,3**	**0,7**		
Local contemp. herbivores (n=18)	-19,9	0,7	0,60	8,1	1,3	0,09	**0,64**
Freshwater fish (Shauke) (n=4)	-23,5	0,9	0,55	9,2	0,5	0,12	**0,11**
C3 plants (wheat, NKZ), (n=1)	-23,0		0,46	5,0		0,02	**0,11**
C4 plants (millet, WChin-NCaus), (n=2)	-10,4		0,47	8,0		0,02	**0,14**
2. Karashoky, 6 (n=6)	**-17,2**	**0,9**		**15,4**	**0,8**		
Local contemp. herbivores (n=18)	-19,9	0,7	0,60	8,1	1,3	0,09	**0,59**
Freshwater fish (Shauke) (n=4)	-23,5	0,9	0,55	9,2	0,5	0,12	**0,14**
C3 plants (wheat, NKZ), (n=1)	-23,0		0,46	5,0		0,02	**0,11**
C4 plants (millet, WChin-NCaus), (n=2)	-10,4		0,47	8,0		0,02	**0,15**
3. TersakkanIA (n=4)	**-18,1**	**0,2**		**14,1**	**1,2**		
Local contemp. herbivores (n=18)	-19,9	0,7	0,60	8,1	1,3	0,09	**0,36**
Freshwater fish (Shauke) (n=4)	-23,5	0,9	0,55	9,2	0,5	0,12	**0,31**

C3 plants (wheat, NKZ), (n=1)	-23,0		0,46	5,0		0,02	**0,17**
C4 plants (millet, WChin-NCaus), (n=2)	-10,4		0,47	8,0		0,02	**0,16**
Central Kazakhstan - Medieval sites							
1. TersakkanMed (n=3)	**-19,1**	**0,5**		**12,8**	**1,0**		
Local IA herbivores (n=18)	-19,9	0,7	0,60	8,1	1,3	0,09	**0,28**
Freshwater fish (Shauke) (n=4)	-23,5	0,9	0,55	9,2	0,5	0,12	**0,41**
C3 plants (wheat, NKZ), (n=1)	-23,0		0,46	5,0		0,02	**0,20**
C4 plants (millet, WChin-NCaus), (n=2)	-10,4		0,47	8,0		0,02	**0,11**
South-eastern Kazakhstan Bronze Age sites							
1. Aktogai (n=9)	**-17,0**	**0,6**		**13,6**	**1,8**		
Local contemp. herbivores (n=29)	-18,8	1,0	0,60	7,2	1,9	0,09	**0,29**
Freshwater fish (Shauke) (n=4)	-23,5	0,9	0,55	9,2	0,5	0,12	**0,28**
C3 plants (wheat, NKZ), (n=1)	-23,0		0,46	5,0		0,02	**0,19**
C4 plants (millet, WChin-NCaus), (n=2)	-10,4		0,47	8,0		0,02	**0,23**
2. Oi-Dzailau VII (11)	**-15,6**	**1,8**		**13,8**	**0,6**		
Local contemp. herbivores (n=29)	-18,8	1,0	0,60	7,2	1,9	0,09	**0,50**
Freshwater fish (Shauke) (n=4)	-23,5	0,9	0,55	9,2	0,5	0,12	**0,16**
C3 plants (wheat, NKZ), (n=1)	-23,0		0,46	5,0		0,02	**0,12**
C4 plants (millet, WChin-NCaus), (n=2)	-10,4		0,47	8,0		0,02	**0,21**
South-eastern Kazakhstan Iron Age sites							
1. Shatyrkul (13)	**-14,7**	**1,2**		**14,0**	**0,9**		
Local contemp. herbivores (n=29)	-18,9	1,0	0,60	7,9	1,6	0,09	**0,40**
Freshwater fish (Shauke) (n=4)	-23,5	0,9	0,55	9,2	0,5	0,12	**0,17**
C3 plants (wheat, NKZ), (n=1)	-23,0		0,46	5,0		0,02	**0,11**
C4 plants (millet, WChin-NCaus), (n=2)	-10,4		0,47	8,0		0,02	**0,33**
2. Turgen (13)	**-16,3**	**0,6**		**12,8**	**0,7**		

