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New results of radiocarbon dating and identification of plant and animal remains from the Oglakhty cemetery provide an insight into the life of the population of southern Siberia in the early 1st millennium CE

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A B S T R A C T

The semi-arid steppe and forest-steppe regions of southern Siberia have a long history of human occupation. During the Bronze and Iron Ages, the area became home to a number of archaeological cultures that greatly influenced the cultural and technological development and exchange processes in the middle latitudes of Eurasia and left a rich archaeological record. One of the lesser-known Iron Age archaeological cultures is the Tashtyk culture, which flourished in the Minusinsk Basin in the upper reaches of the Yenisei during the 1st to 7th centuries CE. Using an extensive set of radiocarbon dates and identifications of plant and animal remains from the best-preserved and most spectacular Grave 4 of the Oglakhty burial ground, our study aims to improve the age determination of the examined grave and to better understand the natural environments and way of life of the local population in this remote region of Central Asia during the early 1st millennium CE. Our dating approach could narrow down the probabilistic age range of the time at which Grave 4 was constructed and used to ca. 250–300 CE. The inferred age together with polychrome *jin* silks documented in Grave 4 suggests a connection between the local populations and silk producing centres in eastern China via either oases-states in the Tarim and Turfan basins or via the Mongolian steppes. The records of zooarchaeological remains and artefacts approve that the local Tashtyk people were skilful craftsmen and had a complex subsistence economy mainly based on animal husbandry, which was supplemented by hunting-gathering and small-scale agriculture. The available evidence on the use of sheep indicates that they played an important role in the local economy, although other domesticated animals (such as goats, cattle, horses) were bred as well. Whether reindeer were present locally (i.e. domesticated) or their skins were obtained through hunting or more distant exchange requires further investigation. Also, the role of agriculture and millet cultivation (mentioned in the reports of the first archaeological excavations) remains an important topic for upcoming research. The available, albeit still rare, palaeoenvironmental records from the region suggest drier conditions during the 4th to 1st centuries BCE, partly corresponding to a colder and dryer phase in the North Atlantic region. The regional pollen and isotope records demonstrate a weak trend towards wetter and warmer climate during the following five centuries representing the Tashtyk culture.

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1. Introduction

The vast steppe regions of Eurasia are extremely rich in archaeological records (e.g. Gryaznov, 1958; Okladnikov, 1968; Parzinger, 2006 and references therein), but still often regarded as peripheral in terms of prehistoric cultural development. However, a growing body of evidence shows that the steppes were the place of origin for many key innovations and that steppe populations were strongly involved in knowledge transfer and shaping the developments in 'cultural core' regions, especially since the 3rd millennium BCE (Anthony, 2007; Allentoft et al., 2015). Therefore, it is of great importance to gain a better picture about the cultural prehistory and palaeoenvironments of the Eurasian steppe regions (e.g. Tarasov et al., 2012). In cultural core regions of Asia, such as that of dynastic China, dating becomes more commonly based on written sources from the 1st millennium BCE. By contrast, the prehistoric period in the steppes did not leave written sources and lasted much longer. This highlights the importance of systematic radiocarbon (^{14}C) dating approaches to build reliable chronologies for available and future archaeological and environmental records from these regions.

One of the lesser-known Iron Age archaeological cultures of southern Siberia is the Tashtyk culture, which flourished in the Minusinsk Basin along the Yenisei during the 1st to 7th centuries CE. What place did Tashtyk people have in the history of Eurasia in the early 1st millennium CE? In 1902, when a local shepherd fell into an old grave-pit located at the slope of the Oglakhty mountain on the left bank of the Yenisei River and Aleksandr V. Adrianov uncovered another sixteen graves in the following year (Sosnovskii, 1933), archaeological research began at the ancient Oglakhty cemetery that still poses as many challenges as it did one hundred years ago. These challenges arise from the unusual treatment of the deceased that was not previously practiced in this region, the grave goods, which include pieces of *jin* silk made in eastern China, and the age of the grave. Using an extensive set of accelerator mass spectrometry (AMS) ^{14}C dates and identifications of plant and animal remains from the best-preserved Grave 4 of the Oglakhty cemetery, our study aims to improve the age determination of the grave and to better understand the lifestyle of the local population in this remote region of Asia during the early 1st millennium CE.

