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Early indicators to C4 plant consumption in central Kazakhstan during the Final Bronze Age and Early Iron Age based on stable isotope analysis of human and animal bone collagen

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ABSTRACT

In this paper, we present new stable isotope data from central, southern and eastern Kazakhstan (KZ) that date to the Early Iron Age. Our primary data together with results from previously published studies demonstrate that the consumption of C_4 plants, possibly millet, started in the Final Bronze Age in central KZ and continued into the Early Iron Age. Data from southern KZ, however, demonstrate that over half the human population consumed C_4 crops in the Early Iron Age as opposed to the central regions of KZ, where just a few individuals within the population, often males buried in elite kurgans, have high $\delta^{13}C$ values indicative of C_4 plant consumption. In this paper we aim first to understand if any dietary changes can be seen in the central KZ population during the transitional period between the Bronze and Iron Ages; secondly, we investigate the extent of C_4 plant consumption in central KZ during these time periods. Here we present new human isotopic data from nine central sites of the Tasmola culture (n = 11), two eastern KZ sites (n = 3) and two southern KZ sites (n = 26).

1. Introduction

Kazakhstan is located in the center of the Eurasian continent. Understanding the social and economic processes there is particularly important as their development could potentially affect both the eastern and western portions of the continent. Soviet archaeology used to see the transitional period from Bronze (ca. 2500–800 BCE[1]) to Iron (ca. 800 BCE–500 CE) Ages as marking the rise of early nomadic cultures in the Kazakh steppe (e.g. Habdulina et al., 2013). Some scholars still argue that in the Late Bronze Age settlements became less abundant and therefore less visible archaeologically as people adapted to a more mobile economy (Kuzmina, 2000), that eventually gave rise to "pure nomadism". The origins of pastoral nomadism and the transitions to it have been reviewed and discussed by several scholars proposing causal relationships with climatic fluctuation, population pressure, and territorial expansion (e.g. Hanks, 2002; Honeychurch and Makarewicz, 2016; Khazanov, 1994; Koryakova and Epimakhov, 2007; Spengler, 2014). During the past decades, however, the idea of a purely nomadic Early Iron Age economy the Early Iron Age has been critiqued and challenged by a growing body of archaeological evidence which points to a more complex economic situation in the steppes in the beginning of Iron Ages (Chang et al., 2003; Chang, 2012; Frachetti, 2008). Systematic archaeological research carried out mainly in south-eastern Kazakhstan has improved our understanding of Early Iron Age socio-economics (e.g. Benecke, 2003; Chang et al., 2003; Chang and Beardmore, 2016; Haruda, 2007; Rosen, 2001; Rosen et al., 2000;

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[1] All dates in this manuscript are in calibrated, calendar years BC (unless specified otherwise).

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Spengler et al., 2013a). Nevertheless, Early Iron Age archaeological realities remain largely enigmatic for other regions of the Kazakh steppe. Recent discoveries of Early Iron Age settlements in central and northern Kazakhstan (e.g. Beisenov, 2015; Habdulina, 2003) and large geometric earthworks (see below) (Motuzaite Matuzeviciute et al., 2016), argue against "pure nomadism" in the region and call for more thorough archaeological research to understand the cultural and economic situation in the heart of the Kazakh steppe during the transitional period.

The transition from the Bronze to Iron Ages in the Kazakh steppe is connected to cultural changes that can be seen from archaeological material. Data for the Early Iron Age of Kazakhstan point towards an increase in a social complexity as suggested by the appearance of very rich burials showing the rise of an elite social order (e. g. Akishev, 1978; Gryaznov, 1980; Rudenko et al., 1971; Samashev, 2011), new forms of warfare (Hanks, 2008), the development of elaborate animal-style ornaments (Yablonskyi, 2000) and the increasing importance of iron. The appearance of massive geometrical earthworks during the Early Iron Age period, ca. 800–750 BCE indicates the presence of centralized power and the consolidation of people into large social units (Motuzaite Matuzeviciute et al., 2016).

Until recently, no stable isotope or macro-botanical research has been carried out for the Early Iron Age of central Kazakhstan. In this paper, we present new stable isotope evidence for human diet during the Early Iron Age in Kazakhstan. Through stable isotope analysis of human and animal bone collagen we examine dietary change during the transitional period between the Bronze and Iron Ages of central Kazakhstan, and we evaluate the role of C_4 plants in the economy and lifestyle of communities in central Kazakhstan during the Final Bronze and Early Iron Ages. Though we focus on the central regions of Kazakhstan, we include both primary and published data from other parts of the country for comparison.

2. Background

2.1. Geography, archaeology, and environment of central Kazakhstan

Central Kazakhstan is situated within the Kazakh Uplands, which is frequently referred to as Sary-Arka. The Kazakh Uplands consist largely of lowland steppes with rocky hills and rare low mountains that reach up to 1000-1500 m above sea level. These mountains often contain small oases with pine forest patches, mountain creeks, and natural shelters from wind created by granite rock outcrops. In contrast to the open steppe landscapes, the environment and resource diversity in these geographic niches attracted humans during the Bronze and Iron Ages, which is evident by the large number of archaeological sites located near mountains within Kazakh Uplands (Beisenov et al., 2016a).

During the Late and Final Bronze Ages (~1300–800 BCE), the Sargary/Alekseevo and Begazy-Dandybaevo archaeological cultures developed in central Kazakhstan. Both cultures are identified archaeologically by "valikovaya" pottery types (Chernykh, 1984), which predominated during the Late Bronze Age. The Begazy pottery type is represented by fine vessels with elaborate design. This type is often found in mausoleums, unique funerary monuments typical of the Begazy culture (Varfolomeev, 2003). In contrast, the Sargary/Alekseevo pottery is found at Late and Final Bronze Age settlements and cemeteries. Varfolomeev (2011a) suggests that the Begazy-Dandybaevo and Sargary/Alekseevo cultures represent the same cultural community due to the scarcity of Begazy vessels at Late and Final Bronze Age sites in central Kazakhstan, and their association with rich mausoleum burials. A great input of time and energy required for construction of mausoleums suggests that Begazy-Dandybaevo funerary monuments were built for high status individuals (Habdulina et al., 2013), which points to the existence of the elite.

Massive settlement sites such as Kent (~30 ha) are also known in the Late Bronze Age period in central Kazakhstan (Varfolomeev, 2011b). The archaeological complex of Kent represents a concentration of smaller settlements located in the Karkaraly mountain oasis. Kent has features of a proto-city such as large territory; monumental architecture; production of ceramic vessels, bone tools, ornaments, metal items; developed trade (Varfolomeev, 2011b), which suggest an increase of social complexity in central Kazakhstan in the Late and Final Bronze Ages.

Major metal production centers dated to the Late and Final Bronze Ages were identified in the steppes of central Kazakhstan (Beisenov and Ermolayeva, 2016). The metallurgical district Alat, which is a part of the Kent complex, provided evidence of iron refining furnaces (Evdokimov and Zhauymbayev, 2013) dated to about 1300 cal. BCE ("Research Center of Ancient East Asian Iron Culture", 2016–2017 pamphlet). This indicates the transition to the Iron Age economy had already begun in the Final Bronze Age.

In the Early Iron Age (~800–200 BCE), a new cultural community Tasmola developed in the steppes of Kazakhstan. Sites of the Tasmola culture are dated to the 800–400 BCE (Beisenov et al., 2016a). Early Iron Age Tasmola settlements in central Kazakhstan are often located on hill slopes and rocky surfaces near mountains and near small creeks, such as the Edirey settlements in the eastern part of central Kazakhstan (Beisenov, 2015). Most of them are small, comprise 2–3 dwellings (Beisenov, 2014), and do not have intense cultural layers, which might indicate their seasonal character. Settlements Sarybuirat and Keregetas-2, however, are quite large. Sarybuirat, dated to 747–403 cal. BCE (Beisenov et al., 2016b) is about 1 ha (Beisenov, 2015). In the past decades, Early Iron Age settlements have been more frequently found in central Kazakhstan steppes than previously. Geographical positions and plans of the Early Iron Age settlements indicate their considerable difference from the Early and Middle Bronze Age settlement sites (Beisenov, 2015). Nevertheless, some similarities between the Late Bronze Age and Early Iron Age settlements are seen in the architectural design of the dwellings, planning of the settlements and their topographic location (Habdulina, 2003). Excavated Early Iron Age settlements look similar to the ethnographic Kazakh winter settlements - kystau (Usmanova and Boyaubayeva, 2011). Dwellings within a Kazakh ethnographic settlement also stand close to each other; they are rectangular in shape, and have large amount of stone in the base. Moreover, few Early Iron Age settlements were found near or occupying the same area as Kazakh kystau (Beisenov, 2015). Burial grounds of the Tasmola culture are represented by kurgans, which can be divided into two types: ordinary mortuary complexes and large (tsarskyi) kurgans. Tsarskyi kurgans can be characterized as rich burials with elaborate artifacts, vast sacrifices of animals, complex constructions of burial chambers, golden jewelry and art objects (Beisenov et al., 2011). Such mortuary monuments dated to the Iron Age were discovered in different areas of Kazakhstan.

It has been suggested that the climatic conditions changed frequently during the Early Iron Age, which forced people to adopt new economic strategies (Koryakova and Epimakhov, 2007). Environmental reconstructions in central Kazakhstan suggest that the climate became colder and moister about 1200–1100 cal. BCE; however, by 1000–900 cal. BCE the conditions changed towards less continental and dryer climate (Kremenetskyi et al., 1994). Palynological data from archaeological sites in the Trans-Ural region indicate an increase in continental climatic conditions during the transitional period from Bronze to Iron Ages (Larin and Matveeva, 1997). Archaeological investigations carried out at Early Iron Age settlements in central Kazakhstan suggest a cold and wet climate during the period of occupation (Beisenov, 2015). Early Iron Age settlements are often located far from river banks, which might indicate that frequent floods made areas around rivers unavailable for human use. Moreover, dwellings within Early Iron Age settlements are often clustered close to each other, and significant quantities of stone were used for wall foundations (Beisenov, 2015). This suggests that inhabitants may have tried to create a defense against the wind and preserve a warm temperature inside the dwellings.