Local contemp. herbivores (n=29)	-18,9	1,0	0,60	7,9	1,6	0,09	**0,37**
Freshwater fish (Shauke) (n=4)	-23,5	0,9	0,55	9,2	0,5	0,12	**0,24**
C3 plants (wheat, NKZ), (n=1)	-23,0		0,46	5,0		0,02	**0,13**
C4 plants (millet, WChin-NCaus), (n=2)	-10,4		0,47	8,0		0,02	**0,26**
Syr Darya oases							
1. Chirik Rabat (n=9)	**-17,3**	**2,0**		**14,6**	**0,7**		
Local contemp. herbivores (n=5)	-15,9	2,2	0,60	9,6	1,1	0,09	**0,54**
Freshwater fish (Shauke) (n=4)	-23,5	0,9	0,55	9,2	0,5	0,12	**0,19**
C3 plants (wheat, NKZ), (n=1)	-23,0		0,46	5,0		0,02	**0,15**
C4 plants (millet, WChin-NCaus), (n=2)	-10,4		0,47	8,0		0,02	**0,13**
Western Kazakhstan Bronze Age							
1. Taskala (n=3)	**-18,6**	**0,3**		**13,7**	**1,1**		
Local IA herbivores (n=17)	-19,9	0,6	0,60	6,6	1,0	0,09	**0,16**
Freshwater fish (Chicha) (n=24)	-22,5	1,9	0,55	10,5	1,5	0,12	**0,49**
C3 plants (wheat, NKZ), (n=1)	-23,0		0,46	5,0		0,02	**0,21**
C4 plants (millet, WChin-NCaus), (n=2)	-10,4		0,47	8,0		0,02	**0,14**
Western Kazakhstan Iron Age							
2. Taksai I,II (n=13)	**-17,7**	**1,7**		**13,7**	**1,7**		
Local contemp. herbivores (n=17)	-19,9	0,6	0,60	6,6	1,0	0,09	**0,20**
Freshwater fish (Chicha) (n=24)	-22,5	1,9	0,55	10,5	1,5	0,12	**0,39**
C3 plants (wheat, NKZ), (n=1)	-23,0		0,46	5,0		0,02	**0,21**
C4 plants (millet, WChin-NCaus), (n=2)	-10,4		0,47	8,0		0,02	**0,19**