2. Study site, material and methods

2.1. Archaeological site setting

The material for this study comes from the Oglakhty burial ground, which is situated in the central part of Asia (Fig. 1A), in the low-mountain Oglakhty Range located on the left bank of the Yenisei River, about 40 km north of Abakan (Fig. 1B), and is assigned to the early stage (i.e. ca. 1st to 4th century CE) of the Tashtyk culture of the Iron Age (e.g. Vadetskaya, 1999; Pankova et al., 2010). This large burial ground with more than 300 graves as well as other (perhaps commemorative) features, most of which have not yet been excavated, was accidentally discovered by A.V. Adrianov, a Siberian official, but also ethnographer, archaeologist and explorer (Sosnovskii, 1933). In August 1903, he excavated altogether 17 graves and laid the foundation for archaeological research at Oglakhty (e.g. Adrianov, 1903a, 1903b; Sosnovskii, 1933; Tallgren, 1937). After a long break, scientific excavations started again in the late 1960s. In 1969–1973, eight graves were excavated by L.R. Kyzlasov and one grave was studied by E.B. Vadetskaya (see Pankova et al., 2010 for details and references). The archaeological surveys (e.g. Adrianov, 1903a, 1903b; Vadetskaya, 1999; Pankova et al., 2020) helped to distinguish several burial areas within the Oglakhty burial ground (Fig. 2), however, this work is still in progress (Pankova et al., 2021; Vodyasov et al., 2021; Zaitceva et al., 2021). The study area belongs partly to the Khakassky State Nature Reserve (Devyatkin et al., 2000; Nepomnyashchii, 2019; https://zapovednik-khakassky.ru/), which was created in 1991 to protect steppe habitats of rare and endemic plant and animal species, as well as numerous archaeological and other sites of historical and cultural heritage, including thousands of rock carvings and paintings related to different historic periods (e.g. Miklashevich, 2015, 2020). Because of its outstanding universal value, the Oglakhty area was nominated as an object of a mixed natural and cultural heritage and included in the Tentative UNESCO World Heritage List (http://whc.unesco.org/en/tentativelists/6165/) in 2016.

The burial ground got its name after the Oglakhty Range, reaching over 600 m a.s.l. The range extends from north to south for about 15 km and rises above the Yenisei valley by 150–300 m. The climate of the study area is continental and relatively dry (New et al., 2002). Measurement data from the Abakan meteorological station (245 m a.s.l.) show a mean temperature of about +20 °C in July and about −18 °C in January (Weatherbase, 2021). The annual precipitation is about 310 mm and ca. 60% of the annual total amount falls during the three summer months. The interannual climate variability is high and extreme temperatures may drop to −45°C in winter and rise to 40°C in summer, causing severe droughts (Alpat'ev et al., 1976). Cold winter temperatures and low snow precipitation contribute to the formation of a thick ice cover on the lakes and rivers, which persists from December to April and reaches about 1 m thickness by the end of February (Genova et al., 2010). The relatively dry climate has a strong influence on the vegetation cover. Various steppe, meadow steppe and shrubby steppe associations with Poaceae and *Artemisia* species predominate in the study area (Gerasimov, 1964). Trees and small forest patches grow in local moist environments and on the northern slopes. At present, birch (*Betula* sp.) is the most common tree in the region followed by Scots pine (*Pinus sylvestris*), larch (*Larix sibirica*) and aspen (*Populus tremula*) (Alpat'ev et al., 1976).

2.2. Grave 4 of the Oglakhty burial ground

The Oglakhty burial ground consists of more than 300 graves, which are grouped into three spatially separated burial areas (e.g. Vadetskaya, 1999; Pankova et al., 2021; Fig. 2). Grave 4, discussed in this study belongs to the burial area 1. It was excavated by L.R. Kyzlasov in 1969 (Kyslassow, 1971; Kyzlasov, 1971, 1992) and the excavated objects were transported to the State Hermitage Museum in St. Petersburg for further research and conservation purposes. Archaeological excavation of the grave revealed a 140-cm-deep pit measuring 300 by 240 cm, in which there was a wooden structure (length 230 cm, width 155 cm, height 85 cm), reminiscent of a blockhouse, built of cut and carefully joined pine and larch logs (Nikolaev and Pankova, 2017). The larch logs were mainly used to construct the walls of the chamber, whereas the ceiling was made mainly of pine logs. Two thick layers of birch bark covered the floor of the cabin, and four or five layers of bark insulated the walls and ceiling. These protective measures, combined with the dry regional climate and the favourable location of the grave on a relatively steep slope, prevented the penetration of melted snow and rainwater into the burial chamber (Kyzlasov and Pankova, 2004) and ensured excellent preservation of its contents (Pankova, 2020b).

