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Mobility of nomads in Central Asia: Chronology and $^{87}Sr/^{86}Sr$ isotope evidence from the Pazyryk barrows of Northern Altai, Russia

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ABSTRACT

In this study we report the first $^{87}Sr/^{86}Sr$ isotopic data and mobility analyses of the Pazyryk culture in Central Asia. Throughout prehistory the Altai Mountains represent a unique cultural frontier characterised by a perpetual state of transition, resulting from highly mobile nomadic inhabitants. We analysed human skeletal remains from barrows in the Manzherok region of the Altai Republic, Russian Federation. The analysis was based on 160 measurements of $^{87}Sr/^{86}Sr$ from Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS) and Thermal Ionisation Mass Spectrometry (TIMS), in tandem with environmental samples and comparative animal material.

The combined dating evidence and strontium isotopic values indicate that after the 5th century BC, residential mobility amongst Altaic nomads is rising, especially long-distance female mobility, leading to contact acquisition with extrinsic territories of Central Asia. The $^{87}Sr/^{86}Sr$ isotopic evidence from Manzherok suggests that members of the Altaic population might have been buried in Scythian tombs located in Tuva and Khakassia, most notably in the Arzhan barrows.

1. Introduction

The Pazyryk populations inhabiting Altai from the 6th-3rd century BC represent a broader Iron Age Scytho-Siberian model of culture, which incorporates several archaeological cultures in southern Siberia and adjacent territories of the Altai Mountains (Map 1). The most distinctive features of the Pazyryk socio-economic model were ecological flexibility, mixed agriculture linked to transhumance, with an advanced textile, dye and leather production. Certain practices such as mummification, the use of narcotics and tattooing, are linked to this culture (Rudenko, 1948; Barkova and Pankova, 2005; Yablonsky, 2011). Archaeological evidence from both urbanised fortifications and rural settlements of the Altai region during the Scythian period, indicates intense horse riding and sheep farming activity. The ongoing debate regarding the Pazyryk culture focuses on three prominent points of contention: the formation and early development of the Pazyryk society, ethnic identification, and chronology (Kubarev and Shulga, 2007). Based on comparative methods, the majority of Pazyryk barrows were dated to the latter half of the 5th century BC (Rudenko, 1960; Marsadolov, 1996). However, newer data (Zaytseva et al., 2005; Mallory et al., 2002) demonstrates that Pazyryk cultural traditions most likely lasted much longer than previously thought. For instance, all five royal tombs at the Pazyryk eponymic site were erected between 300 and 250 cal BC.

The scale of social cohesion among nomadic populations during the Iron Age remains ambiguous due to the extent of regional diversification (Map 1). The main cultural centres were located in the mountainous central Altai. The Pazyryk burial grounds usually feature a chain of kurgans stretching from the north to the south. Large barrow cemeteries with lavishly furnished tombs were uncovered in Pazyryk, Bashadar, and Tuekta, as well as in ice vaults on the Ukok Plateau. The northern Pazyryk territory, however, seems to display a distinct local identity, relating to the steppe of southwestern Siberia (Kireev, 1992; Polosmak and Molodin, 2000). Here the multi-phase use of fortified settlements, such as Barangol or Manzherok, is typical (Kireev et al., 2008). Assessing the role that rearing livestock (cattle and horses) played in Scythian domesticity is fundamental to the understanding of hybrid economic models in the Altai region. The Pazyryk communities from central mountainous plateau during the classic phase (mid-6th - 3rd century BC), represent a purely mobile, pastoral society; while

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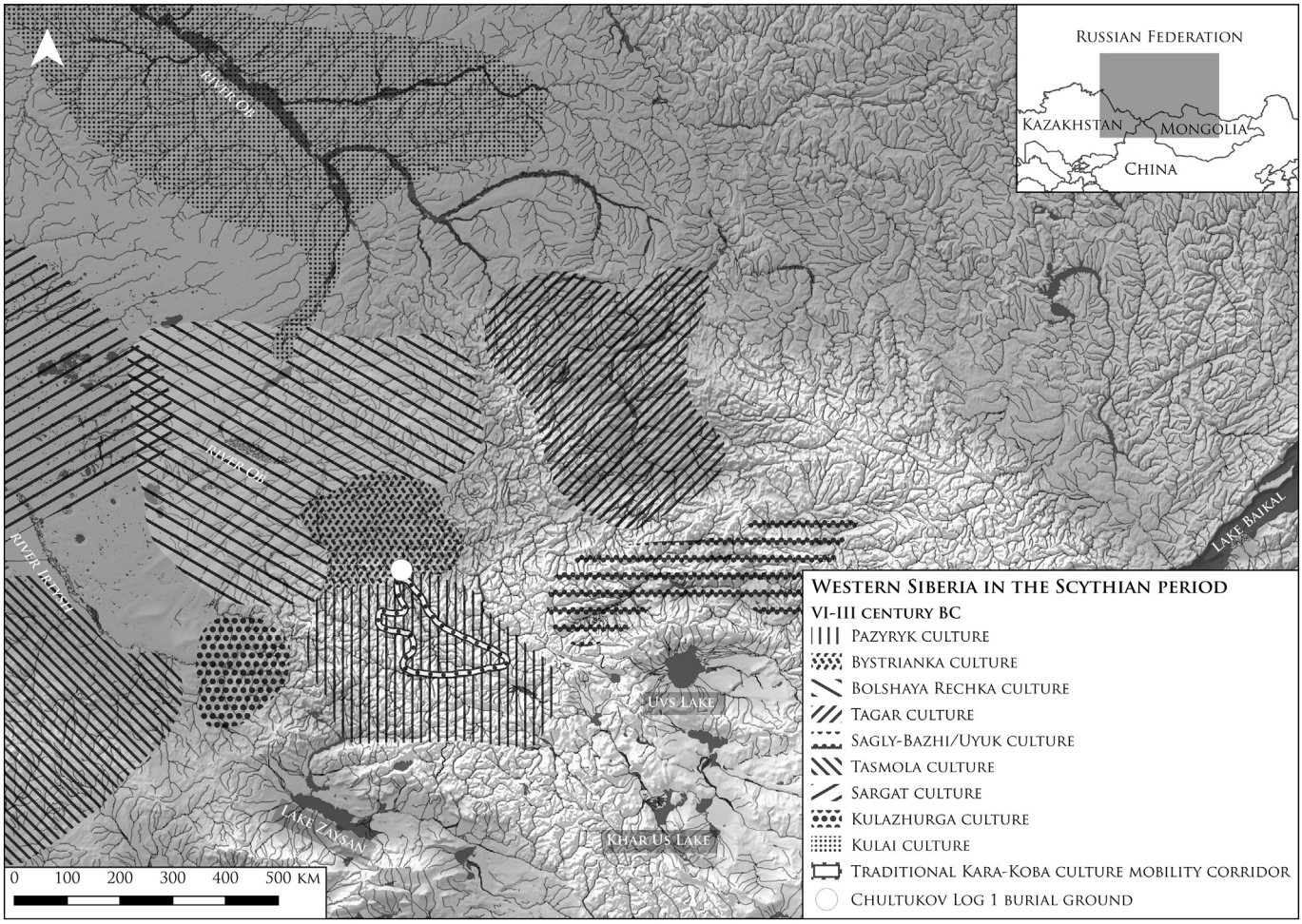


Map 1. Archaeological cultures of Southern Siberia in the Scythian period (8th-3rd century BC).

concurrently, people in northern territories practiced agricultural sedentism. Both anthropological and archaeological evidence (e.g. querns with grinding stones) confirm the prominent role of agriculture in these northern territories during in the Iron Age (Oleszczak et al., 2017; Borodovsky and Tur, 2015).