2.2. Diet in the Bronze and Iron Ages

Over the past few decades, investigations of economic strategies in Kazakhstan during the Bronze and Iron Ages have provided evidence for the consumption of a variety of food resources that include fish, domestic and hunted animals, dairy products, and a wide range of crops (Benecke and von den Driesch, 2003; Chang et al., 2003; Chang and Beardmore, 2016; Doumani et al., 2015; Frachetti and Benecke, 2009; Frachetti et al., 2010; Gaiduchenko and Loman, 2015; Haruda, 2007; Kasparov and Outram, 2013; Kosintsev, 2000; Lightfoot et al., 2015; Motuzaite Matuzeviciute et al., 2015; Motuzaite Matuzeviciute, 2016; O'Connell et al., 2003; Outram et al., 2011, 2012; Potemkina, 1985; Rosen, 2001; Rosen et al., 2000; Spengler et al., 2013a,b; Spengler et al., 2014; Ventresca Miller et al., 2014). Herding was an important component of the economy in Kazakhstan during the Bronze and Iron Ages. Zooarchaeological data from the Middle Bronze Age northern and central Kazakhstan sites demonstrated a major focus on cattle pastoralism (Kosintsev, 2000), while caprines and horses were kept in smaller numbers. However, by the beginning of the Final Bronze Age, evidence from central Kazakhstan points to the increase of horses and decrease of cattle (Evdokimov and Varfolomeev, 2002; Gaiduchenko and Loman, 2015; Outram et al., 2012; Potemkina, 1985; Varfolomeev, 2003). Analysis of lipid residues in ceramic vessels carried out using northern and central Kazakhstan Late Bronze Age material suggested that horse meat was most likely reserved for special feasts (Outram et al., 2011), while ruminant meat and dairy products were consumed on a daily basis. Stable isotope data also suggests a reliance on meat and milk in the Middle and Late Bronze Ages in northern Kazakhstan (Ventresca Miller et al., 2014), and from the Early to Late Bronze Ages in the central region (Lightfoot et al., 2015). Zooarchaeological investigations conducted at a number of southern Kazakhstan sites demonstrate a major focus on caprine herding both in the Bronze Age (Frachetti and Benecke, 2009) in the Iron Age (Benecke, 2003; Haruda, 2007; Chang et al., 2003).

The use of crops in Kazakhstan started in the south-eastern region in the Early Bronze Age onwards (Doumani et al., 2015; Frachetti et al., 2010; Motuzaite Matuzeviciute, 2016; Motuzaite Matuzeviciute et al., 2015). The earliest evidence of cultivated plants discovered in Kazakhstan date to ca. 2600–2500 cal. BCE for wheat (Doumani et al., 2015, Table 1) and to 2460–2150 cal. BCE for broomcorn millet (Frachetti et al., 2010). Macro-botanical and phytolith data from Bronze Age and Iron Age sites such as Begash, Tasbas, Tuzusai and Tseganka 8, indicate that cultivated crops of both southwest Asian and Chinese origin were used and consumed (Chang et al., 2003; Doumani et al., 2015; Frachetti et al., 2010; Rosen, 2001; Spengler et al., 2013a,b; Spengler et al., 2014). Stable isotope investigations point towards the increase of C_4 crop consumption during the Early Iron Age in southern and south-eastern Kazakhstan (Motuzaite Matuzeviciute, 2016; Motuzaite Matuzeviciute et al., 2015), while intake of C_4 produce starts to be visible in the central regions of the country only by the Final Bronze Age and continues developing in the Early Iron Age (Lightfoot et al., 2015; Svyatko and Beisenov, 2017).

3. Materials and methods

3.1. Stable isotope methodology

Stable isotope analysis of bone collagen has been applied to evaluate past human and animal diets. Food consumed by animals and humans during their lifetime corresponds with the chemical composition of their bones. Collagen carbon isotope values tend to reflect mainly the protein part of the diet (Ambrose and Norr, 1993). Isotopic analysis of bone collagen, however, indicates the most regular diet over the adult life and might not demonstrate small changes in the food intake (Hedges et al., 2007). Isotopic values of $\delta^{13}C$ in collagen tend to be more enriched in comparison to the primary food sources (Ambrose and Norr, 1993). The difference between a food source and collagen $\delta^{13}C$ value can be about +5‰ (van der Merwe and Vogel, 1978).

Stable isotope analysis can be used to detect the consumption of C_4 plants. Plants that use C_3 and C_4 photosynthetic pathways have average $\delta^{13}C$ values of −27.1 ± 2.0‰ and −13.1 ± 1.2‰ respectively (O'Leary, 1988), therefore enriched $\delta^{13}C$ values might indicate direct or indirect (through consumption of animals that grazed on C_4 pastures) intake of C_4 plant food. 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. 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 (Frachetti et al., 2010; Chang et al., 2003), use C_4 photosynthetic pathways.

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, omnivores, fish). It is important to study zooarchaeological data from the same geographic area as isotopic values might vary chronologically and spatially (Stevens and Hedges, 2004).

Other factors, such as climatic stress and pathology, can also affect the isotopic values. More arid and temperate environments usually have a larger proportion of C_4 vegetation (van Klinken et al., 1994). $\delta^{13}C$ values of plants growing in such climatic zones tend to be elevated, $\delta^{15}N$ values of plants also increase in arid environments (Chase et al., 2012).

3.2. Materials

Overall, 47 human and 29 animal bone samples were analyzed isotopically (Table 1, Appendices A and B). Samples were often obtained from different sites (Fig. 1) due to the scarcity of the bone material. Materials were provided by Buketov Karaganda State University (Saryarka Archaeological Institute), Margulan Institute of Archaeology, "Archaeology Expertise LLC" and Nazarbayev University.

Samples were prepared and analyzed at the Mass Spectrometry Laboratory, Centre for Physical Science and Technology, Vilnius, Lithuania using pre-treatment procedures outlined below. First, the bone surface was cleaned with the use of a Dremmel™ 3000 polishing point, then approximately 500 mg of bone was sampled from the middle of each specimen. Samples were then demineralized with 0.5 M aq. HCl solution at ~3–5°C for 1–5 days. After demineralization, samples were rinsed 3 times with deionized water, frozen with liquid nitrogen and freeze-dried. Samples between 0.85 and 1.0 mg in weight were then 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 Karlson et al., 2015; Masalaite et al., 2015). 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 N_2. The analytical precision and calibration of reference gas CO_2 (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 N_2 (δ15N measurements) to air.

4. Results

Overall, 41 out of 47 human (87.2% success rate) and 24 out of 29 animal (82.8% success rate) samples showed good preservation of

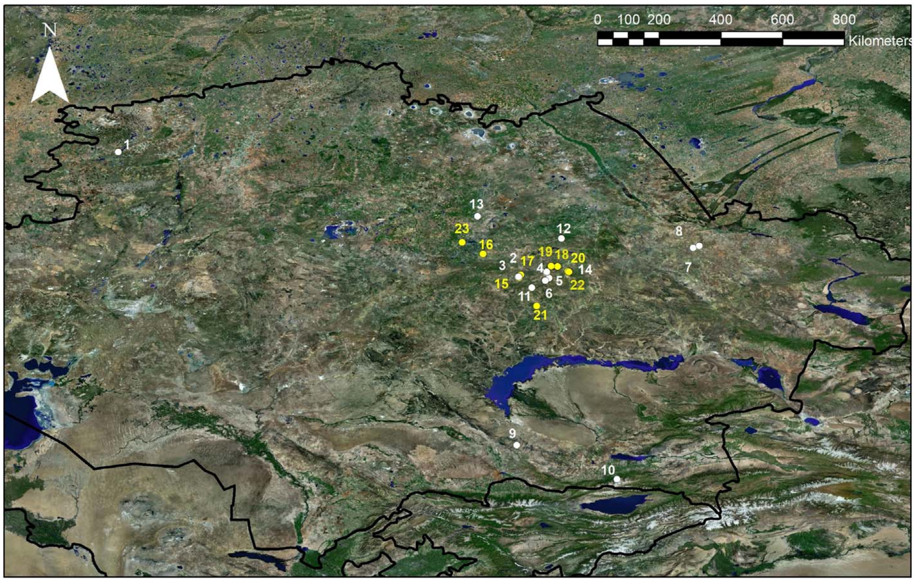

Fig. 1. Map with main sites discussed in the paper.
1. Tobolskyi, 2. Kyzylsuir-2, 3. Abylai, 4. Tandaily, 5. Bakybulak, 6. Baike-2, 7. Karatobe, 8. Kotyrkora, 9. Shatyrkul', 10. Turgen, 11. Karakemer, 12. Kyzylshilik, 13. Okule-5, 14. Dongal.
Yellow points mark sites that contain individuals with high $\delta^{13}C$ values during Final Bronze and Early Iron Ages in central Kazakhstan in this study: 15.Karashoky, 16.Myrzhyk-6; those published previously by Svyatko and Beisenov (2017): 15.Karashoky, 17.Akbeit, 18. Koitas; 19. Taldy-2; and those published by Lightfoot et al. (2015): 20.Kent, 21.Tegiszhol, 22.Tasyrbai, 23.Kyzyl (The map was produced with use of ESRI Geographic Information System software (ArcGIS). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

collagen with C:N ratio from 2.9 to 3.6 (DeNiro, 1985).

4.1. Central Kazakhstan

Human samples from central Kazakhstan sites dated to the Early Iron Age (~900–200 BCE) (n = 11) range from − 22.1‰ to − 16.1‰ with a mean value of − 18.3‰ in $\delta^{13}C$; and from 13.5‰ to 15.2‰ with a mean value of 14.5‰ in $\delta^{15}N$. Although the sample size is limited, great diversity in $\delta^{13}C$ values can be observed. Samples LT-KZ-2 and LT-KZ-18, in particular, show enriched signals of $\delta^{13}C$, which points to consumption of C_4 plants. Sample number LT-KZ-21, on the other hand, has $\delta^{13}C$ value of − 22.1‰. This is indicative of a C_3 diet with little or no consumption of C_4 plants. Samples of cattle, caprines, and horses from central Kazakhstan range from − 21.2‰ to − 18.6‰ with a mean value of − 20.0‰ in $\delta^{13}C$. Animal samples show variation in $\delta^{15}N$ values with the highest value of 10.5‰. Carbon isotope ratios point to a C_3 animal diet with limited or no access to C_4 plants.

4.2. Eastern Kazakhstan

A small sample size of human (n = 4) and animal (n = 1) bone material from the east of the country demonstrates a range of $\delta^{13}C$ values in humans (from − 17.8‰ to − 16.0‰ with a mean value of − 17.3‰), which indicates some consumption of C_4 plants in eastern Kazakhstan in the Iron Age (~800 BCE–300 CE). The signal of $\delta^{15}N$ in human samples ranges from 13.2‰ to 15.2‰ with a mean value of 14.1‰. A single caprine sample from an eastern Kazakhstan archaeological site Karatobe demonstrates $\delta^{13}C$ value of − 19.0‰ and $\delta^{15}N$ value of 10.3‰. This is indicative of animal diet consisting mainly of C_3 plants.

4.3. Southern Kazakhstan

Human samples (n = 26) from two Early Iron Age (~900–200 BCE) sites in southern Kazakhstan demonstrate $\delta^{13}C$ values ranging from − 17.7‰ to − 12.2‰ with a mean value of − 15.5‰ and $\delta^{15}N$ values ranging from 11.6‰ to 15.7‰ with a mean value of 13.3‰. This indicates that C_4 plants were a major component of the diet, however some individuals did not rely solely on C_4 crops for subsistence.