The log chamber of Grave 4 contained the remains of four adults and one child (Fig. 3) buried according to two different rituals. The mummified bodies of two of the adults – a man and a woman – were buried with trepanned skulls and painted plaster masks applied to their faces (Nikolaev and Pankova, 2017; Pankova, 2020b). A male mummy's skin appeared to be tattooed and a surgery seam has been revealed on its face using CT scanning (Shirobokov and Pankova, 2021). A 10–14-year-old child (identification by E. Uchaneva, Peter the Great Museum of Anthropology and Ethnography (Kunstkamera), St. Petersburg) was evidently also buried in a similar way (Kyzlasov and Pankova, 2004). The two other adults were cremated and their ashes were placed in individual leather bags. Each leather bag was then placed in the chest of a life-size grass-filled leather mannequin or 'effigy' imitating a human body (Pankova, 2020b). A leather pocket placed in the chest and stomach area of the second mannequin (4 in Fig. 3) contained cremated

Fig. 1. Maps showing the location of the study area in the central part of Asia (A) and regional topographic features and modern hydrology of the Minusinsk Basin (B) along with the Oglakhty burial ground (white circle) and Lake Shira pollen record (white star) discussed in this study. Elevation is based on the GMTED-2010 digital elevation model (Danielson and Gesch, 2011). Modern cities (marked with red circles) are shown for orientation purposes. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

bones. Examination of the bones revealed that they belonged to a 20–45-year-old man (Pankova and Shirobokov, 2021). Both the human bodies and the mannequins were fully dressed, and their clothing, including fur hats, coats, trousers, skirt, mittens and shoes, remained well preserved (see Nikolaev and Pankova, 2017; Pankova, 2020b for detailed descriptions and photos). The other objects found in Grave 4 include wooden blocks and grass-filled leather pillows placed under the heads of the mummies and mannequins, clay and wooden vessels, a model of a gorytos with bow and arrows, miniature bridles, animal bones and other burial goods (Fig. 3; Kyzlasov and Pankova, 2004; Pankova et al., 2010; Shishlina et al., 2016; Pankova, 2021).

2.3. Organic remains and analytical methods

Most of the finds from Grave 4 are organic remains. The most common remains representing plants and animals are wood and herbaceous plants as well as fur and leather, animal bones, bird feathers, woollen and silk fabrics, and plant-based dyes. Some of the organic remains from Grave 4 were analysed using various morphological (including optical and scanning electron microscopy), chemical and physical methods to get a better understanding of the animals and plants used by the ancient population of Oglakhty.

In 1970, most of the well-preserved specimens were analysed for fur identification by N. Vereshchagin at the Zoological Institute of the USSR Academy of Sciences. Identification was carried out by comparative analysis with reference collections of fur and leather. In the same year, stuffing grass from the two mannequins and pillows under their heads was analysed by A. Kalinina from the Botanical Institute of the USSR Academy of Sciences. In 2003, 2005, numerous wooden objects from the grave as well as logs of the grave chamber were identified by M. Kolosova using microscopic analysis and diagnostic information on basic wood anatomy. More recently, several individual objects from Grave 4 were analysed in order to identify animals used for their making and/or to test the potential of new methods. Among them, animal hairs preserved on the front part of the model gorytus made of poorly processed skin (analysed by E. Mikolaichuk) and feathers preserved on the arrow shafts (analysed by A. Panteleev in the Laboratory of Ornithology, Zoological Institute, RAS). K. Kalinina (State Hermitage Museum) analysed food residue from one of the ceramic vessels and L. Brandt applied proteomic analyses to the leather samples from the mittens.