Appendix 8: Results of the compound-specific amino-acid nitrogen study

Table 1. Faunal isotopic values

Sample name	Site	Occupation period	Period	Specie	%C	%N	C/N	$\delta^{13}C_{col}$	$\delta^{15}N_{col}$	$^{15}N_{Pro}$	$^{15}N_{Asp+Thr}$	$^{15}N_{Ser}$	$^{15}N_{Glu}$	$^{15}N_{Phe}$	$^{15}N_{Hyp}$	TP_{aqua}	TP_{ter}	$\Delta^{15}N_{Glu-Phe}$
EA-SI-152	Kyzylbulak IV	Late Bronze Age		Cattle	34.3	12.1	3.3	–19.2	2.5	7.0	0.0	0.9	5.6	7.4	5.3	0.3	1.9	–1.8
EA-SI-153	Kyzylbulak IV	Early Iron Age		Cattle	38.0	13.3	3.3	–19.2	8.4	11.5	6.5	5.4	11.6	11.8	10.7	0.5	2.1	–0.2
EA-SI-154	Kyzylbulak IV	Iron Age	600-500 BC	Cattle	34.0	11.4	3.5	–16.8	5.8	11.7	6.3	4.3	9.8	11.5	9.9	0.3	1.9	–1.7
EA-SI-155	Turgen-2	Early Iron Age	1400-1300 BC	Cattle	41.8	14.9	3.3	–19.9	5.0	8.2	3.8	0.6	5.8	6.7	7.0	0.4	2.0	–0.9
EA-SI-156	Turgen-2	Early Iron Age	1400-1300 BC	Cattle	41.2	14.9	3.2	–18.1	6.0	8.0	4.5	4.1	9.1	10.3	7.9	0.4	1.9	–1.2
EA-SI-157	Turgen 2	Early Iron Age	1400-1300 BC	Cattle	6.0	0.5	14.0	–22.6	6.0	ND	ND	ND	ND	ND	ND	ND	ND	ND
EA-SI-158	Turgen 2	Early Iron Age	1400-1300 BC	Cattle	38.1	13.5	3.3	–19.1	6.0	11.7	4.9	3.5	10.0	9.4	9.9	0.6	2.2	0.6
EA-SI-159	Turgen 2	Early Iron Age	1400-1300 BC	Cattle	42.7	15.2	3.3	–19.6	6.4	10.4	4.4	3.1	8.9	9.2	8.6	0.5	2.1	–0.2
EA-SI-160	Turgen-2	Early Iron Age	1400-1300 BC	Horse	42.8	15.5	3.2	–18.4	7.6	12.8	6.1	5.2	10.9	11.7	10.5	0.4	2.0	–0.8
EA-SI-161	Turgen 2	Early Iron Age	1400-1300 BC	Horse	40.8	14.6	3.2	–19.8	5.9	7.5	3.9	2.7	8.2	9.2	7.2	0.4	2.0	–1.0
EA-SI-162	Turgen-2	Early Iron Age	1400-1300 BC	Sheep	42.1	14.8	3.3	–18.7	6.0	11.1	4.5	3.2	9.0	11.0	7.9	0.3	1.8	–2.1
EA-SI-163	Turgen 2	Early Iron Age	1400-1300 BC	Sheep	43.1	15.5	3.2	–19.7	5.7	11.0	4.2	2.2	8.9	11.6	8.7	0.2	1.7	–2.7
EA-SI-164	Turgen 2	Early Iron Age	1400-1300 BC	Sheep	42.2	15.3	3.2	–19.3	5.5	9.6	4.0	2.3	8.6	10.1	8.5	0.3	1.9	–1.6
EA-SI-165	Turgen 2	Early Iron Age	1400-1300 BC	Sheep/Goat	39.9	14.2	3.3	–18.4	8.0	11.6	6.7	4.0	11.2	13.4	9.6	0.3	1.8	–2.2