5. Discussion

5.1. Discussion of stable isotope results

Isotopic data from the Early, Middle and Late Bronze Ages published by Lightfoot et al. (2015) indicated a very limited C_4 signal in central Kazakhstan. Four outliers: Kyzyl (KZ092), Kent (KZ104), Tegiszhol (KZ025) and Tasyrbai (KZ053) came from sites dated to the Final Bronze Age. However, no high $\delta^{13}C$ values were observed in earlier time periods. A recent study carried out by Svyatko and Beisenov (2017) demonstrates high variability in diet indicated by a wide range of $\delta^{13}C$ values. Although the sample size is limited, this study contributes to the stable isotope dietary evidence in central Kazakhstan. A scatter plot of isotopic values from Bronze Age and Early Iron Age humans from central Kazakhstan, herbivores from central Kazakhstan, and fish from eastern Kazakhstan (Fig. 2) reveals greater diversity of $\delta^{13}C$ values among the Early Iron Age humans, while Bronze Age $\delta^{13}C$ values tend to cluster in one group,

with the exception of four Final Bronze Age individuals that stand out on the graph. Average $\delta^{13}C$ values for central Kazakhstan from this and other (Lightfoot et al., 2015; Svyatko and Beisenov, 2017) studies are − 18.3‰ for the Bronze Age and − 17.9‰ for the Early Iron Age.

In comparison to the Early Iron Age isotopic values from central Kazakhstan, data from the southern region suggests that over half of the population consumed C_4 plants (Fig. 3). However, it also points to the increase of C_4 plants consumption in the Early Iron Age in comparison to the Bronze Age (Fig. 3). Overall, the changes happening in the transitional period are less clear in southern Kazakhstan than in the central region. Early Iron Age settlements, for example, were situated in the same areas and, often, even on the same spots as Bronze Age settlements (Goryachev, 2011).

This study presents the first published isotopic data from the Early Iron Age sites of eastern Kazakhstan. Although the sample size was very limited, sample LT-KZ-40 from Karatobe indicated high $\delta^{13}C$ value of − 16.0‰. A ceramic vessel filled with remains of *Polygonaceae* identified by a local botanist was discovered at the site of Karatobe. The plant could have been used for medical purposes. More research has to be done in order to analyze the importance of plants in eastern Kazakhstan Early Iron Age communities. Nevertheless, the available data suggest that some individuals there could partially rely on C_4 plants for subsistence.

Table 1
Results of the study.

Human samples							
Lab numb.	Site	Context	Date	Element	δ^{13}C‰	δ^{15}N‰	C/N at.
Central Kazakhstan							
LT-KZ-1	Akbeit	Kurgan 6	~900–500 BCE[a]	Rib	− 18.0	14.5	3.3
LT-KZ-23	Baike 2	Kurgan (with whiskers) 3	~800–400 BCE[b]	Clovicle	− 19.1	14.8	3.3
LT-KZ-19	Bakybulak	Kurgan 9	~900–500 BCE[a]	Skull	− 18.4	13.6	3.5
LT-KZ-24	Karakemer	Kurgan 3	~800–400 BCE[b]	Rib	− 17.9	14.9	3.3
LT-KZ-3	Karashoky	Kurgan 6	760–430 cal. BCE[a]	Rib	− 18.0	15.1	3.3
LT-KZ-2	Karashoky	Kurgan 7	~900–400 BCE[b]	Clovicle	− 16.1	14.6	3.3
LT-KZ-4	Karashoky	Kurgan 9	~900–400 BCE[b]	Vertebra	− 17.8	15.1	3.3
LT-KZ-21	Kyzylshilik	Kurgan 5	~800–400 BCE[b]	Clovicle	− 22.1	13.5	3.3
LT-KZ-18	Myrzhyk 6	Kurgan 3	~700–500 BCE[b]	Skull	− 16.8	15.2	3.4
LT-KZ-20	Tandaily	Kurgan 1	~800–400 BCE[b]	Bone fragm.	− 19.5	13.6	3.3
LT-KZ-25	Tegiszhol	Construction 27, burial 2	~900–200 BCE[b]	Clovicle	− 17.8	14.6	3.4
Eastern Kazakhstan							
LT-KZ-41	Karatobe	Kurgan 1	~200 BCE–200 CE[b]	Radius	− 17.8	14.7	3.3
LT-KZ-40	Karatobe	Kurgan 2		Ulna	− 16.0	13.3	3.4
LT-KZ-39	Karatobe	Kurgan 3		Radius	− 17.6	15.2	3.3
LT-KZ-42	Kotyrkora	Kurgan 1	~800 BCE–300 CE[b]	Bone fragm.	− 17.8	13.2	3.3
Southern Kazakhstan							
LT-KZ-9	Shatyrkul'	Kurgan 3, burial 7	~900–200 BCE[b]	1st plnx	− 15.0	13.7	3.4
LT-KZ-5	Shatyrkul'	Kurgan 3, burial 9		Bone fragm.	− 12.8	13.3	3.4
LT-KZ-7	Shatyrkul'	Kurgan 4, burial 10		1st plnx	− 13.9	13.1	3.3
LT-KZ − 15	Shatyrkul'	Kurgan 4, burial 11		1st plnx	− 15.0	14.8	3.4
LT-KZ-6	Shatyrkul'	Kurgan 11, burial 1		1st plnx	− 15.6	14.4	3.3
LT-KZ-13	Shatyrkul'	Kurgan 11, burial 2		vertebra	-15.7	15.7	3.3
LT-KZ-8	Shatyrkul'	Kurgan 11, burial 4		Bone fragm.	− 14.1	13.8	3.4
LT-KZ-11	Shatyrkul'	Kurgan 12, burial 2		Bone fragm.	− 14.2	14.1	3.4
LT-KZ-14	Shatyrkul'	Kurgan 12, burial 5(1)		Vertebra	− 15.1	15.0	3.5
LT-KZ-16	Shatyrkul'	Kurgan 12, burial 5(2)		Bone fragm.	− 12.2	12.8	3.4
LT-KZ-12	Shatyrkul'	Kurgan 12, burial 6		Bone fragm.	− 15.5	14.2	3.5
LT-KZ-10	Shatyrkul'	Kurgan 12, burial 9		1st plnx	− 15.7	12.9	3.4
LT-KZ-17	Shatyrkul'	Burial 4		1st plnx	− 15.8	13.7	3.4
LT-KZ-26	Turgen'	Kurgan 5, burial 1	~900–200 BCE[b]	Bone fragm.	− 17.7	13.4	3.4
LT-KZ-38	Turgen'	Kurgan 12, burial 1		Vertebra	− 16.9	13.0	3.3
LT-KZ-27	Turgen'	Kurgan 12, burial 2		Vertebra	− 16.4	13.8	3.5
LT-KZ-28	Turgen'	Kurgan 13, burial 2		Bone fragm.	− 16.3	13.3	3.4
LT-KZ-29	Turgen'	Kurgan 17, burial 1		Vertebra	− 17.3	13.5	3.4
LT-KZ-30	Turgen'	Kurgan 17, burial 2		Vertebra	− 16.1	12.6	3.5
LT-KZ-31	Turgen'	Kurgan 17, burial 4		Vertebra	− 16.0	11.9	3.6
LT-KZ-33	Turgen'	Kurgan 18, burial 2		Bone fragm.	− 15.9	12.5	3.3
LT-KZ-32	Turgen'	Kurgan 19, burial 2		Skull	− 16.4	12.3	3.4
LT-KZ-34	Turgen'	Kurgan 19, burial 3		1st plnx	− 16.1	12.1	3.3
LT-KZ-36	Turgen'	Kurgan 19, burial 4		Vertebra	− 16.1	12.6	3.3
LT-KZ-37	Turgen'	Kurgan 25, burial 1		Vertebra	− 16.0	13.5	3.4
LT-KZ-35	Turgen'	Kurgan 26, burial 1		1st plnx	− 15.4	11.6	3.3

Animal samples							
Lab numb.	Site	Context	Date	Specie	δ^{13}C‰	δ^{15}N‰	C/N at.
Central Kazakhstan							
LT-KZ-74	Abylai	Square A1	~800–400 BCE[b]	Caprine	− 19.4	8.7	3.4
LT-KZ-75	Abylai	Square A3	~800–400 BCE[b]	Horse	− 21.2	7.1	3.5
LT-KZ-60	Akbeit	Kurgan 1	~900–500 BCE[a]	Cattle	− 19.9	8.0	3.6
LT-KZ-62	Akbeit	Kurgan 7, individ. 1	~900–500 BCE[a]	Caprine	− 18.6	10.5	3.2
LT-KZ-63	Akbeit	Kurgan 7, individ. 3	~900–500 BCE[a]	Caprine	− 19.9	7.8	3.5
LT-KZ-64	Akbeit	Kurgan 7, individ. 4	~900–500 BCE[a]	Caprine	− 19.0	10.2	3.3
LT-KZ-65	Akbeit	Kurgan 7, individ. 6	~900–500 BCE[a]	Horse	− 20.8	5.3	3.5
LT-KZ-66	Akbeit	Kurgan 7, individ. 5	~900–500 BCE[a]	Caprine	− 20.4	6.7	3.3
LT-KZ-79	Dongal	settlement layers	~1000–800 BCE[b]	Cattle	− 20.2	8.3	3.5
LT-KZ-76	Karashoky	Kurgan 6, individ. 4	~900–400 BCE[b]	Caprine	− 19.2	8.2	3.3
LT-KZ-77	Karashoky	Kurgan 6, individ. 3	~900–400 BCE[b]	Caprine	− 19.7	9.0	3.3
LT-KZ-80	Kent	Settlement layers	~1300–800 BCE[b]	Cattle	− 20.3	7.0	3.4
LT-KZ-81	Kent	Settlement layers	~1300–800 BCE[b]	Animal bone	− 19.8	7.6	3.4
LT-KZ-82	Kent	Settlement layers	~1300–800 BCE[b]	Cattle	− 19.8	10.1	3.4
LT-KZ-67	Kyzylsuir 2	Settlement layers	~700–500 BCE[b]	Cattle	− 20.5	6.9	3.3
LT-KZ-68	Kyzylsuir 2	Settlement layers	~700–500 BCE[b]	Cattle	− 19.5	7.8	3.3
LT-KZ-69	Kyzylsuir 2	Settlement layers	~700–500 BCE[b]	Cattle	− 20.0	9.5	3.3
LT-KZ-70	Kyzylsuir 2	Settlement layers	~700–500 BCE[b]	Cattle	− 20.3	8.3	3.3
LT-KZ-71	Kyzylsuir 2	Settlement layers	~700–500 BCE[b]	Cattle	− 19.9	8.6	3.3
LT-KZ-73	Kyzylsuir 2	Settlement layers	~700–500 BCE[b]	Cattle	− 20.2	7.8	3.3

(continued on next page)

Table 1 (*continued*)

Animal samples							
Lab numb.	Site	Context	Date	Specie	δ^{13}C‰	δ^{15}N‰	C/N at.
LT-KZ-78	Okule 5	Kurgan	~700–600 BCE[b]	Caprine	− 20.9	7.4	3.4
Northern Kazakhstan							
LT-KZ-56	Tobolskyi	Central burial	~1000–800 BCE[b]	Horse	− 21.3	4.3	3.3
LT-KZ-57	Tobolskyi	Eastern half of the kurgan	~1000–800 BCE[b]	Caprine	− 19.7	9.2	3.6
Eastern Kazakhstan							
LT-KZ-83	Karatobe	Kurgan 3	~200 BCE–200 CE[b]	Caprine	− 19.0	10.3	3.3

[a] Calibrated dates for these sites were published earlier by Beisenov et al. (2016b).
[b] The features are dated by cultural affiliation.