Examination of food residues from archaeological contexts (e.g. ancient vessels and ceramic sherds) can provide important insights into the palaeodiet (e.g. Demirci et al., 2021). A black porous coating preserved in the ceramic pot (object No. 2864/4) that was located in the south-eastern corner of the burial chamber, next to the right leg of the male mummy, was analysed using the method of thermally assisted hydrolysis and methylation-pyrolysis-gas chromatography/mass spectrometry (THM-Py-GC/MS) (Scalarone et al., 2001; Mazzeo et al., 2004; He et al., 2007). The method is particularly effective for studying non-volatile organic substances, reflecting the composition of ancient degraded archaeological materials. In this study, a 25% solution of tetramethylammonium hydroxide (TMAH) in methanol (Sigma) was used as a methylating reagent. An Agilent 7890B chromatograph with an Agilent 5977NT MSD quadrupole mass-selective detector (Agilent Technologies, USA) was used for analysis (Hao et al., 2019). For pyrolysis, a double-shot pyrolyzer PY-3030iD (Frontier Lab, Fukushima, Japan) was used. The results were processed using the AMDIS program and the NIST mass spectral library (D'Arcy and Mallard, 2004).

Three samples from the left mitten (inv. No. 2864/70) and six samples from the right mitten (inv. No. 2864/76) of the male mummy were taken for species identification by ZooMS (Zooarchaeology by Mass Spectrometry). ZooMS is a method for species identification based on small differences in specific sequences (markers) of the protein collagen between animal species (Buckley et al., 2009). The combination of markers seen in the MS spectra make up the so-called 'fingerprints' of the sample which can be matched to fingerprints from known animal species and thus identified. Collagen is abundant in tissues such as bone, antler, sinew and skin, therefore the method is useful for archaeological remains of these materials. Several studies have demonstrated the success of ZooMS on both leather (Brandt et al., 2020; Brandt and Mannering, 2021) and untanned skin (Fiddyment et al., 2015; Teasdale et al., 2017).

Samples were analysed using a MALDI-TOF MS instrument and spectra were recorded over the m/z range of 800–4000. Spectral

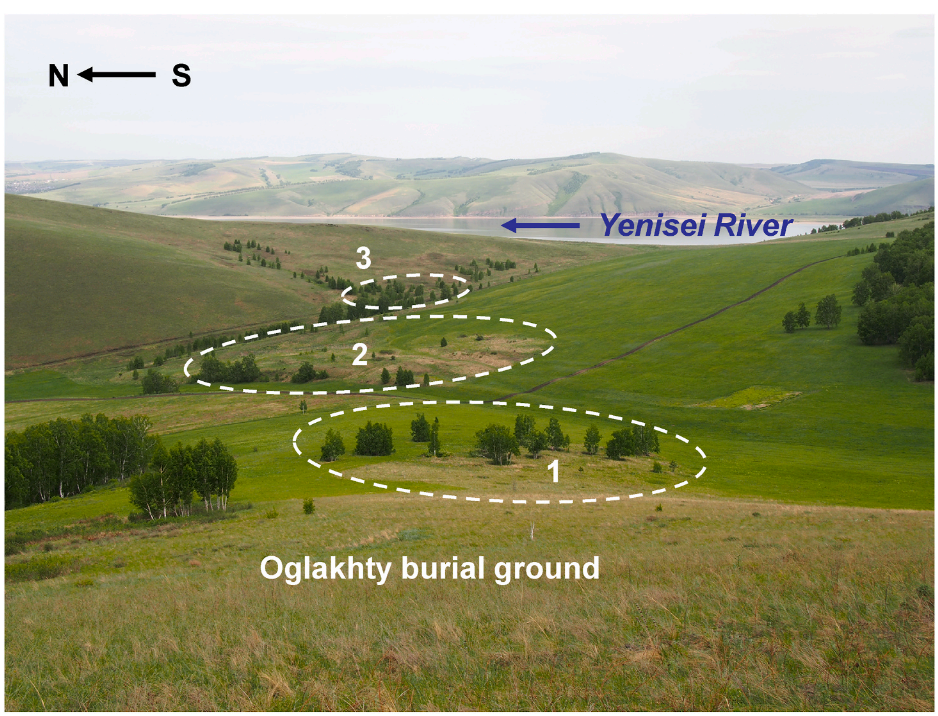

Fig. 2. View of the Oglakhty burial ground with the three burial areas in 2018 (Photo: S. Pankova).

analysis was undertaken using the open-source software mMass (Strohalm et al., 2008). The three spectra generated for each sample were averaged and the average spectrum was manually inspected for the presence of peptide markers designated A–G (Buckley et al., 2009), and P1 and P2 (Buckley et al., 2014). Marker names are also listed according to Brown et al. (2021). Although the ZooMS reference list is not complete, it includes a large amount of species and subspecies in the families of amongst others Bovidae, Cervidae, Carnivora and Perissodactyla, which would be relevant resources for skin items in Siberia. Taxonomic identifications were at the most conservative level (species, genus or family), based on the presence of unambiguous markers. The samples were prepared according to a previously published ZooMS protocol (Fiddyment et al., 2015) modified for archaeological skin (Ebsen et al., 2019).