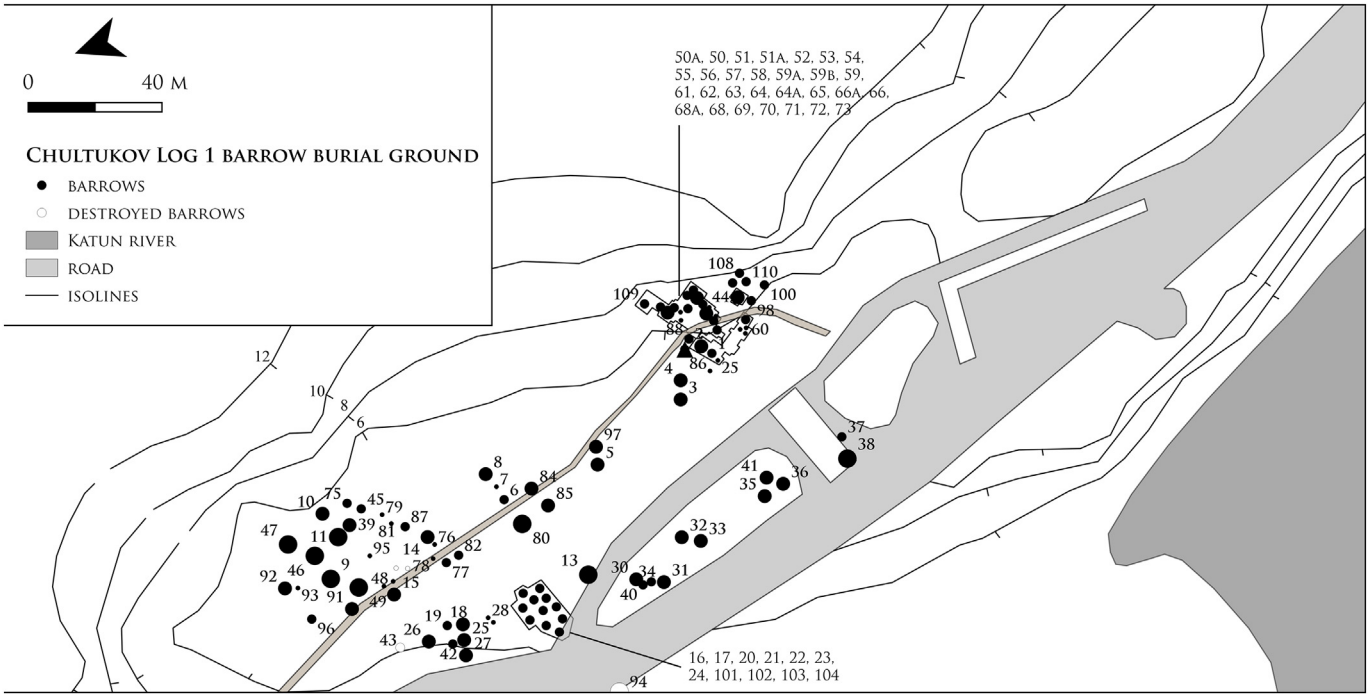
The Manzherok settlement, with the adjacent Chultukov Log 1 cemetery, is located at the foot of the Cherepan Mountain in the northern part of the Altai Republic (Soyonov et al., 2016; Borodovskiy et al., 2017). The spatial distribution of monuments in the surrounding landscape of Chultukov Log 1 shows several interesting patterns; barrows are situated in binary pairs, clusters, or along a linear N-S alignment (Map 2). Several types of barrows and forms of interment have been identified, including flat graves with stone sarcophagi. The size of the barrows varies greatly, with diameters ranging from 4 to 13 m. The majority of tombs can be linked to the Pazyryk culture (northern variant), although the Kara Koba and Bystrianka cultures are present also (Oleszczak, 2017). Some later monuments are associated with the Hunnic Maima culture, dating from the 2nd century BC onwards.

In this study we focus on mobility patterns among sub-adults. Premolars were used in $^{87}Sr/^{86}Sr$ analysis, extracted from adult individuals. Despite the differences amongst populations, dental formation is genetically driven and less influenced by environmental factors than other growth-related characteristics. For premolars, various authors indicate that the crown formation is complete around the age of 6–8 (Moorrees et al., 1963; Gustafson and Koch, 1974; Smith, 1991; Ubelaker, 1999). Small differences relating to population background and the upper/down maxillary position can be included within the 6 ± 1.5 year margin. Mobility-related aspects of childhood have not been studied so far in nomadic groups from prehistoric Central Asia. During this period biological development and social identities undergo substantial changes. Therefore, we focused on how mobility was linked to tribal identity transitions associated with childhood and inter-generational transmission of culture.

2. The site: Chultukov Log 1 barrow burial ground

The Chultukov Log cemetery, located in close proximity to the Manzherok fortified settlement, is so far considered to be the biggest nomadic burial ground found in the Upper Altai and Sayan Mountains. It is comprised of 123 barrows and flat inhumations (Borodovskiy and Borodovskaya, 2013; Map 2; Fig. 1). The chronological sequence of the burials covers 1100 years, spanning the 7th century BC - 4th century AD. The cemetery is associated with three archaeological cultures, which represent distinct nomadic ethnic groups: the Pazyryk culture (7th-3rd century BC), the Bystrianka culture, and the Kara Koba culture (6th-3rd century BC). The final chronological phase was associated with an abrupt cultural change, coinciding with the arrival of the Huns and the Maima culture (2nd century BC- 5th century AD). The Pazyryk burial tradition dictated that the body was oriented SE-NW, with the head placed at the SE. This is contrasted by neighbouring cultures where a N-S alignment is prevalent (Fig. 2.2; 3.1; Fig. 3.2). The barrows were circular in shape and relatively flat (0.2–0.3 m high). The main chamber was typically located in the middle of a large circle built of irregular boulders (Gryaznov, 1969; Sulimirski, 1970; Kubarev and Shulga, 2007).

The human remains found in the barrows only accounts for a



Map 2. Chultukov Log cemetery, Manzherok region, Altai, Russia. After Borodovskiy and Borodovskaya, 2013 with modifications.

fraction of the individuals present. The burials of commoners in Altai are absent, and it is likely that the evidence present does not reflect the rites afforded to the majority of the dead, remaining invisible in the archaeological record. The diversity of burial rites and cultural traditions covers the whole range of atypical interments. According to Stepanova (2003) approximately 13% of Scythian burials were placed in stone cists, and these flat graves were usually interspersed with typical Pazyryk graves, but are representative of the Kara Koba burial tradition (Map 1; Surazakov, 1983). There is ongoing debate as to whether the so-called Kara Koba inhumations are indicative of a specific chronological phase or, potentially, a discrete idiosyncratic group within a local nomadic community (Borodovskiy and Oleszczak, 2016). During the Scythian period, the Northern Altai represents a cultural borderland that served as an integration platform for societies, linking the mountains with the steppe zone of southern Siberia. The graves of the Bystrianka culture, within the Pazyryk burial grounds, indicate extensive contact with Siberian populations. The Chultukov Log cemetery is the southernmost site where Bystrianka burials are found in the region (Borodovskiy and Borodovskaya, 2013; Fig. 2.1).

2.1. Theoretical model of nomadic mobility

Movement is a time-space process, and in a world of perpetual mobility, terms such as *local* or *non-local* have a looser meaning. The first theory of mobility was formulated in 1885 by a British geographer, E.G. Ravenstein, and it is called Ravenstein's Laws (Ravenstein 1885; Ravenstein, 1889). The first of Ravenstein's laws states that the migration flow volume is the reverse function of the distance. Migration consists of stages which are directed towards centres of higher development, e.g. rural to urban migration. According to Ravenstein, each migration flow generates a corresponding counter-flow, and women constitute the majority of short distance migrants. The sixth law refers to the relationship between mobility and technology; that technological changes often play an important role in the displacement of human groups. The final, seventh law of Ravenstein, claims that human mobility is favoured by all negative aspects of living, e.g. wars, high taxes, or climate (Ravenstein, 1889; cf. Stewart, 1942; Zipf, 1946; White, 2016). In the last 30 years however, significant progress has been made in the study of human mobility, including differences in migration and mobility to geographies of power, spatial scale, home-occupation relationships, and the links between place and identity (e.g., Chant and Radcliffe, 1992; Silvey, 2006). Samers (2010) differentiates between various migrant-types: short distance, long-journey, and temporary migrants.

To reveal universal dynamics of the nomadic environment, we have to consider three basic dimensions of movement: *when* (temporal dimension), *where* (spatial dimension), and *how fast* (speed of migration). Nomadic groups understand space and territoriality differently to most agrarian societies. Space is a common property and it is not privately appropriated, with anyone allowed to use the resource. Such models of occupation and territory are strongly decentralised. In semi-arid and montane areas human mobility is shaped by available resources in annual seasonal cycles, such as foraging potential, or pasture and water access. Therefore, the interpretation of permanence at Scythian sites is frequently hampered by the difficulty of correlating sedentary or mobile behaviour with specific material culture traits. Often, the archaeological record from sites in Siberia, Altai, or northern China, comprises evidence for trade, settlement and behaviour, and at times also provides conflicting signals for a sedentary, semi-sedentary (transhumance), or non-sedentary occupation (Gryaznov, 1969). Taking under consideration culture-specific theoretical preconditions, this study was designed to address two key factors of nomadic mobility, the spatial and chronological. The Chultukov Log cemetery is located at the entrance to the ancient trade route, the so-called *Chuysky Trakt*, a grand highway running through the most remote wilderness of the Altai Mountains, linking Siberia with Mongolia. This route has attracted various nomadic populations, and an ancient 1000 km communication corridor creates an excellent opportunity to study prehistoric mobility (Map 3).