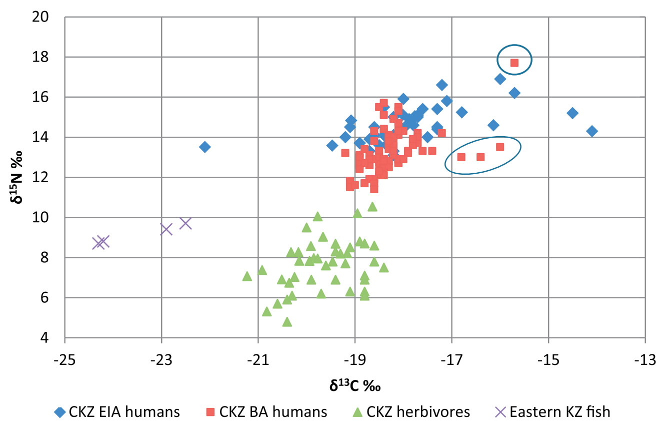

Fig. 2. Scatter graphs demonstrate distribution of human isotopic values: CKZ – central Kazakhstan, BA - Bronze Age, EIA – Early Iron Age, herbivores - caprines, cattle and horse values from archaeological sites of the Bronze and Iron Ages; (includes previously published data by Lightfoot et al., 2015; Motuzaite Matuzeviciute et al., 2015; Svyatko and Beisenov, 2017); eastern Kazakhstan fish values were taken from a previously published study by Svyatko et al. (2015).

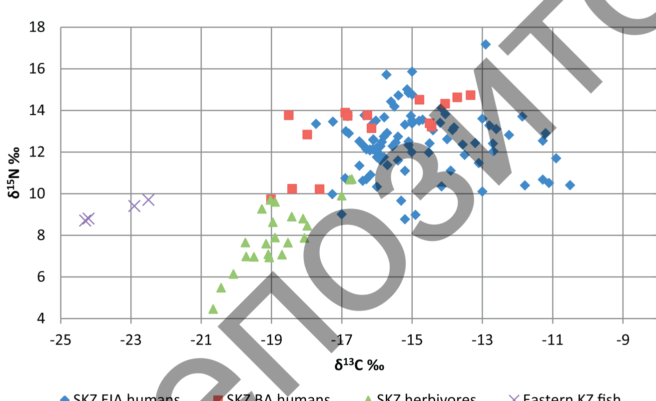

Fig. 3. Scatter graphs demonstrate distribution of human isotopic values: SKZ – southern Kazakhstan, BA - Bronze Age, EIA – Early Iron Age, herbivores - caprines, cattle and horse values from archaeological sites of the Bronze and Iron Ages; (includes previously published data by Lightfoot et al., 2015; Motuzaite Matuzeviciute et al., 2015; Svyatko and Beisenov, 2017).

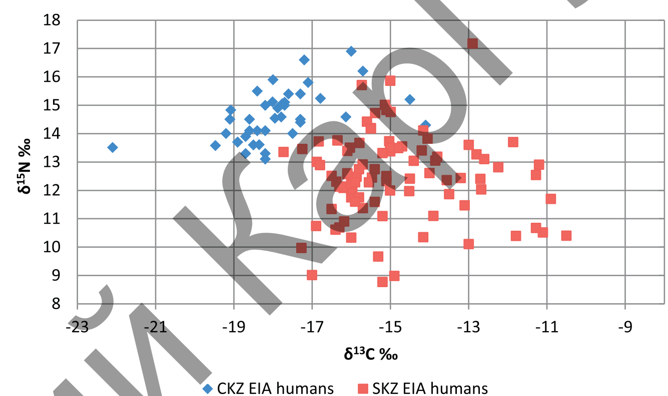

Fig. 4. Scatter graphs demonstrate distribution of human isotopic values during the Early Iron Age in Central and Southern Kazakhstan: CKZ EIA – Central Kazakhstan Early Iron Age, SKZ EIA – Southern Kazakhstan Early Iron Age (this graph uses previously published data by Lightfoot et al., 2015; Motuzaite Matuzeviciute et al., 2015; Svyatko and Beisenov, 2017).

5.2. Individuals with C_4 signal in central Kazakhstan

Stable isotope evidence suggests that there was limited consumption of C_4 crops in central Kazakhstan during the Early Iron Age. Enriched carbon values are identified at various Final Bronze Age and Early Iron Age sites. However, only one individual per site demonstrates consumption of C_4 plants, with the exception of Karashoky cemetery, where two individuals (LT-KZ-2 and UBA-23674) have enriched δ^{13}C values (Table 2).

At least three samples (LT-KZ-2, LT-KZ-18 and UBA23672) with enriched δ13C values belong to adult males according to the anthropological identification. Two more samples (UBA23674 and UBA-23667) could also belong to adult males. Archaeological data from mortuary ritual contexts of the Middle Bronze Age Petrovka culture cemetery at Bestamak located in northern Kazakhstan suggests that women and men had similar public status (Logvin, 2002). Sintashta and Petrovka burials indicate differences associated with sex and age of the individuals, however, special treatment of the deceased related to higher social status is not as prominent (Koryakova and Epimakhov, 2007). In the Early Iron Age, on the other hand, we see not only social differentiation, but also gender differences reflected in the funerary ceremony and evident by rich burials.

Analysis of lifestyle and social structure in the Early Iron Age societies of central Kazakhstan has been carried out by researchers working with sites of Tasmola culture (Habdulina, 2007; Yarygin and Lapin, 2015). They suggested that the Early Iron Age community inhabiting central and northern regions of Kazakhstan was highly stratified. At least five samples with enriched values (Table 2) were collected from the elite (tsarskyi) kurgans: Akbeit, kurgan 1 (UBA23672), Karashoky, kurgans 1 (UBA-23674) and 7 (LT-KZ-2), Koitas, kurgan 1 (UBA-23664) and Taldy-2 (UBA-23667). The presence of enriched δ^{13}C values in individuals buried in rich kurgans indicates that social elites were consuming C_4 crops, an observation that has been noted by Svyatko and Beisenov (2017). It is not clear, however, if C_4 produce, possibly millet, was reserved only for the high society. Osteological investigations of Tasmola population (Beisenov et al., 2015) indicated that some samples with high δ^{13}C values were obtained from individuals with trepanning holes in the skull (LT-KZ-2, UBA-23672). One more sample could also come from a child with four trepanning holes (UBA-23674). The character of the holes suggests that they were done after death

Table 2
Isotopic data of the individuals with enriched $\delta^{13}C$ values from Final Bronze Age and Early Iron Age in central Kazakhstan.

Sample ID	Date	Site	Context	Sex	Age	Other information	$\delta^{13}C$‰	$\delta^{15}N$‰	C/N at.	Source
KZ025	~1300–800 BCE[b]	Tegiszhol	Kurgan 3	–	–	–	−16.4	13	3,1	Lightfoot et al., 2015
KZ053	~1300–800 BCE[b]	Tasyrbai	Kurgan 10, grave 1	–	–	–	−15.7	17.7	3,2	Lightfoot et al., 2015
KZ092	~1300–800 BCE[b]	Kyzyl	Kurgan 8	–	–	–	−16.8	13	3,2	Lightfoot et al., 2015
KZ104	~1300–800 BCE[b]	Kent (settlement)	Cultural layers	–	Adult	Single human femur discovered	−16	13.5	3,3	Lightfoot et al., 2015
LT-KZ-2	~900–400 BCE[b]	Karashoky	Kurgan 7	M	35–45 y.o.	The individual has 7 trepanning holes in the skull	−16.1	14.6	3.3	This study
LT-KZ-18	~700–500 BCE[b]	Myrzhyk 6	Kurgan 3	M	25 + y.o.	Buried with inventory of a «warrior»	−16.8	15.2	3.4	This study
UBA-23672	829–546 cal. BCE[a]	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. BCE[a]	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. BCE[a]	Koitas	Kurgan 1	–	–	–	−14.1	14.3	3,2	Svyatko and Beisenov, 2017
UBA-23667	807–540 cal. BCE[a]	Taldy-2[c]	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

[a] Calibrated dates for these sites were published earlier by Beisenov et al. (2016b).
[b] The features are dated by cultural affiliation.
[c] The context of the sample is not clear.

(Beisenov et al., 2015, 127). Trepanning holes could be performed as a part of embalming process to secure the preservation of body until the burial ceremony. Beisenov et al. (2015, 128–129) also consider trepanning holes as a marker of status and indication of social stratification in the Early Iron Age.

Isotopic data from human enamel from the Southern region of Kazakhstan shows that millet was consumed by younger members of the society as well as by adults, probably in the form of porridge (Motuzaite Matuzeviciute, 2016). For central Kazakhstan, a single high $\delta^{13}C$ value (UBA-23674) published earlier in Svyatko and Beisenov (2017) may belong to a 1-year-old child.

5.3. Social change and the introduction of C_4 plants in central Kazakhstan

Despite widespread acceptance of an Early Iron Age date for the rise of nomadic pastoralism in the central Kazakhstan steppes, the evidence suggests that people started to consume C_4 plants in the Final Bronze Age, a diet that continued into the Early Iron Age. Evidence for the cultural changes that happened in the Early Iron Age such as the appearance of elites, increase in social complexity, new forms of warfare and ornament styles coincides with the introduction of C_4 agriculture both chronologically and spatially.

As to the economic implications of the beginning of crop consumption in central Kazakhstan, there are two possible hypotheses that fit the existing evidence. Firstly, Final Bronze Age and Early Iron Age populations could grow C_4 plants, possibly millet, which does not necessarily imply that their primary economic strategy was not pastoral nomadism. For example, ethngraphic research has examined agricultural activity within pastoral nomadic societies. Nomadic Kazakhs cultivated millet, wheat, and barley (Masanov, 1995). Growing crops, however, did not transform a nomadic population into a sedentary one. Nomadic groups that cultivated crops traveled around their pastures while growing spring-sown crops. After the reaping, they processed the harvest, took part of it and put the rest in the soil until the next season (Levshin, 1832). A review of ethnographic and archaeological evidence for steppe nomadic communities suggests that nomads did not require large amounts of agricultural products to survive (Di Cosmo, 1994), which suggests that evidence for agriculture in Early Iron Age nomads can be difficult to find.