EA-SI-166	Turgen 2	Early Iron Age	1400-1300 BC	Sheep/Goat	42.6	15.6	3.2	–19.3	5.4	10.6	3.5	2.6	8.8	10.6	7.3	0.3	1.9	–1.7
EA-SI-175	Ak-Koitas IV	Early Iron Age	1400-1200 BC	Sheep	22.2	7.3	3.5	–17.7	10.5	14.9	6.7	6.2	12.1	13.1	11.2	0.4	2.0	–1.1
EA-SI-176	Tersakkan	Iron Age	800-600 BC	Sheep	27.9	10.0	3.3	–18.6	8.5	13.8	8.0	6.0	11.9	14.0	13.6	0.3	1.8	–2.1
#225	Kent			Sheep	36.9	13.1	3.3	–18.4	9.2	16.0	6.0	6.0	11.8	13.4	9.3	0.3	1.9	–1.7
#226	Kent			Sheep	43.2	15.3	3.3	–18.0	9.0	14.5	7.5	5.7	12.8	12.3	9.6	0.6	2.2	0.5
#227	Kent			Sheep	40.2	13.8	3.4	–17.9	8.5	13.2	7.7	5.2	13.2	13.7	9.8	0.5	2.0	–0.4
#228	Kent			Sheep	34.8	11.9	3.4	–18.7	7.2	16.0	6.0	5.4	11.3	12.0	11.3	0.5	2.0	–0.8
#229	Kent			Sheep	49.1	17.4	3.3	–17.5	8.5	19.0	7.3	6.8	12.3	12.8	12.4	0.5	2.0	–0.5
#230	Kent			Sheep	35.7	12.8	3.2	–18.3	8.3	16.9	5.6	6.1	11.2	11.7	11.5	0.5	2.0	–0.5
#231	Kent			Sheep	38.5	13.3	3.4	–18.4	9.8	20.3	7.4	7.5	13.0	13.3	12.5	0.5	2.1	–0.3
#232	Kent			Sheep	41.1	14.0	3.4	–18.6	7.2	17.0	6.1	5.1	11.3	12.1	9.3	0.5	2.0	–0.8
#233	Kent			Sheep	42.5	15.2	3.3	–18.0	8.8	18.0	5.9	5.9	11.6	11.9	11.2	0.5	2.1	–0.3
#234	Kent			Sheep	40.4	13.9	3.4	–18.4	8.5	19.1	6.5	4.5	11.7	12.9	9.8	0.4	2.0	–1.1
EA-SI-199	Taldysai	Bronze Age		Sheep/Goat	44.4	16.4	3.2	–19.4	5.5	15.7	2.9	1.1	7.8	10.3	6.1	0.2	1.8	–2.5
EA-SI-202	Taldysai	Bronze Age		Sheep/Goat	45.2	16.6	3.2	–18.6	9.1	16.5	7.3	6.2	11.9	13.1	10.5	0.4	1.9	–1.2
EA-SI-205	Taldysai	Bronze Age		Cattle	43.0	15.8	3.2	–19.6	10.4	16.0	8.3	7.8	12.5	13.0	13.3	0.5	2.0	–0.5
EA-SI-208	Taldysai	Bronze Age		Sheep/Goat	44.9	16.6	3.2	–18.5	9.9	23.0	8.1	7.3	13.3	14.7	14.1	0.4	1.9	–1.4
EA-SI-209	Taldysai	Bronze Age		Cattle	46.4	17.0	3.2	–19.4	10.3	16.8	8.5	7.4	13.5	13.8	13.7	0.5	2.1	–0.4
EA-SI-212	Serektas	Bronze Age		Sheep/Goat	43.7	16.1	3.2	–18.4	6.9	14.6	4.8	2.9	9.0	11.7	8.3	0.2	1.7	–2.7
EA-SI-215	Serektas	Bronze Age		Horse	46.7	16.9	3.2	–18.2	8.3	13.7	7.2	4.6	11.4	13.1	12.7	0.3	1.9	–1.7
EA-SI-217	Serektas II	Bronze Age		Horse	43.5	15.6	3.3	–18.8	8.5	16.0	5.8	5.6	11.5	13.4	14.5	0.3	1.9	–1.9
EA-SI-218	Serektas II	Bronze Age		Cattle	45.6	16.5	3.2	–17.9	12.6	20.2	11.9	10.8	15.9	16.4	16.1	0.5	2.0	–0.5