3. Methods and materials

3.1. Sampling strategy and decontamination

Human dental enamel is deposited incrementally in growth layers called striae of Retzius. In the lateral and cervical region of a tooth, these growth layers emerge at the surface as perikymata. The number of

Fig. 1. a-b. Katun River Valley and Manzherok, c- Chultukov Log during excavations, Altai Republic, Russia. Photo by A. Borodovskiy.

Fig. 2. Chultukov Log cemetery: 1) barrow 53, adult male, Bystrianka culture; 2) multiple inhumations in barrow 47, Pazyryk culture. Photo by A. Borodovskiy.

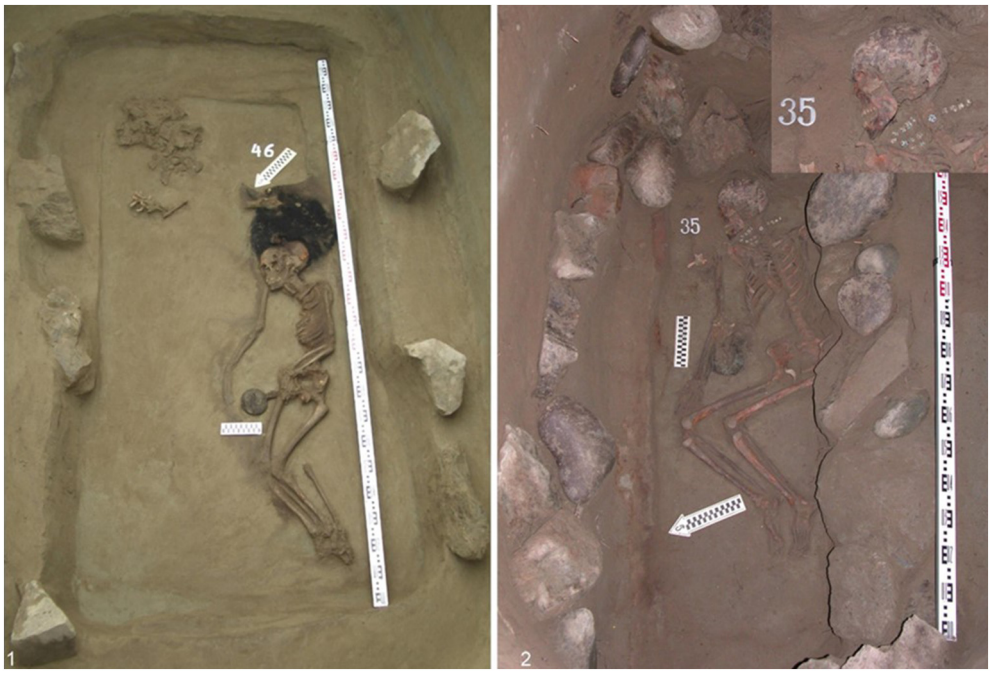


Fig. 3. Chultukov Log cemetery: 1) female with wig and bronze mirror in barrow 46, Pazyryk culture; 2) female with necklace in barrow 35; the necklace is foreign import possibly from the Near East or Egypt. Photo by A. Borodovskiy.

days represented by each *stria* is known as its periodicity, defined as the number of daily growth increments (cross-striations) that occur between adjacent striae. Periodicity varies amongst individuals in a population, but is consistent within an individual's dentition (Mann et al., 1991; Smith et al., 2007). The perikymata geometrically represents closed circles, which form in clearly defined time intervals of days and weeks (Guatelli-Steinberg and Reid, 2008).

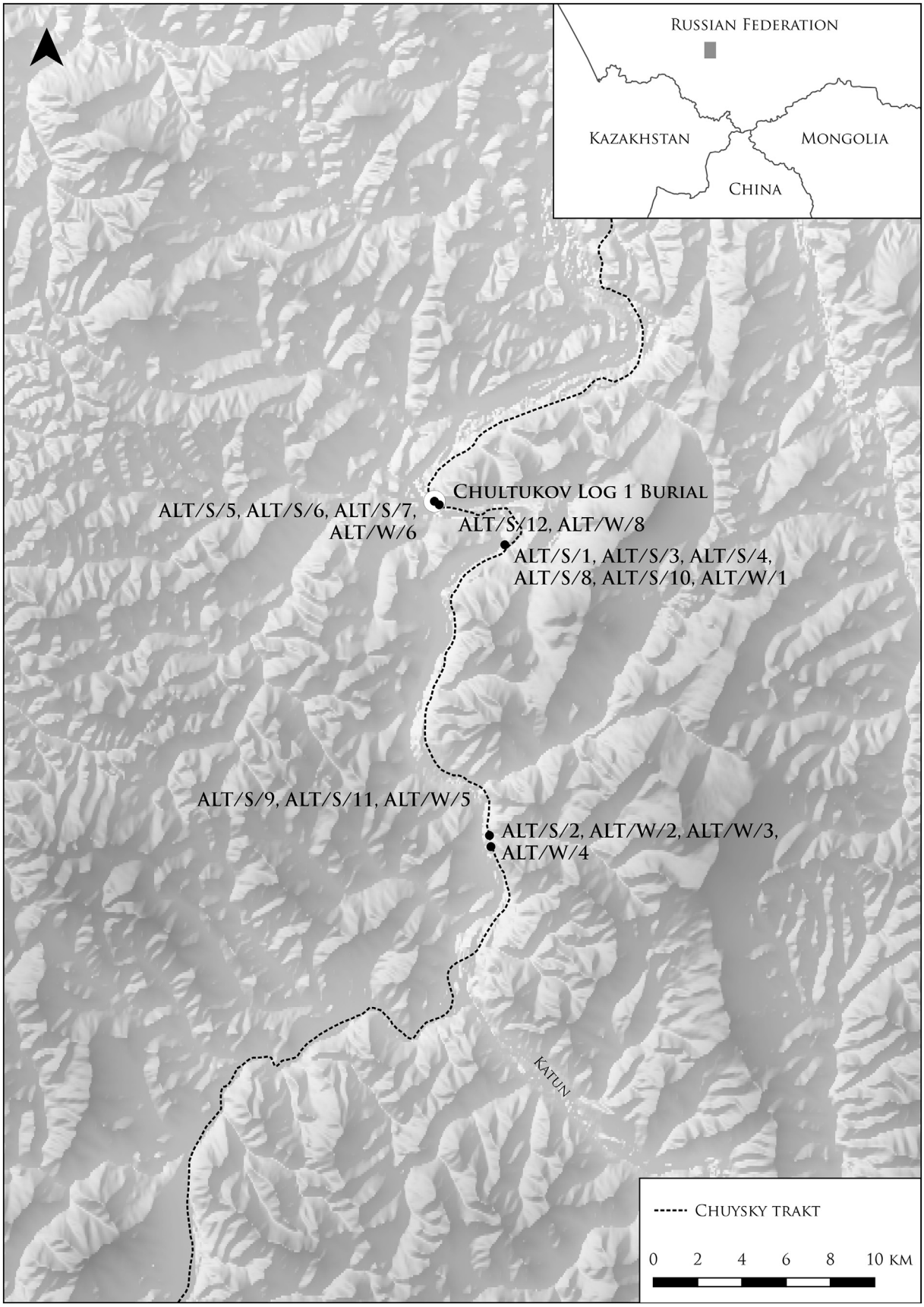
The preservation of dental material ranged from moderate to poor based on the Brabant index (grade 3, type1; Brabant and Sally, 1962; stages 3–6 of microwear according to Hillson, 1996). The deposition in the ground had resulted in patchy stripes of erosion in the dental surface, occasional decalcification, as well as vertical cracking of the enamel. Obtaining high quality measurements required the samples to be decontaminated, involving the complete removal of dental calculus, necrotic tissue, organic debris, and soil. The aim was to expose perikymata lines to better identify the chronological indicators for given individuals. For in-depth decontamination, a clinical irrigation procedure was applied using NaOCl (5.25%) and EDTA (17%, Merck®) at a temperature of 60 °C in accordance with Castagnola et al. (2014). During pre-ablation scanning, the fragments of enamel surface affected by any pathological changes were omitted.