On the other hand, high C_4 values are only seen in individual representatives of the Final Bronze and Early Iron Age society in central Kazakhstan, which might point to the development of long-distance trade with agricultural communities. It has been previously suggested that a long-distance exchange between desert-oasis cities and the hinterland population could influence the spread of trade items as indicated by discoveries of luxury artifacts made in animal-style over a vast geographic territory (Chang, 2008). In the case of southeastern Kazakhstan Early Iron Age sites Chang (2008), suggests that the image of “early nomads” could be biased by the evidence coming from rich kurgans of the nomadic elite, since archaeological evidence from the Early Iron Age settlements does not demonstrate major social differences. Similarly, for central Kazakhstan, the stable isotope results presented here and published earlier (Lightfoot et al., 2015; Svyatko and Beisenov, 2017) suggest that only a small percentage of the population consumed C_4 plants. However, rich kurgan graves targeted by archaeologists do not represent the overall diet of the population in the region, as there is a chance that the majority of the sampled population belonged to the class of warriors that practiced a mobile lifestyle and did not have frequent access to a plant based diet. Possible agricultural tools found at some Early Iron Age settlement sites in central Kazakhstan, however, indicate that local populations could have been involved in agriculture as well (Beisenov, 2015). Further research and archaeobotanical investigation in particular of those settlement sites in central Kazakhstan, could therefore lead to a better understanding of the human diet during the transitional period from Bronze to Iron Ages.

6. Conclusion

This paper presents the results of a stable isotope analysis based on samples from the Final Bronze and the Early Iron Age sites of central, southern, and eastern Kazakhstan. The evaluation of previously conducted isotopic studies together with the new data indicate that C_4 crops were already consumed in central Kazakhstan in the Final Bronze Age, and that this trend continued in the early Iron Age. Isotopic data suggest that C_4 plants were more important to the people of southern Kazakhstan during the Early Iron Age than they were to the people of central Kazakhstan during the same time. Despite the limited sample size, the data suggest that the people of eastern Kazakhstan also consumed C_4 plants to some degree during the Early Iron Age. Our research suggests that certain individuals who consumed C_4 plants in central Kazakhstan during the Early Iron Age often represent high class males buried in elite kurgans. This could point to both the beginning of the development of C_4 agriculture in the region and/or the expansion of trading networks with other areas that produced C_4 crops such as millet. Yet the origins of these plants remains unclear; we have no direct evidence for the local cultivation of them. Nevertheless, we can conclude that the earliest appearance of C_4 plant consumption in the central Kazakhstan region coincides with important social and economic changes in the region.

Acknowledgements

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Appendix A

Sample ID	Site	Context	Period	Element	$\delta^{13}C$‰	$\delta^{15}N$‰	C/N atomic	Region	Source
LT-KZ-1	Akbeit	Kurgan 6	EIA	Rib	−17.95	14.54	3.3	Central	This study
LT-KZ-2	Karashoky	Kurgan 7	EIA	Clovicle	−16.14	14.59	3.3	Central	This study
LT-KZ-3	Karashoky	Kurgan 6	EIA	Rib	−18.01	15.12	3.3	Central	This study
LT-KZ-4	Karashoky	Kurgan 9	EIA	Vertebra	−17.76	15.05	3.3	Central	This study
LT-KZ-5	Shatyrkul'	Kurgan 3, burial 9	EIA	Human bone (fragm)	−12.80	13.27	3.4	Southern	This study
LT-KZ-6	Shatyrkul'	Kurgan 11, burial 1	EIA	Phalanx	−15.60	14.42	3.3	Southern	This study
LT-KZ-7	Shatyrkul'	Kurgan 4, burial 10	EIA	Phalanx	−13.85	13.05	3.3	Southern	This study
LT-KZ-8	Shatyrkul'	Kurgan 11, burial 4	EIA	Human bone (fragm)	−14.05	13.82	3.4	Southern	This study
LT-KZ-9	Shatyrkul'	Kurgan 3, burial 7	EIA	Phalanx	−15.03	13.73	3.4	Southern	This study
LT-KZ-10	Shatyrkul'	Kurgan 12, burial 9	EIA	Phalanx	−15.71	12.91	3.4	Southern	This study
LT-KZ-11	Shatyrkul'	Kurgan 12, burial 2	EIA	Human bone (fragm)	−14.16	14.11	3.4	Southern	This study
LT-KZ-12	Shatyrkul'	Kurgan 12, burial 6	EIA	Human bone (fragm)	−15.50	14.19	3.5	Southern	This study
LT-KZ-13	Shatyrkul'	Kurgan 11, burial 2	EIA	Vertebra	−15.73	15.71	3.3	Southern	This study
LT-KZ-14	Shatyrkul'	Kurgan 12, burial 5	EIA	Vertebra	−15.14	15.01	3.5	Southern	This study
LT-KZ-15	Shatyrkul'	Kurgan 4, burial 11	EIA	Phalanx	−14.99	14.76	3.4	Southern	This study
LT-KZ-16	Shatyrkul'	Kurgan 12, burial 5	EIA	Human bone (fragm)	−12.24	12.81	3.4	Southern	This study
LT-KZ-17	Shatyrkul'	Burial 4	EIA	Phalanx	−15.79	13.67	3.4	Southern	This study
LT-KZ-18	Myrzhyk 6	Kurgan 3	EIA	Human skull (fragm)	−16.79	15.24	3.4	Central	This study
LT-KZ-19	Bakybulak	Kurgan 9	EIA	Human skull (fragm)	−18.35	13.61	3.5	Central	This study
LT-KZ-20	Tandaily	Kurgan 1	EIA	Human bone (fragm)	−19.47	13.58	3.3	Central	This study
LT-KZ-21	Kyzylshilik	Kurgan 5	EIA	Human clovicle	−22.10	13.51	3.3	Central	This study
LT-KZ-23	Baike 2	Kurgan 3	EIA	Human clovicle	−19.08	14.83	3.3	Central	This study
LT-KZ-24	Karakemer	Kurgan 3	EIA	Human rib	−17.88	14.90	3.3	Central	This study
LT-KZ-25	Tegiszhol	Construction 27, burial 2	EIA	Human clovicle	−17.79	14.59	3.4	Central	This study

LT-KZ-26	Turgen	Kurgan 5, burial 1	EIA	Human bone (fragm)	− 17.73	13.35	3.4	Southern	This study
LT-KZ-27	Turgen	Kurgan 12, burial 2	EIA	Human vertebra	− 16.35	13.76	3.5	Southern	This study
LT-KZ-28	Turgen	Kurgan 13, burial 2	EIA	Human bone (fragm)	− 16.30	13.30	3.4	Southern	This study
LT-KZ-29	Turgen	Kurgan 17, burial 1	EIA	Vertebra	− 17.25	13.46	3.4	Southern	This study
LT-KZ-30	Turgen	Kurgan 17, burial 2	EIA	Vertebra	− 16.10	12.57	3.5	Southern	This study
LT-KZ-31	Turgen	Kurgan 17, burial 4	EIA	Vertebra	− 15.97	11.93	3.6	Southern	This study
LT-KZ-32	Turgen	Kurgan 19, burial 2	EIA	Skull	− 16.38	12.30	3.4	Southern	This study
LT-KZ-33	Turgen	Kurgan 18, burial 2	EIA	Human bone (fragm)	− 15.86	12.48	3.3	Southern	This study
LT-KZ-34	Turgen	Kurgan 19, burial 3	EIA	Phalanx	− 16.12	12.13	3.3	Southern	This study
LT-KZ-35	Turgen	Kurgan 26, burial 1	EIA	Phalanx	− 15.40	11.59	3.3	Southern	This study
LT-KZ-36	Turgen	Kurgan 19, burial 4	EIA	Vertebra	− 16.10	12.60	3.3	Southern	This study
LT-KZ-37	Turgen	Kurgan 25, burial 1	EIA	Vertebra	− 16.03	13.50	3.4	Southern	This study
LT-KZ-38	Turgen	Kurgan 12, burial 1	EIA	Vertebra	− 16.88	13.00	3.3	Southern	This study
LT-KZ-39	Karatobe	Kurgan 3	EIA	Radius	− 17.64	15.24	3.3	Eastern	This study
LT-KZ-40	Karatobe	Kurgan 2	EIA	Ulna	− 15.99	13.29	3.4	Eastern	This study
LT-KZ-41	Karatobe	Kurgan 1	EIA	Radius	− 17.84	14.73	3.3	Eastern	This study
LT-KZ-42	Kotyrkora	Kurgan 1	EIA	Human bone (fragm)	− 17.81	13.19	3.3	Eastern	This study
GM_028	Oi-Dzailau VII	Grave 5/ construction 2	LBA		− 17.98	12.83	3.4	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_029	Oi-Dzailau VII	Grave 1/ construction 2	LBA		− 18.51	13.76	3.4	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_025	Oi-Dzailau VII	Grave 5/ construction 3	LBA		− 16.9	13.89	3.2	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_033	Oi-Dzailau VII	Kurgan 1	LBA		− 16.15	13.14	3.2	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_035	Oi-Dzailau VII	Kurgan 9/grave 8	LBA		− 14.79	14.51	3.2	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_034	Oi-Dzailau VII	Grave 2/ construction 3	LBA		− 14.44	13.22	3.2	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_020	Oi-Dzailau VII	Kurgan 3/grave 2	LBA		− 14.5	13.38	3.1	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_026	Oi-Dzailau VII	Grave 4/ construction 3	LBA		− 13.71	14.62	3.3	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_024	Oi-Dzailau VII	Grave 1/ construction 3	LBA		− 13.33	14.73	3.2	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_027	Oi-Dzailau VII	Grave 1/ construction 2	LBA		− 14.06	14.32	3.3	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_022	Oi-Dzailau VII	Grave 7	LBA		− 16.83	13.73	3.5	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_036	Kyzyl Bulak-1	Construction 38/ grave 9	LBA		− 16.27	12.76	3.2	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_031	Kyzyl Bulak-1	Construction 65	LBA		− 18.41	10.23	3.2	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_021	Kyzyl Bulak-1	Construction 42	LBA		− 19.01	9.72	3.2	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_030	Kyzyl Bulak-1	Construction 45	LBA		− 17.63	10.21	3.4	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_049	Karatuma	Kurgan 55	EIA		− 15	13.37	3.2	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_050	Karatuma	Kurgan 19/grave 2	EIA		− 15.1	14.83	3.3	Southern	Motuzaite Matuzeviciute et al., 2015'