EA-SI-219	Serektas II	Bronze Age		Horse	44.6	16.4	3.2	–17.0	9.5	18.8	6.3	7.5	11.9	13.1	9.6	0.4	1.9	–1.2
EA-SI-220	Serektas II	Bronze Age		Cattle	45.4	16.6	3.2	–17.3	8.7	11.6	6.6	5.8	11.5	14.3	14.6	0.2	1.7	–2.8
EA-SI-222	Serektas II	Bronze Age		Sheep/Goat	44.7	16.2	3.2	–16.9	7.7	10.8	4.0	4.5	9.0	9.4	8.2	0.5	2.0	–0.4
EA-SI-223	Serektas II	Bronze Age		Sheep/Goat	48.2	17.5	3.2	–17.5	10.0	18.6	6.5	7.1	13.0	13.8	10.9	0.4	2.0	–0.8
EA-SI-226	Serektas II	Bronze Age		Cattle	46.0	16.7	3.2	–17.4	9.9	11.8	8.3	6.2	12.6	12.1	15.5	0.6	2.2	0.5
EA-SI-177	Cemetery Zheken		1800 AD	Sheep/Goat	48.5	17.7	3.2	–18.9	10.7	18.6	7.2	7.5	13.6	14.9	12.2	0.4	1.9	–1.3
EA-SI-193	Tcyganak	Late sarmatian		Dog	43.9	15.5	3.3	–19.2	9.9	22.5	4.9	9.2	15.3	9.9	15.4	1.3	2.8	5.4
EA-SI-197	Kuigenzhar	Bronze Age-Iron Age		wild boar	45.4	16.5	3.2	–20.4	7.6	12.6	5.4	6.0	10.7	10.9	11.7	0.5	2.1	–0.2
KZ-31F	Unknown	Bronze Age-Iron Age		Dog/Wolf	45.4	16.6	3.2	–18.1	9.7	16.0	2.5	7.5	14.5	10.0	14.4	1.1	2.7	4.5
Paueon 1 kl. 52	Kosasar	Medieval age	700-1000 AD	Fish	ND	ND	ND	ND	ND	30.9	8.4	5.4	26.3	5.2	21.8	3.3	4.9	21.1
DZ 52	Dzhankent	Medieval age		Fish	37.4	13.5	3.2	–10.9	12.1	28.6	6.1	4.8	27.0	3.6	21.3	3.6	5.2	23.4
DZ 53	Dzhankent	Medieval age		Fish	39.6	14.2	3.3	–11.4	12.1	29.9	7.8	7.1	29.0	5.9	22.9	3.6	5.1	23.1

Table 2. Human isotopic values

Sample name	Site	Occupation period	Period	Cluster	%C	%N	C/N	$\delta^{13}C_{col}$	$\delta^{15}N_{col}$	$^{15}N_{Pro}$	$^{15}N_{Asp+Thr}$	$^{15}N_{Ser}$	$^{15}N_{Glu}$	$^{15}N_{Phe}$	$^{15}N_{Hyp}$	TP_{aqua}	TP_{ter}	$\Delta^{15}N_{Glu-Phe}$

EA-SI-23	Tersakhan	Iron Age	800-600 BC	West-central	47.0	16.7	3.3	-18.3	15.0	15.7	9.0	14.1	18.1	14.3	18.6	1.1	2.6	3.8
EA-SI-24	Tersakhan	Iron Age	748-399 BC	West-central	44.1	14.9	3.5	-17.5	16.7	18.2	9.7	16.0	20.2	17.4	20.2	0.9	2.5	2.8
EA-SI-25	Tersakhan	Iron Age	200 BC-100 AD	West-central	45.6	15.7	3.4	-17.9	13.1	ND	6.1	12.7	16.0	12.2	17.2	1.1	2.6	3.9
EA-SI-26	Tersakhan	Iron Age		West-central	38.8	13.9	3.3	-17.6	14.3	23.5	7.8	14.5	17.6	13.3	17.1	1.1	2.7	4.3
EA-SI-27	Tersakhan	Iron Age		West-central	46.3	13.4	4.0	-18.4	14.8	18.5	9.2	14.3	17.8	13.6	17.5	1.1	2.7	4.2
EA-SI-28	Tersakhan	Iron Age	200 BC-100 AD	West-central	40.4	12.7	3.7	-17.9	13.2	15.9	5.7	12.6	13.7	12.3	15.0	0.7	2.3	1.3
EA-SI-61	Zheken	Iron Age	487-236 BC	West-central	47.9	16.9	3.3	-17.8	14.5	ND	7.1	13.1	14.7	11.8	17.9	0.9	2.5	2.9
EA-SI-64	Zheken	Medieval Age	1800 AD	West-central	46.1	16.6	3.2	-17.4	15.0	20.3	10.2	14.6	18.7	14.6	19.7	1.1	2.6	4.1
EA-SI-51	Aktogai	Bronze Age	1400-1200 BC	East-central	46.9	16.6	3.3	-15.9	14.5	18.9	9.6	14.6	18.1	13.2	19.6	1.2	2.7	4.9
EA-SI-52	Aktogai	Bronze Age	1400-1200 BC	East-central	31.6	11.6	3.2	-16.4	14.8	28.2	11.5	16.3	19.9	14.8	20.1	1.2	2.8	5.1
EA-SI-53	Aktogai	Bronze Age	1400-1200 BC	East-central	48.2	17.3	3.3	-15.7	11.6	ND	7.6	10.4	14.7	11.2	14.8	1.0	2.6	3.5