The size of teeth varied depending on the individual levels of microwear and preservation. Laser pre-ablation scanning targeted perikymata layers observable on the dental surface under the microscope and $^{87}Sr/^{86}Sr$ values were collected along these lines, in enamel buccal surfaces running from tip to cervix. The number of ablation lines for human samples ranged from 13 to 20, flexibly adjusting to the size of the tooth. On average we measured $^{87}Sr/^{86}Sr$ isotopic signals of 16 points, representing approximately 3 months each. For baselines we used environmental standards representing local fauna, waters and soils from archaeological settlement zones in Manzherok (Maps 3–4; Table 2).

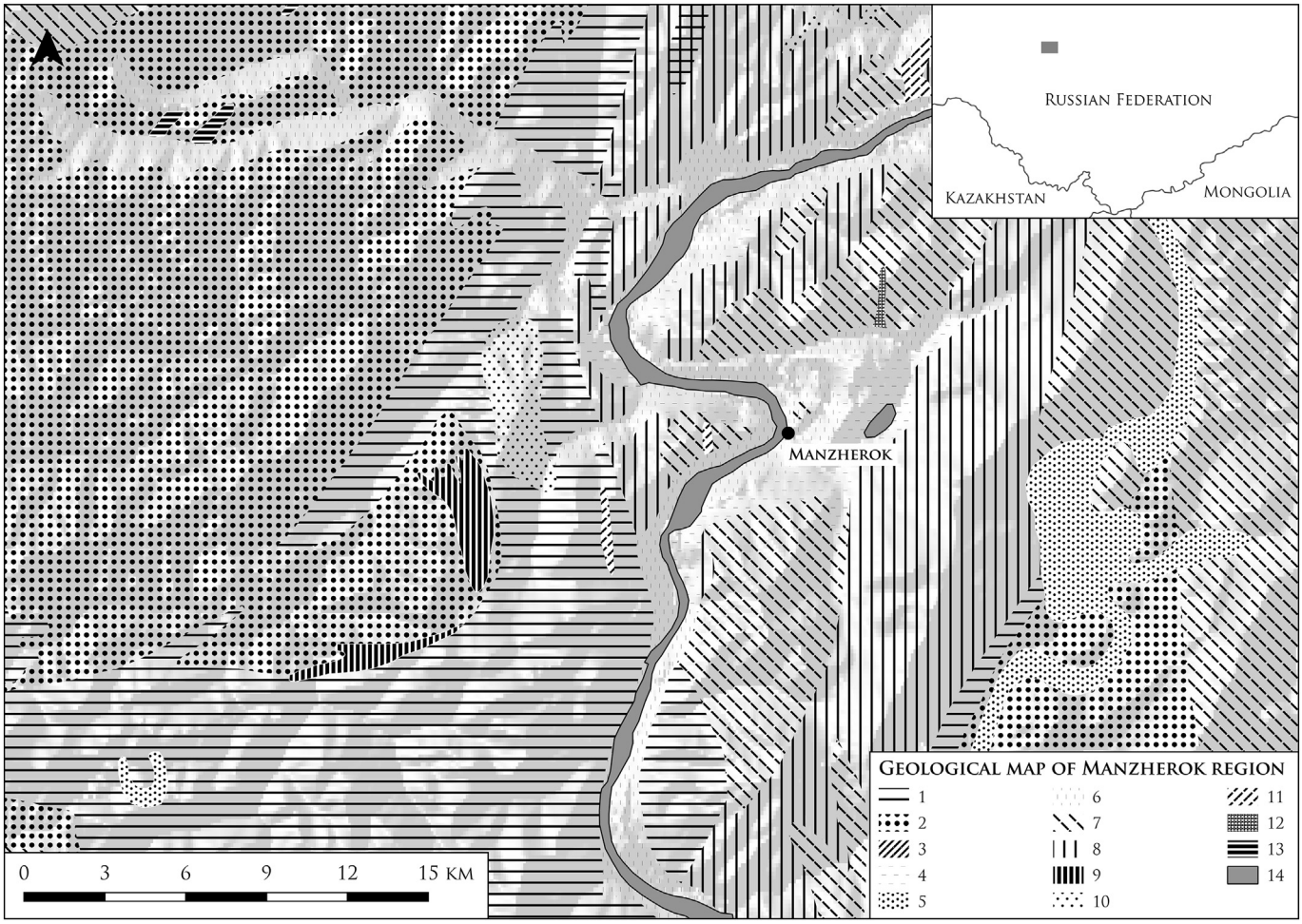
3.2. Geological setting: laser ablation and TIMS

Northern Altai is morphotectonically complex, with dividing ranges that decrease in elevation from 4000 to 1000 m to the north and west. It is also an active seismic zone, currently undergoing intracontinental deformation (Babichev et al., 2009; Chlachula and Little, 2011). The modern mountain system originated in the latest Paleogene, while its final sculpturing since the Quaternary appears to continue, judging by high local seismicity (Babichev et al., 2009). The Manzherok is located within the structural-compositional complexes of the Gorno-Altai terrane (Maps 3–4). The local bedrock is based on an accretionary wedge consisting of Early Cambrian olistostrome and basalts. The olistostrome includes large blocks of Vendian-Early Cambrian seamounts (Barnaul, Biya-Katun, Kadrin and Baratal), sheets of metaperidotites and serpentinite mélanges with high pressure rocks and various Early-Middle Cambrian volcanic series. The bedrock forms north-south trending belts (Map 4). The Katun River Valley is composed of weakly metamorphosed basalts, limestone, and mudstone with the minor addition of sandstone (Rusanov, 2007). Dynamic erosion and displacement of rocks as well as glacial activity have a direct impact upon the strontium isoscape in the discussed region.

The use of strontium in human mobility studies has been employed in an archaeological context for over 30 years (cf. Grupe et al., 1997; Katzenberg and Harrison, 1997; Chenery et al., 2010; Evans et al., 2009; Müller and Anczkiewicz, 2016). In this study teeth were measured for $^{87}Sr/^{86}Sr$ ratios using a Nu plasma (II) MC-ICP-MS equipped with ESI NWR193-based laser ablation system in the Vegacenter at the Natural History Museum, Stockholm. Rodent *Otomys* specimen 26-r52 was used as a standard (Le Roux et al., 2014). The sample surface was wiped with ethanol prior to mounting. The ablated surface, with clearly exposed perikymata was parallel to the laser cell. Problems with laser ablation analysis of the $^{87}Sr/^{86}Sr$ usually result from the Kr, Rb, Ca and Ar molecular background, which can limit the accuracy (Jackson and Günther, 2003). In this study the corrections for Kr were removed by measuring gas blanks (30s) before each measurement. The fractionation of Rb for mass 85 and applied on mass 87 was corrected assuming $^{87}Rb/^{85}Rb = 0.3861$. For laser ablation the absolute error was 0.00032, which means 0.044% of relative error (2sd). For TIMS it was 0.012%, nearly 4 times lower, but the comparison of TIMS-LA shows that measurements were still accurate within error margins. The typical duration for data acquisition during laser firing was 120 s, with a measurement every 0.2 s. Instrument settings and operation conditions are shown in Table 3 (cf. Glykou et al., 2018).



Map 3. Territory of Manzherok, Northern Altai: ALT S/W- water and soil samples collection points (cf. Table 2); black dotted line: the Chuysky Trakt route.



Map 4. Geological map of Manzherok, Northern Altai. Legend: 1) Porphyries and pyroxenites, splits and tuffs, schists and metamorphic slates, rarely jaspers, conglomerates, keratophyres, quartzites; 2) Diluvial and periglacial fluvial successions, loams and clays; 3) Sands, pebbles and gravels; 4) Gneiss and granodiorite, opdalites; 5) Permian granites, biotite mica, diorites and plagioclase feldspar, trondemites and porphyroclasts; 6) Lower series of Kayancha unit: limestones, less often sandstones, metamorphic slates, conglomerates, quartzites, dolomitic limestones; 7–8) Baratal unit: limestones, quartzites, schist, tuffs and diabase (dolerites); 9) Lower Cambrian Manzherok unit: diabase porphyrites, tuffs and slates, sandstones, marbled limestones;10) porphyry and diorites; 11) conglomerates and porphyries; 12) Ordovician clays and loams, gravels and conglomerates, varves and sedimentary rocks; 13) serpentinites; 14) River Katun. Based on: Geological map: M-45-II. Geological map of the USSR. Scale: 1: 200000, series: Altai, compiled by: West Siberian Geological Administration, 1956.