GM_051	Karatuma	Kurgan 10	EIA	− 16	11.75	3.2	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_053	Karatuma	Kurgan 90	EIA	− 16.3	12.13	3.2	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_054	Karatuma	Kurgan 80/grave 2	EIA	− 15.5	14.18	3.1	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_055	Karatuma	Kurgan 80/grave 2	EIA	− 15.2	11.09	3.1	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_058	Karatuma	Kurgan 36	EIA	− 16	12.03	3.2	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_059	Karatuma	Kurgan 62	EIA	− 14.5	12.41	3.1	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_062	Karatuma	Kurgan 35	EIA	− 14.9	8.98	3.3	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_063	Karatuma	Kurgan 112	EIA	− 15	13.5	3.2	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_065	Karatuma	Kurgan 165/grave 2	EIA	− 16.2	12.08	3.2	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_068	Karatuma	Kurgan 11	EIA	− 14.4	13.04	3.3	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_070	Karatuma	Kurgan 26	EIA	− 16.2	12.12	3.3	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_072	Karatuma	Kurgan 59	EIA	− 13.2	12.43	3.1	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_074	Karatuma	Kurgan 35	EIA	− 12.9	17.17	3.3	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_075	Karatuma	Kurgan 20/grave 1	EIA	− 16.9	10.74	3.2	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_076	Karatuma	Kurgan 112	EIA	− 14.7	13.55	3.2	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_077	Karatuma	Kurgan 26	EIA	− 16.5	12.51	3.1	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_079	Karatuma	Kurgan 52	EIA	− 15.4	12.74	3.1	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_080	Karatuma	Kurgan 34	EIA	− 16	12.21	3.1	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_082	Karatuma	Kurgan 26	EIA	− 15.9	12.28	3.1	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_083	Karatuma	Kurgan 21	EIA	− 15.8	12.74	3.1	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_086	Karatuma	Kurgan 20/g1	EIA	− 16.1	13.39	3.2	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_087	Karatuma	Kurgan 21	EIA	− 16.3	10.69	3.2	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_090	Karatuma	Kurgan 163	EIA	− 16.8	12.89	3.4	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_092	Karatuma	Kurgan 92	EIA	− 15.1	12.33	3.2	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_095	Karatuma	Kurgan 107	EIA	− 15.2	13.31	3.2	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_098	Karatuma	Kurgan 150	EIA	− 13.8	13.18	3.1	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_099	Karatuma	Kurgan 8	EIA	− 15.8	11.75	3.1	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_109	Karatuma		EIA	− 17	9.01	3.3	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_077B	Karatuma	Kurgan 7	EIA	− 14	12.61	3.3	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_077A	Karatuma	Kurgan 65	EIA	− 14.8	13.49	3.3	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_F78	Karatuma	Kurgan 45	EIA	− 16.5	11.34	3.3	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_148	Karatuma	Kurgan 64	EIA	− 15.1	12.5	3.3	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_155	Karatuma	Kurgan 59	EIA	− 13.5	11.86	3.4	Southern	Motuzaite Matuzeviciute et al., 2015'

GM_156	Karatuma	Kurgan47	EIA	− 15.7	11.37	3.3	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_157	Karatuma	Kurgan49	EIA	− 16.4	10.61	3.4	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_082	Karatuma	Kurgan 26	EIA	− 16.83	13.72	3.3	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_158	Karatuma	Kurgan 59	EIA	− 15.2	8.77	3.5	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_118	Kainarbulak-1	urgan 6/grave 3?	EIA	− 14.2	13.4	3.3	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_120	Kainarbulak-1	Kurgan 11/grave 2	EIA	− 13	13.6	3.1	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_123	Kainarbulak-1	Kurgan 6	EIA	− 12.7	12.4	3.1	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_128	Kainarbulak-1	Kurgan 3/grave 2	EIA	− 13.9	11.1	3.1	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_132	Kainarbulak-1		EIA	− 12.6	13.1	3.1	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_130	Kainarbulak-2	Kurgan 11/grave 2	EIA	− 10.5	10.4	3.3	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_116	Kainarbulak-1	Kurgan 7/grave 2	EIA	− 11.2	12.9	3.3	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_135	Kainarbulak-2	Kurgan 3	EIA	− 10.9	11.7	3.3	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_125B	Kainar Bulak-1	Kurgan13/grave 1	EIA	− 11.1	10.51	3.3	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_115	Kainarbulak-1	Kurgan 7/grave 1	EIA	− 11.86	13.7	3.2	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_125A	Kainarbulak-1	Kurgan13/grave 2	EIA	− 11.79	10.39	3.3	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_126	Kainar Bulak-1	Kurgan 8	EIA	− 13.1	11.47	3.2	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_127	Kainar Bulak-1	Kurgan 3/grave 2	EIA	− 14.52	11.97	3.1	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_129	Kainarbulak-2	Kurgan 11/grave 1	EIA	− 13	10.1	3.3	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_117	Kainarbulak-1	Kurgan 11/grave 1	EIA	− 12.68	12.03	3.2	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_119	Kainarbulak-1	Kurgan 5	EIA	− 11.28	12.54	3.2	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_121	Kainarbulak-1	Kurgan 4	EIA	− 15.39	14.72	3.4	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_046	Kargaly-I	Kurgan 1/12	EIA	− 13.56	12.36	3.3	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_047	Kargaly-I		EIA	− 15.47	12.45	3.4	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_044	Kargaly-I		EIA	− 14.16	10.35	3.4	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_045	Kargaly-I	Kurgan 2/14	EIA	− 15.01	11.99	3.2	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_037	Alatau-1	Kurgan 1/grave 1	EIA	− 16.18	10.9	3.1	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_038	Alatau-1	Kurgan 1/grave 2	EIA	− 17.27	9.97	3.2	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_039	Alatau-1	Kurgan 1/grave 3	EIA	− 15.9	11.6	3.3	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_040	Kamenka	Kurgan 5/grave 1	EIA	− 16	10.33	3.3	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_042	Kamenka	Kurgan 5/grave 2	EIA	− 15.31	9.66	3.2	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_041	Kamenka	Kurgan 12	EIA	− 15.55	12.28	3.2	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_43	Khatau-1	Konstruction 12/ grave 1	EIA	− 15	15.86	3.2	Southern	Motuzaite Matuzeviciute et al., 2015'
GM_131	Shymkent	Kurgan 9	EIA	− 11.28	10.67	3.3	Southern	Motuzaite Matuzeviciute et al., 2015'

KZ001	Tegiszhol	Kurgan 26	FBA	Rib	− 17.9	13.3	3.2	Central	Lightfoot et al., 2015'
KZ002	Tegiszhol	Kurgan 7, grave 1	MBA-LBA	Rib	− 18.3	13.4	3.2	Central	Lightfoot et al., 2015'
KZ003	Tegiszhol	Kurgan 8	MBA-LBA	Rib	− 18.5	12.7	3.2	Central	Lightfoot et al., 2015'
KZ004	Tegiszhol	Kurgan 26, grave 3	FBA	Rib	− 18.1	12.7	3.2	Central	Lightfoot et al., 2015'
KZ005	Tegiszhol	Kurgan 29	FBA	Rib	− 18.3	13.7	3.2	Central	Lightfoot et al., 2015'
KZ007	Tegiszhol	Kurgan 32, grave 1	MBA-LBA	Rib	− 18.5	12.1	3.2	Central	Lightfoot et al., 2015'
KZ008	Tegiszhol	Kurgan 31, grave 1	MBA-LBA	Rib	− 18.3	12.8	3.2	Central	Lightfoot et al., 2015'
KZ009	Tegiszhol	Kurgan 9	BA	Rib	− 17.4	13.3	3.1	Central	Lightfoot et al., 2015'
KZ010	Tegiszhol	Kurgan 9, grave 1	MBA-LBA	Rib	− 18.6	11.9	3.2	Central	Lightfoot et al., 2015'
KZ011	Tegiszhol	Kurgan 9, grave 2	MBA-LBA	Rib	− 18.1	12.7	3.2	Central	Lightfoot et al., 2015'
KZ012	Tegiszhol	Kurgan 9, grave 3	MBA-LBA	Rib	− 18.4	12.9	3.2	Central	Lightfoot et al., 2015'
KZ013	Tegiszhol	Kurgan 9, grave 4	MBA-LBA	Long bone	− 18.1	12.9	3.2	Central	Lightfoot et al., 2015'
KZ014	Tegiszhol	Kurgan 27, grave 1	EIA	Rib	− 17.3	14.4	3.2	Central	Lightfoot et al., 2015'
KZ015	Tegiszhol	Kurgan 24	MBA	Rib	− 18.4	12.1	3.2	Central	Lightfoot et al., 2015'
KZ016	Tegiszhol	Kurgan 20	MBA	Rib	− 18.9	12.6	3.2	Central	Lightfoot et al., 2015'
KZ017	Tegiszhol	Kurgan 19	BA	Crania	− 19.1	11.8	3.3	Central	Lightfoot et al., 2015'
KZ018	Tegiszhol	Kurgan 18	MBA	Crania	− 18.1	15.5	3.2	Central	Lightfoot et al., 2015'
KZ019	Tegiszhol	Kurgan 17	MBA	Rib	− 17.9	13.2	3.2	Central	Lightfoot et al., 2015'
KZ020	Tegiszhol	Kurgan 31, grave 2	MBA-LBA	Rib	− 18.6	12.9	3.2	Central	Lightfoot et al., 2015'
KZ021	Tegiszhol	Kurgan 21	MBA	Rib	− 18.3	14.1	3.2	Central	Lightfoot et al., 2015'
KZ023	Tegiszhol	Kurgan 5	BA	Rib	− 17.7	13.7	3.2	Central	Lightfoot et al., 2015'
KZ024	Tegiszhol	Kurgan 4	FBA	Rib	− 18.1	12.9	3.2	Central	Lightfoot et al., 2015'
KZ025	Tegiszhol	Kurgan 3	FBA	Rib	− 16.4	13	3.1	Central	Lightfoot et al., 2015'
KZ026	Tegiszhol	Kurgan 1	BA	Rib	− 18.3	12.8	3.1	Central	Lightfoot et al., 2015'
KZ095	Tegiszhol	Kurgan 27, grave 1	EIA	Mandible	− 18.2	14.1	3.3	Central	Lightfoot et al., 2015'
KZ103	Tegiszhol	Kurgan 10, grave 1	MBA-LBA	Crania	− 18.9	13	3.2	Central	Lightfoot et al., 2015'
KZ027	Nurataldy		EBA	Jaw	− 18.6	14.3	3.3	Central	Lightfoot et al., 2015'
KZ042	Dariya	Grave 9	EBA	Rib	− 18	14.3	3.2	Central	Lightfoot et al., 2015'
KZ043	Dariya	Grave 5	EBA	Rib	− 18.1	14.2	3.2	Central	Lightfoot et al., 2015'
KZ044	Dariya	Grave 7	EBA	Rib	− 17.7	14.2	3.2	Central	Lightfoot et al., 2015'
KZ045	Tashik	Kurgan 3, grave 2	EBA	Radius	− 18.7	12.6	3.2	Central	Lightfoot et al., 2015'
KZ046	Tashik	Kurgan 8, grave 4	EBA	Pelvis	− 18.7	13.1	3.3	Central	Lightfoot et al., 2015'
KZ047	Tashik	Kurgan 8, grave 2	EBA	Rib	− 18.6	13.8	3.3	Central	Lightfoot et al., 2015'
KZ048	Tashik	Kurgan 8, grave 4	EBA	Clavicle	− 18.5	13.3	3.2	Central	Lightfoot et al., 2015'
KZ049	Tashik	Kurgan 3, grave 1	EBA	Femur	− 18.5	13	3.2	Central	Lightfoot et al., 2015'
KZ067	Tashik	Kurgan 10, grave 4	EBA	Mandible	− 18.2	13.6	3.3	Central	Lightfoot et al., 2015'
KZ068	Tashik	Kurgan 7	EBA	Pelvis	− 18.9	12.7	3.3	Central	Lightfoot et al., 2015'
KZ069	Tashik	Kurgan 10, grave 5	EBA	Crania	− 18.1	14.7	3.2	Central	Lightfoot et al., 2015'
KZ070	Tashik	Kurgan 10, grave 1	EBA	Colar bone?	− 18.3	14	3.2	Central	Lightfoot et al., 2015'
KZ071	Tashik	Kurgan 10, grave 5	EBA	Pelvis	− 18.2	14.9	3.3	Central	Lightfoot et al., 2015'
KZ072	Tashik	Kurgan 7, grave 1	EBA	Pelvis	− 18.7	12.6	3.2	Central	Lightfoot et al., 2015'
KZ073	Tashik	Kurgan 10, grave 5	EBA	Humerus	− 18.2	13.1	3.2	Central	Lightfoot et al., 2015'
KZ088	Tashik	Kurgan 12	EBA	Crania	− 18.7	12.9	3.2	Central	Lightfoot et al., 2015'
KZ089	Tashik	Kurgan 17, grave 1	EBA	Crania	− 18	12.9	3.3	Central	Lightfoot et al., 2015'
KZ090	Tashik	Kurgan 5, grave 1	EBA	Mandible	− 18.3	12.5	3.3	Central	Lightfoot et al., 2015'
KZ050	Aschisu	Kurgan 5, grave 1	EBA-MBA	Crania	− 18.9	12.4	3.2	Central	Lightfoot et al., 2015'
KZ052	Aschisu	Kurgan 1, grave 1	EBA-MBA	Rib	− 17.2	14.2	3.3	Central	Lightfoot et al., 2015'
KZ054	Aschisu	Kurgan 1, grave 2	EBA-MBA	Rib	− 18.7	11.9	3.2	Central	Lightfoot et al., 2015'
KZ055	Aschisu	Kurgan 1, grave1	EBA-MBA	Rib	− 18.6	11.7	3.2	Central	Lightfoot et al., 2015'
KZ056	Aschisu	Kurgan 2, grave 1	EBA-MBA	Humerus	− 19.1	11.5	3.2	Central	Lightfoot et al., 2015'