EA-SI-54	Aktogai	Bronze Age	1579-1477 BC	East-central	35.3	13.0	3.2	-16.1	11.6	13.6	7.9	10.0	14.7	11.1	14.7	1.0	2.6	3.6
EA-SI-47	Aktogai	Bronze-Iron Age		East-central	45.6	16.3	3.3	-16.9	15.0	15.9	7.9	14.3	17.0	12.7	18.2	1.1	2.7	4.3
EA-SI-48	Aktogai	Bronze-Iron Age		East-central	46.2	16.5	3.3	-15.9	13.5	16.9	8.2	13.8	17.0	12.7	18.9	1.1	2.7	4.4
EA-SI-56	Aktogai	Bronze-Iron Age		East-central	38.4	13.9	3.2	-17.1	15.8	ND	9.6	13.0	17.2	12.9	18.2	1.1	2.7	4.4
EA-SI-57	Aktogai	Bronze-Iron Age		East-central	45.9	16.6	3.2	-17.2	12.4	ND	8.2	13.4	16.8	13.2	16.3	1.0	2.6	3.6
EA-SI-49	Aktogai	Iron Age	600-400 BC	East-central	46.1	16.7	3.2	-17.5	12.7	ND	6.9	11.9	14.9	12.4	16.0	0.9	2.4	2.5
EA-SI-55	Aktogai	Iron Age	333-209 BC	East-central	38.9	14.2	3.2	-16.2	15.8	19.0	9.1	14.9	17.8	15.3	14.7	0.9	2.4	2.5
EA-SI-58	Ak-Koitas IV	Bronze Age	1400-1200BC	East-central	45.3	16.4	3.2	-18.5	13.4	ND	7.0	13.2	16.4	11.8	17.3	1.2	2.7	4.6
EA-SI-59	Ak-Koitas V	Bronze Age	1400-1200BC	East-central	45.7	16.4	3.3	-17.7	13.9	16.7	7.4	14.1	17.2	12.2	16.4	1.2	2.8	5.0
LT-KZ-20	Turgen-2	Early Iron Age		South-eastern	45.3	15.9	3.3	-17.4	13.4	26.7	10.7	11.6	18.7	13.2	17.9	1.3	2.8	5.6
LT-KZ-26	Turgen-2	Early Iron Age		South-eastern	44.6	15.8	3.3	-17.3	13.2	31.7	8.2	10.6	17.5	10.4	19.2	1.5	3.0	7.1