Water and soil samples have been collected from several locations within the main settlements around Manzherok and Chultukov Log (Map 3; Table 2), and their Sr isotopic composition was analysed using TIMS on a Thermo Scientific TRITON® in multiple collector mode. All water samples were exposed to UV irradiation for 2 h in a Spectronics XL-1000 UV Crosslinker, to inactivate and destroy organic matter. The samples were then filtered using glass funnels with cellulose membranes to remove soil particles. In pre-treatment we used 250 µL of 8 N HNO_3, based on Eichrom recommendations for analyses of water samples (high purity reagents by SEASTAR®). Soil samples were dried in 58 °C for 24 h to remove water. The soil was then mechanically sieved several times (sieves 45-20 µ mesh) to remove plant roots, seeds and stones. Some heavy clays from the Manzherok region, unfit for sieving, were dried in lumps and then pulverised in a vibratory micromill. All soil and rock samples were powederised and then muffled in a furnace for 1 h at 900 °C (100 mg). Decontaminated soil samples were dissolved following the method outlined by Chaofeng et al. (2016). Cation exchange procedure used standard Eichrom Sr Resin separation columns (50-100 µ mesh). Measured ^{87}Sr intensities were corrected for Rb interference using $^{87}Rb/^{85}Rb = 0.38600$ and ratios were reduced using the exponential fractionation law with $^{88}Sr/^{86}Sr = 8.375209$. Total procedural blank for soils was recorded to be 54 ng, and for water 0.6 ng. The external precision for $^{87}Sr/^{86}Sr$ from 987 standard was 20 ppm ($n = 12$).

4. Results

4.1. Local geological background

The primary sources for determining the local $^{87}Sr/^{86}Sr$ baselines were soil samples from archaeological sites along the Chuysky Trakt and water from the Katun river (Ob aquifer, Table 2; model after Pokutta, 2014). The samples cover an area which includes the first section of the Chuysky Trakt from the north, 470 km south from Novosibirsk (Map 3). The sampled soil and water $^{87}Sr/^{86}Sr$ values are coherent with the geological maps of the territory. The local bedrock comprises Cambrian and Devonian olistostrome and basalt clusters with some conglomerate sedimentary rocks. Typical $^{87}Sr/^{86}Sr$ isotopic values for basalts have been reported in many geological studies, ranging from 0.705 to 0.710 (Aldrich et al., 1953; Herzog et al., 1953; Faure et al., 1963). The prevailing $^{87}Sr/^{86}Sr$ value from relevant soils is 0.710 (Table 3). The water samples collected from the Katun River represent the broader isoscape of the Ob River aquifer. Isotopic values for aquatic environments are reasonably consistent across the northern Altai region, with a typical $^{87}Sr/^{86}Sr$ value of 0.7088 (samples collected in summer; Map 4).

In this study we analysed a randomly collected horse incisor from the Chultukov Log settlement site 9, as a comparative material. A comparison of the strontium data shown in Table 2 (Figs. 5–6) and the environmental $^{87}Sr/^{86}Sr$ values of 0.7092 (n = 18), indicates this horse lived locally in the Manzherok region (Fig. 6). We do not recommend, however using isotopic $^{87}Sr/^{86}Sr$ values from animal remains instead of environmental samples when defining local underlying geology. Lokhov et al. (2007) failed to establish a local isotopic signal for the Arzhan barrows and other Scythian monuments, mainly because they used animal samples. The faunal strontium data in their study had a mean of 0.7078 (n = 9), but was not representative (e.g. 9 samples covered territory of *c.* 92,600 km^2) and displayed significant variation. The data published by Lokhov et al. (2007) show that in the territories of Tuva and Northern Altai, herbivorous species display $^{87}Sr/^{86}Sr$ values between 0.706 and 0.709. However, all measurements were taken from long bones, often without details regarding species or geographic location.

4.2. Chronology of barrows

Alekseev et al. (2001, 2002, 2005) have provided an extended list of sites and tombs that have so far been radiocarbon dated, comprising 40 monuments and 98 ^{14}C-dates (cf. Görsdorf et al. 2004). The authors clearly demonstrated an expansion of the Scythian cultures from the 9th/8th century BC over the vast territories from the Volga River to Mongolia, claiming that many barrows were chronologically contemporary with the Arzhan royal barrow in Tuva. The majority of tombs in our study belong to the classic Pazyryk period (Table 1; Fig. 4; Table 4). The exception was barrow 62 that was previously thought to belong to the Hunnic period, starting around 2nd century BC. Radiocarbon dating indicates, however, that monument 62 is of much earlier chronology, in line with the monuments in Aldy Biel, Dogee Baary 2, and barrow 10 in Tuva (Alekseev et al., 2002). Barrow 53, associated with the Bystrianka culture, is contemporary with the Dogee Baary 2, barrow 6.

Barrow 10, linked to the Kara Koba tradition, was built at the same time as Cheremshino barrow (grave 1) in southern Siberia, Chinge 2 barrow 22 (grave 2) and Pazyryk 2 in Altai. Moreover, the chronological distance between this monument and the first Pazyryk barrow within a cemetery (barrow 35) is very narrow indeed. This may indicate that the Kara Koba stone cists burial tradition was contemporary with the early classic Pazyryk in Northern Altai, and that both traditions coexisted for a certain period of time. The youngest among the analysed barrows, kurgan 47 is contemporary with Vishneva Mogila (barrow 11), Oguz (grave 9) and barrows in Temir in Kazakhstan (Alekseev et al., 2002; Table 4).

4.3. Non-locals and territory X

Some of the non-local individuals in our dataset appear to be linked with a territory out of the baseline grid for the Manzherok region (Fig. 5). It is not yet possible to place this area on the map; this unidentified territory will be referred to as *territory X*. Provided here is a basic description and information regarding this territory.

We anticipate that inhabitants of *territory X*, would display $^{87}Sr/^{86}Sr$ isotopic values ranging from 0.711 to 0.713 (dental samples), linking them with a geological bedrock of an entirely different composition than that in the Manzherok region. The geological background of *territory X* seems to be built of much older geological formations, likely granites or metamorphic rocks. In search for a potential location of *territory X*, we can exclude the Tuva region and also Khakassia based on the range of $^{87}Sr/^{86}Sr$ isotopic values in these regions. Human remains with specific $^{87}Sr/^{86}Sr$ isotopic signals typical for the *territory X* have so far been found only in the Northern Altai region. Isotopic data available for Arzhan, Serala, Kaznovka or Toplaya and other Scythian monuments (Lokhov et al., 2007) clearly shows that the inhabitants of other northern and eastern territories in Siberia had no direct contact with *territory X*.

The individuals, buried at the Chultukov Log 1 cemetery that can be linked with *territory X*, are associated with the Pazyryk culture (Table 1; Figs. 7–8). Data from at least 2 individuals, males 53 and 112, indicate a rapid but direct movement between *territory X* and the Manzherok. The data highlights one, very important feature of nomadic mobility patterns, namely an all-year-round mobility engagement. From a chronological perspective, the contacts between the *territory X* population and Northern Altai can be confirmed from at least the 6th until the 3rd century BC. The oldest inhumation associated with an individual from *territory X* is barrow 53, dated to 2415 ± 30 BP, while the most recent burial is the female burial in barrow 47, dated to 2230 ± 30 BP (Fig. 4; Table 4).

4.4. Mobility of females

Barrows 12, 35, 46 and 47 belong to females (Table 1; Figs. 2–3). All of them were buried with artefacts linking them to the Pazyryk culture, such as Scythian wigs, jewellery, mirrors and private belongings. The isotopic $^{87}Sr/^{86}Sr$ values of these females are shown in Fig.8. All analysed females can be identified as non-locally born.

Table 1
Barrow interments from Chultukov Log 1 analysed in this study: archaeological overview.