KZ057	Aschisu	Kurgan 5, grave 2	EBA-MBA	Rib	− 18.4	12.8	3.2	Central	Lightfoot et al., 2015'
KZ058	Aschisu	Kurgan 1, grave 1	EBA-MBA	Rib	− 18.8	11.7	3.2	Central	Lightfoot et al., 2015'
KZ059	Aschisu	Kurgan 2, grave 1	EBA-MBA	Rib	− 18.4	12.5	3.2	Central	Lightfoot et al., 2015'
KZ076	Aschisu		EBA-MBA	Rib	− 17.8	13.6	3.2	Central	Lightfoot et al., 2015'
KZ051	Ayapbergen	Kurgan 1, grave 2	EBA-MBA	Rib	− 18.5	12.3	3.2	Central	Lightfoot et al., 2015'
KZ053	Tasyrbai	Kurgan 10, grave 1	FBA	Vertebra	− 15.7	17.7	3.2	Central	Lightfoot et al., 2015'
KZ066	Tasyrbai	Kurgan 13	FBA	Crania	− 18.6	11.4	3.3	Central	Lightfoot et al., 2015'
KZ061	Kopa-I	Grave 1	EBA-MBA	Crania	− 18.3	12.5	3.3	Central	Lightfoot et al., 2015'
KZ062	Akimbek	Grave 4	EBA-MBA	Rib	− 18.4	14.4	3.2	Central	Lightfoot et al., 2015'
KZ063	Akimbek	Kurgan 1	EBA-MBA	Femur	− 18.1	14.1	3.2	Central	Lightfoot et al., 2015'
KZ064	Akimbek	Kurgan 1, grave 1	EBA-MBA	Femur	− 18.2	13.3	3.2	Central	Lightfoot et al., 2015'
KZ065	Akimbek	Kurgan 2, grave 1	EBA-MBA	Femur	− 18.4	12.9	3.2	Central	Lightfoot et al., 2015'
KZ087	Akimbek	Kurgan 5, grave 1	EBA-MBA	Crania	− 18.5	15.5	3.3	Central	Lightfoot et al., 2015'
KZ075	Kudryavaya Sopka-1	Kurgan 1, grave 2	FBA	Femur	− 18.1	15.3	3.2	Central	Lightfoot et al., 2015'
KZ085	Kudryavaya Sopka-1	Kurgan 1, grave 1	FBA	Crania	− 18.4	15.7	3.3	Central	Lightfoot et al., 2015'
KZ077	Kyzylkol	Kurgan 1, grave 9	EBA-MBA	Rib	− 18.2	14	3.2	Central	Lightfoot et al., 2015'
KZ078	Kyzylkol	Kurgan 1, grave 8	EBA-MBA	Rib	− 18.3	13.8	3.2	Central	Lightfoot et al., 2015'
KZ079	Kyzylkol	Kurgan 1, grave 6	EBA-MBA	Rib	− 18.9	13.1	3.4	Central	Lightfoot et al., 2015'
KZ080	Kyzylkol	Kurgan 1, grave 5	EBA-MBA	Rib	− 18.4	15.1	3.3	Central	Lightfoot et al., 2015'
KZ081	Kyzylkol	Kurgan 1, grave 4	EBA-MBA	Rib	− 18.8	13.4	3.2	Central	Lightfoot et al., 2015'
KZ082	Kyzylkol	Kurgan 1, grave 3	EBA-MBA	Rib	− 18.9	13	3.3	Central	Lightfoot et al., 2015'
KZ083	Kyzylkol	Kurgan 1, grave 2	EBA-MBA	Rib	− 19.2	13.2	3.3	Central	Lightfoot et al., 2015'
KZ084	Kyzylkol	Kurgan 1, grave 1	EBA-MBA	Long bone	− 18.4	14.4	3.3	Central	Lightfoot et al., 2015'
KZ092	Kyzyl	Kurgan 8	FBA	Mandible	− 16.8	13	3.2	Central	Lightfoot et al., 2015'
KZ093	Temirkash	Kurgan 4	FBA	Crania	− 18.8	12.7	3.2	Central	Lightfoot et al., 2015'
KZ094	Temirkash	Kurgan 9	FBA	Crania	− 17.6	13.3	3.2	Central	Lightfoot et al., 2015'
KZ096	Karatugai	Kurgan 5	FBA	Crania	− 18.4	12.8	3.3	Central	Lightfoot et al., 2015'
KZ097	Karatugai	Kurgan 1	FBA	Crania	− 17.7	14	3.2	Central	Lightfoot et al., 2015'
KZ098	Karatugai	Kurgan 10	FBA	Mandible	− 17.8	13.9	3.2	Central	Lightfoot et al., 2015'
KZ099	Karatugai	Kurgan 6	FBA	Crania	− 18.1	14.3	3.2	Central	Lightfoot et al., 2015'
KZ100	Karatugai	Kurgan 8	FBA	Mandible	− 18.8	12.7	3.2	Central	Lightfoot et al., 2015'
KZ101	Zhartas		EIA	Mandible	− 18.6	14.5	3.2	Central	Lightfoot et al., 2015'
KZ102	Kairakty		EBA-MBA	Crania	− 19	11.6	3.2	Central	Lightfoot et al., 2015'
KZ104	Kent		FBA	Femur	− 16	13.5	3.3	Central	Lightfoot et al., 2015'
UBA-2367-2	Akbeit	Kurgan 1	EIA		− 15.7	16.2	3.3	Central	Svyatko and Beisenov, 2017'
UBA-2367-0	Akbeit	Kurgan 2	EIA		− 17.7	15	3.3	Central	Svyatko and Beisenov, 2017'
UBA-2835-1	Akbeit	Kurgan 7	EIA		− 17.3	15.4	3.2	Central	Svyatko and Beisenov, 2017'

UBA-2836-6	Bakybulak	Kurgan 2	EIA	− 18.2	15	3.2	Central	Svyatko and Beisenov, 2017'
UBA-2834-4	Bakybulak	Kurgan 14	EIA	− 19.1	14.5	3.1	Central	Svyatko and Beisenov, 2017
UBA-2366-6	Bakybulak	Kurgan 15	EIA	− 17.1	15.8	3.2	Central	Svyatko and Beisenov, 2017'
UBA-2834-5	Bektauata	Kurgan 1	EIA	− 17.2	16.6	3.2	Central	Svyatko and Beisenov, 2017'
UBA-2835-2	Birlik	Kurgan 15	EIA	− 18.6	14.1	3.2	Central	Svyatko and Beisenov, 2017'
UBA-2835-3	Birlik	Kurgan 29	EIA	− 17.5	14	3.2	Central	Svyatko and Beisenov, 2017'
UBA-2491-8	Complex «37 voinov»	Kurgan 11	EIA	− 18.4	15.5	3.1	Central	Svyatko and Beisenov, 2017'
UBA-2367-4	Karashoky	Kurgan 1	EIA	− 16	16.9	3.2	Central	Svyatko and Beisenov, 2017'
UBA-2367-1	Karashoky	Kurgan 8	EIA	− 17.6	15.4	3.3	Central	Svyatko and Beisenov, 2017'
UBA-2366-8	Karashoky-6	Kurgan 1	EIA	− 17.7	15.1	3.2	Central	Svyatko and Beisenov, 2017'
UBA-2366-4	Koitas		EIA	− 14.1	14.3	3.2	Central	Svyatko and Beisenov, 2017'
UBA-2491-7	Kosoba	Kurgan 2	EIA	− 18.5	13.6	3.1	Central	Svyatko and Beisenov, 2017'
UBA-2547-4	Kyzyl	Kurgan 3, left burial	EIA	− 18.9	13.7	3.1	Central	Svyatko and Beisenov, 2017'
UBA-2834-6	Kyzylkoi	Kurgan 1	EIA	− 18	15.9	3.3	Central	Svyatko and Beisenov, 2017'
UBA-2491-6	Kyzylshilik	Kurgan 2	EIA	− 18.2	13.1	3.1	Central	Svyatko and Beisenov, 2017'
UBA-2835-0	Kyzylshilik	Kurgan 8	EIA	− 19.2	14	3.2	Central	Svyatko and Beisenov, 2017'
UBA-2366-5	Nazar-2	Kurgan 1	EIA	− 18.7	13.9	3.2	Central	Svyatko and Beisenov, 2017'
UBA-2366-9	Nazar-2	Kurgan 2	EIA	− 18.4	14.1	3.2	Central	Svyatko and Beisenov, 2017'
UBA-2834-3	Nurken-2	Kurgan 1, lower skeleton	EIA	− 17.3	14.5	3.2	Central	Svyatko and Beisenov, 2017'
UBA-2366-7	Taldy-2	Kurgan 2	EIA	− 14.5	15.2	3.3	Central	Svyatko and Beisenov, 2017'
UBA-2834-7	Tandaily-2	Kurgan 2	EIA	− 18.7	13.3	3.2	Central	Svyatko and Beisenov, 2017'
UBA-2367-3	Taisoigan	Kurgan 3	EIA	− 18.2	13.3	3.2	Central	Svyatko and Beisenov, 2017'