LT-KZ-27	Turgen-2	Early Iron Age	South-eastern	41.1	14.7	3.2	-15.8	13.5	24.1	9.4	13.5	18.1	13.5	20.4	1.2	2.7	4.7
LT-KZ-28	Turgen-2	Early Iron Age	South-eastern	44.8	16.0	3.3	-16.3	13.3	14.2	8.6	11.6	17.2	13.0	18.0	1.1	2.7	4.2
LT-KZ-30	Turgen-2	Early Iron Age	South-eastern	29.0	10.0	3.4	-15.9	12.4	33.0	8.8	12.0	17.5	12.0	20.6	1.3	2.8	5.4
LT-KZ-31	Turgen-2	Early Iron Age	South-eastern	42.5	15.3	3.2	-15.4	11.8	22.5	8.9	10.6	16.8	12.3	17.3	1.1	2.7	4.5
LT-KZ-32	Turgen-2	Early Iron Age	South-eastern	44.9	15.6	3.3	-16.2	12.5	5.9	9.0	12.1	16.9	12.2	19.8	1.2	2.7	4.7
LT-KZ-33	Turgen-2	Early Iron Age	South-eastern	42.5	15.2	3.3	-15.3	12.4	21.8	7.5	9.0	15.0	10.8	16.7	1.1	2.6	4.1
LT-KZ-34	Turgen-2	Early Iron Age	South-eastern	47.2	16.6	3.3	-15.4	11.8	19.1	7.7	11.3	15.9	12.8	18.0	1.0	2.5	3.1
LT-KZ-35	Turgen-2	Early Iron Age	South-eastern	45.7	16.4	3.2	-15.7	11.3	19.7	7.4	10.9	15.2	10.7	17.2	1.2	2.7	4.6
LT-KZ-36	Turgen-2	Early Iron Age	South-eastern	44.4	16.1	3.2	-15.6	12.3	21.1	8.6	9.7	15.8	12.2	16.7	1.0	2.6	3.5
LT-KZ-37	Turgen-2	Early Iron Age	South-eastern	42.1	15.0	3.3	-15.5	13.3	15.8	8.5	12.2	17.6	12.3	20.1	1.3	2.8	5.3
LT-KZ-38	Turgen-2	Early Iron Age	South-eastern	43.9	15.4	3.3	-16.5	12.9	17.5	7.6	9.0	14.6	10.6	16.6	1.1	2.6	4.1

LT-KZ-5	Shatyrkul	Early Iron Age	South-eastern	42.2	14.7	3.4	-13.9	13.5	20.1	10.5	12.1	17.4	12.0	20.1	1.3	2.8	5.4
LT-KZ-6	Shatyrkul	Early Iron Age	South-eastern	45.6	16.2	3.3	-15.1	14.7	18.5	11.3	14.4	19.7	14.5	22.0	1.2	2.8	5.2
LT-KZ-7	Shatyrkul	Early Iron Age	South-eastern	40.0	14.2	3.3	-13.3	13.3	11.7	10.8	13.3	18.7	13.4	20.6	1.2	2.8	5.3
LT-KZ-8	Shatyrkul	Early Iron Age	South-eastern	43.9	15.4	3.3	-13.0	15.8	11.1	11.9	15.1	19.8	14.0	22.3	1.3	2.9	5.8
LT-KZ-9	Shatyrkul	Early Iron Age	South-eastern	44.7	15.6	3.3	-14.9	14.0	22.1	10.6	13.1	18.0	13.3	21.6	1.2	2.7	4.7
LT-KZ-11	Shatyrkul	Early Iron Age	South-eastern	38.0	13.4	3.3	-14.0	14.3	19.8	11.0	11.5	17.3	13.4	18.4	1.1	2.6	3.8
LT-KZ-12	Shatyrkul	Early Iron Age	South-eastern	42.1	15.0	3.3	-14.7	14.7	16.1	8.8	12.1	18.0	13.3	17.9	1.2	2.7	4.7
LT-KZ-13	Shatyrkul	Early Iron Age	South-eastern	44.5	15.5	3.3	-15.4	16.0	24.6	10.0	13.5	19.4	13.3	20.2	1.4	2.9	6.1
LT-KZ-14	Shatyrkul	Early Iron Age	South-eastern	44.6	15.2	3.4	-14.9	14.7	28.6	10.9	15.0	19.1	14.4	19.2	1.2	2.7	4.7
LT-KZ-15	Shatyrkul	Early Iron Age	South-eastern	45.2	15.9	3.3	-13.7	14.2	21.5	13.1	15.8	20.7	16.4	20.1	1.1	2.7	4.3
LT-KZ-17	Shatyrkul	Early Iron Age	South-eastern	44.0	15.3	3.4	-15.2	14.0	20.8	9.7	12.3	17.8	12.7	19.2	1.2	2.8	5.1

LT-KZ-19	Shatyrkul	Early Iron Age	South-eastern	42.6	15.2	3.3	-15.0	13.3	25.0	9.5	11.7	17.7	14.0	18.6	1.0	2.6	3.6

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