Barrow ID	Gender	Archaeological culture	Tomb's diameter	Head orientation/ body alignment	$^{87}Sr/^{86}Sr$ sample	Grave goods
ALT 62	Male	Early Scythian period	3.5 m	NW	PM1	No grave finds
ALT 53	Male	Bystrianka culture	3.5 m	NE	PM2	No grave finds
ALT 10	Male	Kara-Koba culture	4.5 m	E	PM1	No grave finds
ALT 35	Female	Pazyryk culture	6.2 m	SE	PM1	Barrow mantel showered with fragments of broken vessels; imported glass beads necklace and bronze mirror
ALT 12	Female	Pazyryk culture	3.5 m	SE	PM2	No grave finds
ALT 112	Male	Pazyryk culture	3.5 m	SE	PM2	bronze buckle, large ceramic vessel, bronze knife, quiver, ritual miniature armament: *akinaka* dagger and small pickaxe, food (sheep bones)
ALT 46	Female	Pazyryk culture	8 m	SE	PM2	wig with bronze ornaments, bronze mirror and iron knife, large ceramic vessel, food (sheep bones)
ALT 47	Female	Pazyryk culture	8 m	SE	PM	wig with bronze ornaments, bronze pins, 2 ceramic vessels, silver plates and bronze beads (dress embellishment), 2 iron knives, food (sheep bones)

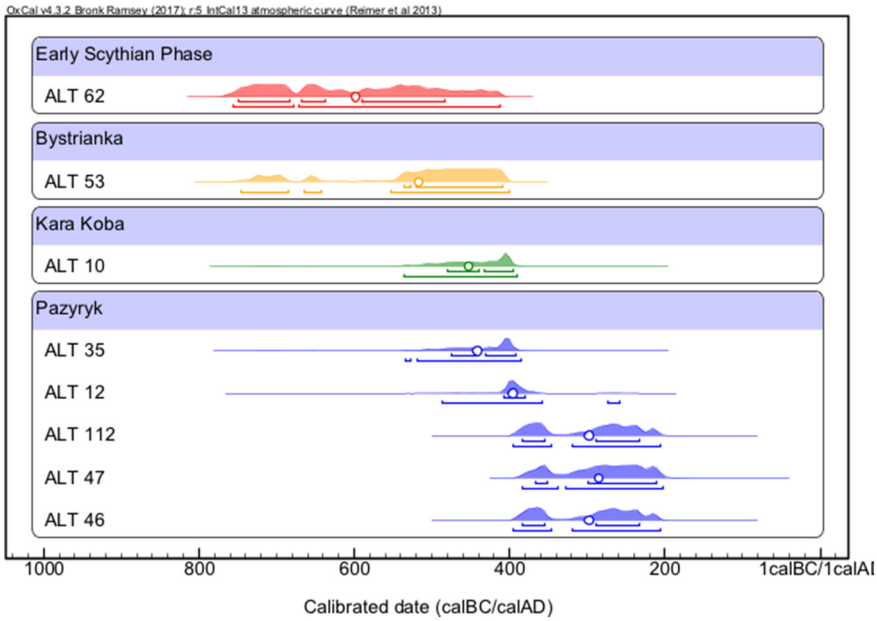


Fig. 4. Chronology of barrows from Chultukov Log 1, Altai Republic, Russia. The graph plots 'likelihood' distributions; 'posterior' distributions are not included; Oxcal (cf. Table 4).

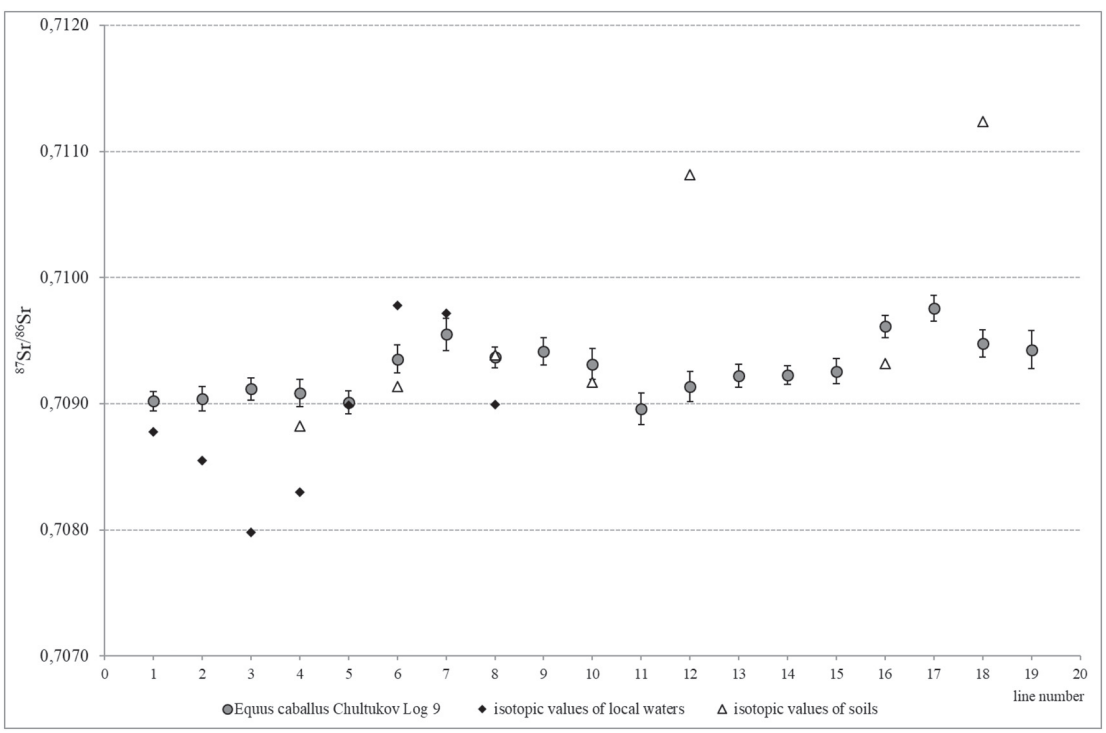


Fig. 5. Manzherok local baseline values: LA-ICP-MS and TIMS plot of $^{87}Sr/^{86}Sr$ values from soils and water samples compared to faunal data. Sample LA-2-ALT-AB-10: *Equus caballus* from settlement Chultukov 9.

The $^{87}Sr/^{86}Sr$ isotopic data indicates a specific dynamic pattern of long distance mobility for females. The analysed women travelled in steps, reaching intervallic interim destinations, which again are clearly marked by specific $^{87}Sr/^{86}Sr$ isotopic signals (stages A-B-C in Fig.8). This may correspond with archaeological evidence for nomadic females travelling in family groups usually in wagons (Gryaznov, 1969). In the Altaic region, such forms of mobility can be seen as cultural adaptation to long-distance travel, in what we would define as frontier territories. The oldest female burial, barrow 12, dates to 2329 ± 31 BP, whereas the youngest, tomb 47, dates to 2230 ± 30 BP (Table 4; Fig. 4). It should be highlighted that there is a positive correlation between the volume and quality of grave goods, and the overall scale of mobility for females. The longer the distances, the higher likelihood that imported goods and expensive items will appear in burials of non-local females (Table 1).

4.5. Mobility of males

Scythian men display distinctly different mobility patterns. For them, short distance and possibly pedestrian-oriented mobility prevails

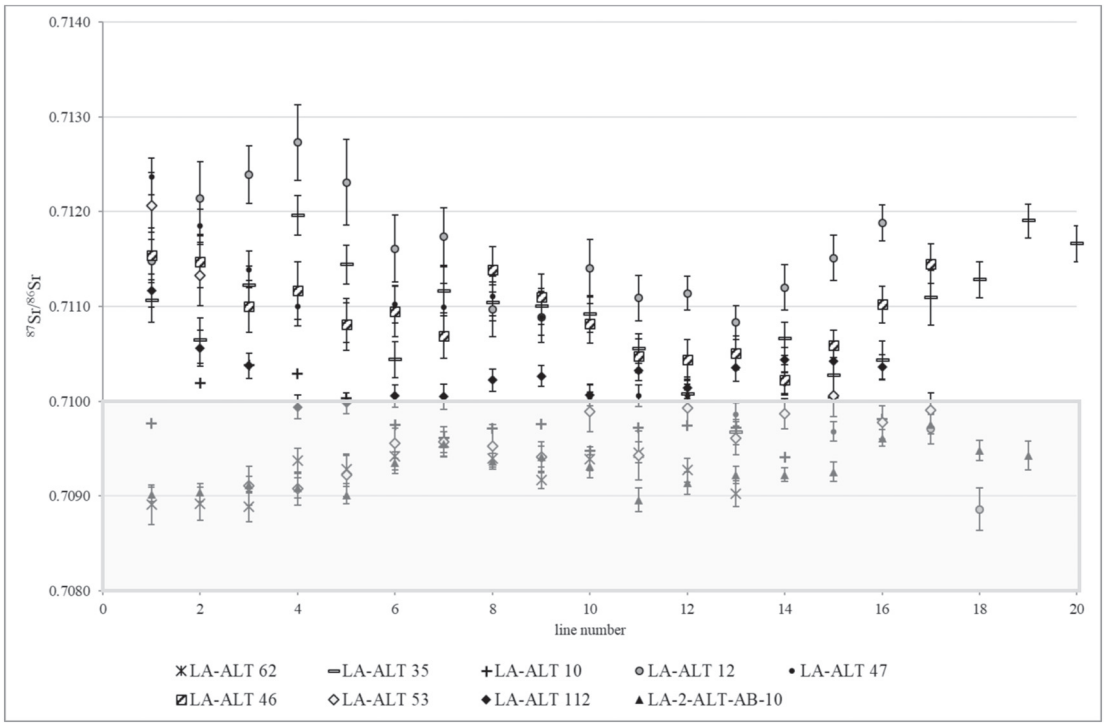


Fig. 6. LA-ICP-MS plot of $^{87}Sr/^{86}Sr$ values from all analysed individuals; grey band: local strontium baseline level (TIMS measurements of soils and water samples Tab.2); sample LA-2-ALT-AB-10: *Equus caballus* from Chultukov 9.