2.4. Radiocarbon dating

Despite the fact that a lot of wood in Grave 4 is well-preserved, dendrochronological dating turned out to be problematic due to the lack of a reliable master chronology available for the studied region (Pankova et al., 2010). In order to reconstruct the age of the Oglakhty Grave 4, we collected a total of 13 organic matter samples associated with the burial and buried objects (Table 1) for AMS ^{14}C dating. We also recycled two published ^{14}C dates (Table 1) on the outermost rings of two liquid scintillation-dated tree-ring sequences (Pankova et al., 2010), one larch and one pine log (i.e. logs 10 and 17) from the burial chamber (Pankova et al., 2010). All these dates, newly obtained and recycled, were calibrated and analysed in OxCal v.4.4.3 (Bronk Ramsey, 1995) using the up-to-date calibration curve IntCal20 (Reimer et al., 2020). Because the two dates Poz-127827 and Poz-132852 are from the same birch bark sample, they were combined into one modelled date, R_Combine_(Cover), using the 'R_Combine' command in OxCal v.4.4.3 (Lienkaemper and Bronk Ramsey, 2009).

We set up a Bayesian chronological model to estimate the age of the grave. In this chronological model, all abovementioned dates were incorporated as sample data points from an archaeological phase that conceptually models the burial, confined by a start (oldest) and end (youngest) boundary. For the two recycled log-based dates, we applied the default 'charcoal' outlier model in OxCal to treat possible 'old wood' effect associated with them. The threshold values for the agreement indices and convergence followed the software defaults, 60% and 95%, respectively. The ages (i.e. their 99.7% probabilistic ranges) of the two boundaries were considered to be the constraints for a *conservative* age range that encapsulates the probabilistic distribution of the archaeological phase of the burial. In addition to this modelled *conservative* age range, we also analysed the overlap between the calibrated age distributions (99.7% probabilistic ranges) of all the available dates, which can be regarded a *high probability density* estimate of the age of the grave.

2.5. Palaeoenvironmental data

High-resolution pollen records stored in lake sediments are a reliable source of information about vegetation and climate changes and human-environment interactions at regional to local scale (e.g. Kobe et al., 2020; Leipe et al., 2018; Litt et al., 2009; Schubert et al., 2020; Stebich et al., 2015; Zhao et al., 2017). For the purpose of the current study, we employed pollen data from Lake Shira (ca. 353 m a.s.l.), which is a saline-water meromictic lake (e.g. Genova et al., 2010) with an area of 35.9 km^2 and a water depth of ca. 24 m (Kalugin et al., 2013). It is situated ca. 100 km northwest of the Oglakhty burial ground (Fig. 1B) in the climatically and environmentally similar central part of the Minusinsk Basin (Alpat'ev et al., 1976; New et al., 2002). The palynological analysis of the lake sediment core covers the past 2450-year interval with an average 1-cm-sample resolution of 22 years (Hildebrandt et al., 2015). For a comparison with the results from Grave 4 of Oglakhty, we present here in detail the lower part of the published LS9 pollen record and use it for discussion of the vegetation and climate changes in the study area during the Tashtyk culture period along with the published climatic records from the North Atlantic region. The percentage diagram represents pollen and spores of all identified land-plant taxa, which includes arboreal pollen (AP), non-arboreal pollen (NAP) and spores of terrestrial cryptogams. The diagram was constructed using the Windows