UBA-2834-9	Kurgan Zhamantas	EIA		− 18.9	13.7	3.2	Central	Svyatko and Beisenov, 2017'

BA - Bronze Age, EBA - Early Bronze Age, MBA - Middle Bronze Age, LBA - Late Bronze Age, FBA - Final Bronze Age; IA - Iron Age, EIA - Early Iron Age.

Appendix B

Sample ID	Site	Period	Specie	δ^{13}C‰	δ^{15}N‰	C/N atomic	Region	Source
LT-KZ-56	Tobolskyi	EIA	Horse	− 21.28	4.31	3.3	Northern	This study
LT-KZ-57	Tobolskyi	EIA	Caprine	− 19.72	9.15	3.6	Northern	This study
LT-KZ-60	Akbeit	EIA	Cattle	− 19.85	7.97	3.6	Central	This study
LT-KZ-62	Akbeit	EIA	Caprine	− 18.64	10.54	3.2	Central	This study
LT-KZ-63	Akbeit	EIA	Caprine	− 19.94	7.83	3.5	Central	This study
LT-KZ-64	Akbeit	EIA	Caprine	− 18.95	10.20	3.3	Central	This study
LT-KZ-65	Akbeit	EIA	Horse	− 20.82	5.31	3.5	Central	This study
LT-KZ-66	Akbeit	EIA	Caprine	− 20.36	6.74	3.3	Central	This study
LT-KZ-67	Kyzylsuir 2	EIA	Cattle	− 20.51	6.91	3.3	Central	This study
LT-KZ-68	Kyzylsuir 2	EIA	Cattle	− 19.46	7.80	3.3	Central	This study
LT-KZ-69	Kyzylsuir 2	EIA	Cattle	− 20.00	9.50	3.3	Central	This study
LT-KZ-70	Kyzylsuir 2	EIA	Cattle	− 20.32	8.27	3.3	Central	This study
LT-KZ-71	Kyzylsuir 2	EIA	Cattle	− 19.91	8.57	3.3	Central	This study
LT-KZ-73	Kyzylsuir 2	EIA	Cattle	− 20.15	7.84	3.3	Central	This study
LT-KZ-74	Abylai	EIA	Caprine	− 19.40	8.69	3.4	Central	This study
LT-KZ-75	Abylai	EIA	Horse	− 21.23	7.07	3.5	Central	This study
LT-KZ-76	Karashoky	EIA	Caprine	− 19.16	8.21	3.3	Central	This study
LT-KZ-77	Karashoky	EIA	Caprine	− 19.66	9.04	3.3	Central	This study
LT-KZ-78	Okule 5	EIA	Caprine	− 20.92	7.38	3.4	Central	This study
LT-KZ-79	Dongal	FBA	Cattle	− 20.17	8.27	3.5	Central	This study
LT-KZ-80	Kent	FBA	Cattle	− 20.25	7.03	3.4	Central	This study
LT-KZ-81	Kent	FBA		− 19.77	7.59	3.4	Central	This study
LT-KZ-82	Kent	FBA	Cattle	− 19.77	10.05	3.4	Central	This study
LT-KZ-83	Karatobe	EIA	Caprine	− 19.04	10.33	3.3	Eastern	This study
	Temirlanovka	EIA	Caprine	− 18.9	9.6	3.2	Southern	Motuzaite Matuzeviciute et al., 2015'
	Karatuma	EIA	Caprine	− 16.71	10.7	3.32	Southern	Motuzaite Matuzeviciute et al., 2015'
	Karatuma	EIA	Caprine	− 16.77	10.67	3.31	Southern	Motuzaite Matuzeviciute et al., 2015'
	Kainar Bulak-1	EIA	Caprine	− 19.27	9.27	3.12	Southern	Motuzaite Matuzeviciute et al., 2015'
	Kainar Bulak-1	EIA	Caprine	− 19.09	7.08	3.13	Southern	Motuzaite Matuzeviciute et al., 2015'
	Kainar Bulak-1	EIA	Caprine	− 18.7	7.06	3.11	Southern	Motuzaite Matuzeviciute et al., 2015'
	Kainar Bulak-1	EIA	Caprine	− 19.5	6.96	3.2	Southern	Motuzaite Matuzeviciute et al., 2015'
	Kainar Bulak-1	EIA	Caprine	− 19.74	7.65	3.14	Southern	Motuzaite Matuzeviciute et al., 2015'
	Kainar Bulak-1	EIA	Caprine	− 20.43	5.48	3.35	Southern	Motuzaite Matuzeviciute et al., 2015'
	Kainar Bulak-1	EIA	Caprine	− 19.06	6.93	3.35	Southern	Motuzaite Matuzeviciute et al., 2015'
	Kainar Bulak-1	EIA	Caprine	− 19.03	9.7	3.5	Southern	Motuzaite Matuzeviciute et al., 2015'
	Kainar Bulak-1	EIA	Caprine	− 19.15	7.59	3.34	Southern	Motuzaite Matuzeviciute et al., 2015'
	Kainar Bulak-1	EIA	Caprine	− 18.42	8.89	3.09	Southern	Motuzaite Matuzeviciute et al., 2015'
	Kainar Bulak-1	EIA	Caprine	− 18.53	7.64	3.14	Southern	Motuzaite Matuzeviciute et al., 2015'
	Karatuma	EIA	Cattle	− 17	9.9	3.31	Southern	Motuzaite Matuzeviciute et al., 2015'
	Kanar Bulak-1	EIA	Cattle	− 19.72	6.98	3.55	Southern	Motuzaite Matuzeviciute et al., 2015'
	Kanar Bulak-1	EIA	Cattle	− 18.96	8.62	3.35	Southern	Motuzaite Matuzeviciute et al., 2015'
	Kanar Bulak-1	EIA	Cattle	− 18.06	7.87	3.38	Southern	Motuzaite Matuzeviciute et al., 2015'
	Kanar Bulak-1	EIA	Cattle	− 18.1	8.8	3.37	Southern	Motuzaite Matuzeviciute et al., 2015'
	Kainar Bulak-1	EIA	Horse	− 20.66	4.45	3.33	Southern	Motuzaite Matuzeviciute et al., 2015'
	Kainar Bulak-1	EIA	Horse	− 17.98	8.45	3.53	Southern	Motuzaite Matuzeviciute et al., 2015'
	Kainar Bulak-1	EIA	Horse	− 20.08	6.14	3.14	Southern	Motuzaite Matuzeviciute et al., 2015'
	Kainar Bulak-1	EIA	Horse	− 18.9	7.89	3.54	Southern	Motuzaite Matuzeviciute et al., 2015'
KZF05	Temirkash	LBA	Herbivore	− 18.8	8.7	3.1	Central	Lightfoot et al., 2015'
KZF06	Temirkash	LBA	Herbivore	− 20.4	4.8	3.2	Central	Lightfoot et al., 2015'
KZF06B	Temirkash	LBA	Herbivore	− 19.2	7.7	3.2	Central	Lightfoot et al., 2015'
KZF07	Temirkash	LBA	Herbivore	− 18.6	8.6	3.2	Central	Lightfoot et al., 2015'
KZF09	Temirkash	LBA	Herbivore	− 20.4	5.9	3.2	Central	Lightfoot et al., 2015'
KZF10	Temirkash	LBA	Herbivore	− 18.6	7.8	3.1	Central	Lightfoot et al., 2015'
KZF11	Temirkash	LBA	Herbivore	− 18.9	8.8	3.2	Central	Lightfoot et al., 2015'
KZF13	Temirkash	LBA	Herbivore	− 19.7	6.2	3.3	Central	Lightfoot et al., 2015'

KZF14	Temirkash	LBA	Herbivore	− 19.3	8.2	3.2	Central	Lightfoot et al., 2015'
KZF14B	Temirkash	LBA	Herbivore	− 18.8	6.9	3.2	Central	Lightfoot et al., 2015'
KZF15	Temirkash	LBA	Herbivore	− 19.6	7.6	3.1	Central	Lightfoot et al., 2015'
KZF16	Temirkash	LBA	Herbivore	− 19.1	6.3	3.1	Central	Lightfoot et al., 2015'
KZF17	Temirkash	LBA	Herbivore	− 18.8	6.3	3.2	Central	Lightfoot et al., 2015'
KZF18	Temirkash	LBA	Herbivore	− 19.4	8.3	3.2	Central	Lightfoot et al., 2015'
KZF19	Temirkash	LBA	Herbivore	− 18.4	7.5	3.1	Central	Lightfoot et al., 2015'
KZF20	Temirkash	LBA	Herbivore	− 18.8	7.1	3.2	Central	Lightfoot et al., 2015'
KZF21	Temirkash	LBA	Herbivore	− 20.6	5.7	3.2	Central	Lightfoot et al., 2015'
KZF22	Temirkash	LBA	Herbivore	− 19.4	6.9	3.2	Central	Lightfoot et al., 2015'
KZF23	Temirkash	LBA	Herbivore	− 18.8	6.1	3.2	Central	Lightfoot et al., 2015'
KZF24	Temirkash	LBA	Herbivore	− 20.3	6.1	3.2	Central	Lightfoot et al., 2015'
UBA-23677	Tagybaibulak	EIA		− 19.1	8.5	3.2	Central	Svyatko and Beisenov, 2017
UBA-24915	Kyzylshilik, k. 2	EIA		− 19.6	13.4	3.1	Central	Svyatko and Beisenov, 2017

BA - Bronze Age, EBA - Early Bronze Age, MBA - Middle Bronze Age, LBA - Late Bronze Age, FBA - Final Bronze Age; IA - Iron Age, EIA - Early Iron Age.

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