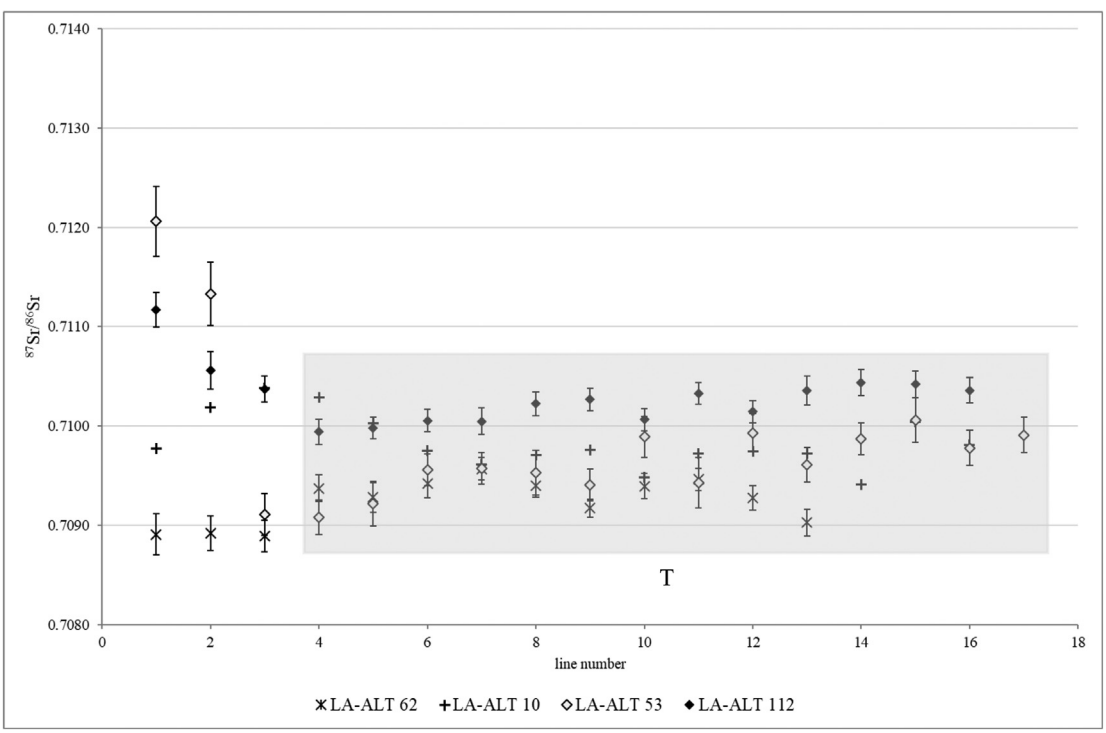


Fig. 7. LA-ICP-MS plot of $^{87}Sr/^{86}Sr$ values for males from Chultukov Log cemetery, Altai; phase T (grey band) represents short distance mobility within local strontium range, typical for seasonal transhumance.

(Fig.6; Fig.7). Sedentary residential life in the area can be attributed to two males buried in barrows 62 and 10. These individuals represent the chronologically oldest, Early Scythian inhumations associated with the Kara Koba tradition. These individuals, as children lived in the vicinity of the Manzherok settlement. Seasonal mobility between summer and winter pastures and transhumance, can be identified in two other cases; the horse from Chultukov Log 9, and the adult warrior-hunter interred in barrow 112 (phase T in Fig.7). Horse teeth grow continuously until the age of 25, so the $^{87}Sr/^{86}Sr$ signal indicates this particular animal was locally raised and used for short-distance haulage, covering much the same area across annual cycles. The mobility pattern, attributed to the male in barrow 112, also indicates short-distance mobility with a

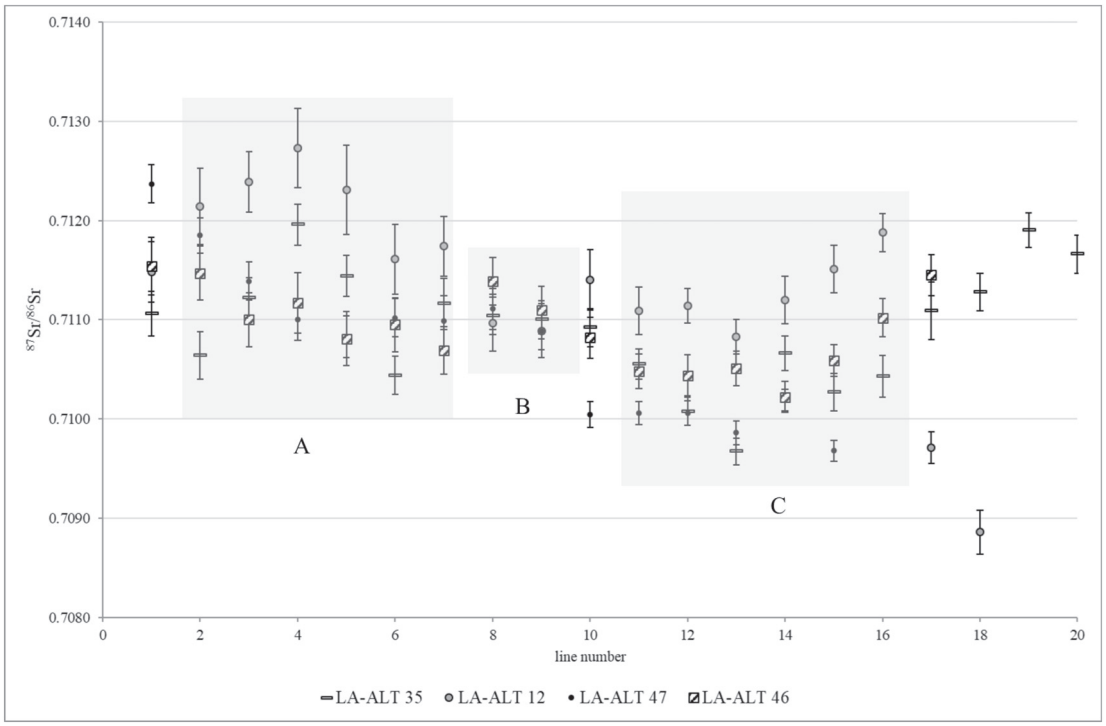


Fig. 8. LA-ICP-MS plot of $^{87}Sr/^{86}Sr$ values for Pazyryk females from Chultukov Log cemetery, Altai; phases A-C (grey bands) represent a leapfrog model of long distance mobility.

tendency to return to designated locations.

Chronologically, the data revealed a significant increase in forms of residential mobility for both genders and intensive use of horse transportation from the mid-5th century BC onwards. Journeys in the classic Pazyryk period were not only more frequent, but faster and in many cases probably organised in chain systems. Archaeological and ethnographic evidence indicate no gender-based differences in horse riding skills between men and women of the Pazyryk culture (Taylor, 2017; Lepetz, 2013), however our data shows that girls travelled over significantly longer distances, more frequently than boys.

5. Discussion

The barrows of Arzhan in the Tuva Republic located approximately 1000 km northeast of the Altai foreground, are considered the key monuments for establishing the chronology of Eurasian Scythian cultures. The Arzhan 1 barrow, excavated in 1970–1974 by M.P. Gryaznov and M.H. Mannay-Ool, had a diameter of 120 m and its central chamber was surrounded by 70 other chambers with wood-framed beams, spread in 4–5 circles (Gryaznov, 1980). This multiple inhumation contained in total over 160 horses and other unique finds, including stone altars with numerous luxurious artefacts. The Arzhan 2 barrow, excavated in 1998–2003, is 80 m in diameter, containing burials of Scythian warlords and their families, and was lavishly furnished with goods, including exotic foreign artefacts (Chugunov et al., 2017). The bedrock in Tuva, specifically in the Arzhan region represents a complex mixture of conglomerate sedimentary rocks, marlstones and volcanic tuffs, with $^{87}Sr/^{86}Sr$ signatures of 0.707–0.708. The majority of individuals buried in the Arzhan 2 barrow display a local isotopic value, but there are exceptions. According to Lokhov et al. (2007), the female (skeleton no.2) buried in the main chamber of burial 5 (central inhumation of barrow), was of non-local provenance with a $^{87}Sr/^{86}Sr$ value of 0.705. The authors speculate about her possible links to the Altai region. Our data shows that the discussed female was almost certainly not linked with the Altai region.

There are, however, several other inhumations in the same barrow (Arzhan 2), that display isotopic signals typical of the Altai region: skeleton 1, an adult male buried in interment 5 ($^{87}Sr/^{86}Sr$ 0.7089); an adult male buried in interment 24 ($^{87}Sr/^{86}Sr$ 0.7088); a female buried in grave 13A (0.7089); both males from barrow 20 ($^{87}Sr/^{86}Sr$ 0.7089/0.7088); a female from burial 13B ($^{87}Sr/^{86}Sr$ 0.7088); both males from inhumation 14 ($^{87}Sr/^{86}Sr$ 0.7089/0.7089) and an adult male in grave 23 (0.7088). These individuals display $^{87}Sr/^{86}Sr$ isotopic values very similar to the underlying bedrock of the Altai region (Table 2). Moreover, craniometric data published by Chikisheva (2008) supports the hypothesis that populations of Tuva and Altai were also anthropologically linked to each other. In her study, Chikisheva (2008) focused on cranial variation, tracking affinities with diverse population groups in the Scythian period. According to the research, the population of Tuva was probably related to the Early Scythian population of Northern Altai. The $^{87}Sr/^{86}Sr$ isotopic signal typical for the Altaic population, has been identified in several other monuments in central and southern Khakassia. In the Serala barrows, adult individuals buried in tombs 1 (burial 3) and 2 (burial 4) both show isotopic values of 0.709. In Kazanovka 2 (barrow 3A, burial 2) an adult individual displays isotopic values of 0.7093, and in Toplaya (Uvs Valley, kurgan 2, grave 1) the value recorded was 0.7098. It is possible that certain individuals were linked to the Altai territory, but the tombs they were interred in are located approximately 670-750 km northeast of this region.

6. Conclusions

Undoubtedly, nomadic mobility represents a complex, adaptable, but also a well-organised and efficient, global transportation system. The mobility of the Pazyryk community inhabiting the Manzherok region, show that the dynamics of inter-tribal activity increased after the 5th century BC, when compared with earlier periods. Furthermore, the mobility patterns for men and women were linked to their social roles, however, in an entirely different way than in typically agrarian societies. Isotope analysis has helped to identify several features of nomadic mobility, among them flexibility and a year-round travelling model. The data infers that at least some people had been travelling in stages

Table 2
Location and $^{87}Sr/^{86}Sr$ values of soil and water samples from Manzherok area.

Sample ID	Location	GPS sample coordinates	Depth	$^{85}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$ Norm*	Ext. prec. 2σ
		Water samples				
ALT/W/1	Manzherok spring	N 51°49,151′ E 85°46,721’	≥ 0.5 m	0.000001	0.708780	0.000015
ALT/W/2	Barangol river	N 51°41,856′ E 85°46,176’	≥ 0.5 m	0.000001	0.708549	0.000015
ALT/W/3	Bolotov Log river	N 51°41,856′ E 85°46,176’	≥ 0.5 m	0.000001	0.707982	0.000015
ALT/W/4	Barangolskyi Kluch	N 51°41,856′ E 85°46,176’	≥ 0.5 m	0.000001	0.708300	0.000015
ALT/W/5	Munushka river	N 51°42,127′ E 85°46,121’	≥ 0.5 m	0.000012	0.708991	0.000015
ALT/W/6	Katun river near Chultukov-Log 1 site	N 51°50,199′ E 85°43,971’	≥ 0.5 m	0.000001	0.709782	0.000015
ALT/W/7	Katun river near Manzherok village	N 51°50,199′ E 85°43,971’	≥ 0.5 m	0.000065	0.709719	0.000015
ALT/W/10	Manzherochka river, Manzherok-3 site	N 51°50,116′ E 85°44,160’	≥ 0.5 m	0.000009	0.708992	0.000015
CIT39	–	–	–	0.000005	0.709154	0.000015
		Soil samples				
ALT/S/1	Manzherok-12	N 51°49,151′ E 85°46,721’	2 m	0.000003	0.713140	0.000015
ALT/S/2	Barangol-5	N 51°41,856′ E 85°46,176’	1.5 m	0.000001	0.708826	0.000015
ALT/S/3	Manzherok-12, kurgan 3	N 51°49,151′ E 85°46,721’	2 m	0.000001	0.709136	0.000015
ALT/S/4	Manzherok-12, kurgan 3	N 51°49,151′ E 85°46,721’	1.5 m	0.000001	0.709387	0.000015
ALT/S/5	Chultukov Log-1	N 51°50,199′ E 85°43,971’	2 m	0.000004	0.709169	0.000015
ALT/S/6	Chultukov Log-9, trench 13	N 51°50,199′ E 85°43,971	1 m	0.000001	0.710817	0.000015
ALT/S/7	Chultukov Log-9	N 51°50,199′ E 85°43,971	1 m	0.000006	0.715575	0.000015
ALT/S/8	Manzherok-12, kurgan 2	N 51°49,151′ E 85°46,721’	2 m	0.000001	0.709317	0.000015
ALT/S/9	Muny site 1	N 51°42,127′ E 85°46,121’	1 m	0.000011	0.711236	0.000015
CIT39	–	–	–	0.000018	0.709169	0.000015

Table 3
Laser ablation and ICP-MS operating parameters.

ICP-MS adjustment	
Mass spectrometer	Nu plasma (II) MC-ICP-MS
Cooling gas flow rate	13 L/min
Aux gas flow rate	0.84–0.89 L/min
Mass resolution	Low
Cones	common Ni cones
Torch	glass
Laser ablation adjustment	
System	ESI NWR193 ArF eximer based laser ablation system
Ar flow rate (Mix Gas)	0.83–0.85
He flow rate	0.32 L/min
Preablation frequency	10 Hz
Preablation translation rate	100 μm/s
Preablation spotsize	150 μm
Ablation frequency	25 Hz
Ablation translation rate	5 μm/s
Ablation spotsize	148 μm
Line raster length	450–600 μm
Data collection	
Gas background	45 s
Integration	0.5 s

Table 4
Radiocarbon data from Chultukov Log cemetery, Altai, Russia.

Barrow ID	^{14}C-dating BP	$\delta^{13}C$‰VPDB	Probability range 95.4% (years BC)	Mean calBC
ALT 62	2456 ± 32	−18,6	756–414	598
ALT 53	2415 ± 30	-18,5	746–401	518
ALT 10	2370 ± 29	−17,8	537–391	453
ALT 35	2362 ± 29	−18,8	535–385	442
ALT 12	2329 ± 31	−19,7	487–260	396
ALT 112	2293 ± 26	−18,2	395–207	298
ALT 46	2251 ± 30	−17,7	395–207	298
ALT 47	2230 ± 30	−18,5	384–204	285

across the Altai region. This can be linked to the specific conditions in the high mountains along the Chuysky Trakt corridor and beyond, but also to the long distances to be covered.

The mobility of the nomadic inhabitants of Central Asia was also shaped by climatic changes associated with the presence of major deserts. Yang et al. (2006) analysed and reported fluctuations of precipitation in the Taklamakan desert, stating that the last occurrence of wetter environmental conditions in the Taklamakan was in the Late Scythian and early Hunnic periods. In this period, according to Chinese chronicles some parts of the Taklamakan desert were inhabited by humans. Uncovered ruined settlements in the vicinity of the Keriya River have been radiocarbon dated to the western Han dynasty (*c.* 206 BC-25 AD; Yang et al., 2006, 931). The development and fluctuations in hyper-arid territories in central Asia ultimately had a major impact upon all human activity, including mobility throughout prehistory. Wetter conditions in Taklamakan desert could be the key to understanding important historical events associated with the contemporaneous rise of the Hunnic Empire and their military expansion into the steppe.

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