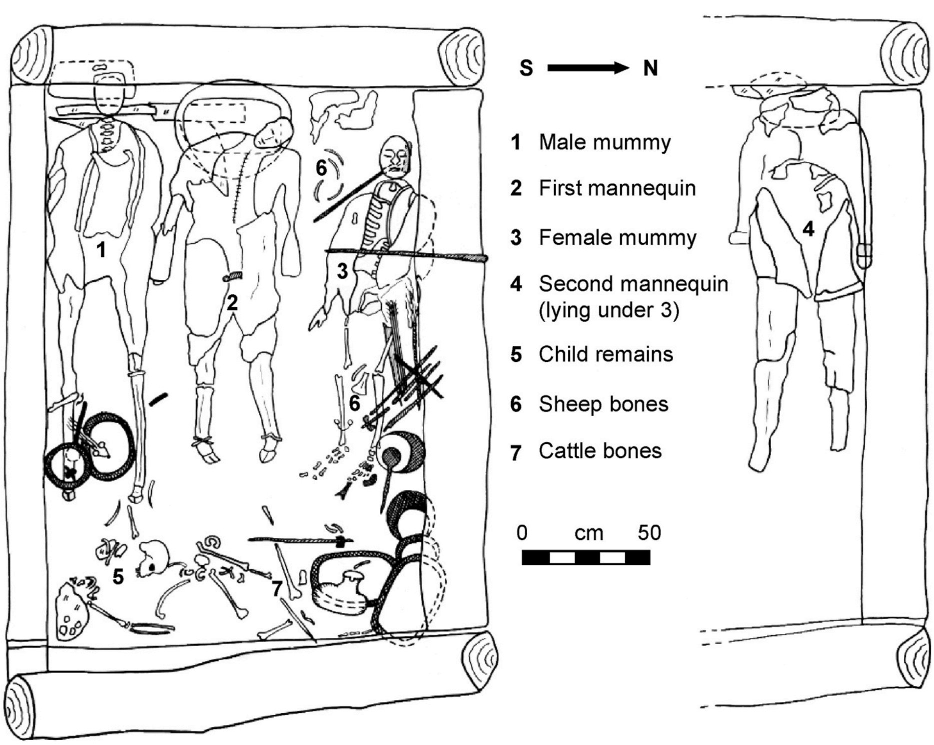

Fig. 3. Drawing of the burial chamber made by L.R. Kyzlasov during the excavation of Grave 4, Oglakhty, in 1969 (after Pankova, 2020b, with modifications).

Table 1
Calibration of ^{14}C dates from Grave 4, Oglakhty. The two re-examined dates are from two published tree-ring sequences based on a *Larix* and a *Pinus* log from the burial chamber (Pankova et al., 2010). The calibrated ages were obtained using the IntCal20 curve in the OxCal v.4.4.3 software package.

Data type	Laboratory code	Dated material	Conventional age (^{14}C BP)	Calibrated 99.7% range (CE)
Published	Le7354	Outermost 10 rings of a larch chamber log	1801 ± 25	128–350
	Le7331	Outermost 6 rings of a pine chamber log	1699 ± 80	76–604
New dates	Poz-127827	Birch bark as part of the wraps for the chamber	1870 ± 30	30–314
	Poz-132852	Same piece of birch bark as Poz-127827	1850 ± 30	76–328
	Poz-75143	Grass as part of the first mannequin's stuffing	1750 ± 30	220–411
	Poz-75196	Sewing leather from the first mannequin's 'skin'	1725 ± 30	238–418
	Poz-128129	Piece of polychrome silk from the first mannequin's head	1815 ± 30	120–361
	Poz-127829	Red woollen textile from the first mannequin's face (chin area)	1850 ± 30	76–328
	Poz-128175	Grass as part of the second mannequin's stuffing (right foot area)	1795 ± 30	126–381
	Poz-127858	Birch bark from a mat under the second mannequin	1800 ± 30	126–377
	Poz-128130	Outer fur coat of the male mummy (right shoulder area)	1725 ± 30	238–418
	Poz-128174	Hair of the male mummy	1840 ± 30	80–335
	Poz-127993	Woollen textile from the female mummy's skirt	1660 ± 30	254–542
	Poz-127826	Birch bark spiral under the left foot of the female mummy	1715 ± 30	240–421
	Poz-129086	Bark strip from a willow stick near the female mummy	1705 ± 30	240–430

version of the Tilia-Tilia-Graph software package (Grimm, 2000, 2011). In the pollen diagram individual taxa percentages are based on the sum of terrestrial pollen taxa taken as 100% and the percentages of cryptogam spore taxa are based on the sum of terrestrial pollen and spores taken as 100%.

Furthermore, the variations in the AP percentages are used as a qualitative indicator of the changes in the regional woody cover and the *Artemisia*/Chenopodiaceae (A/C) pollen ratio as a reliable indicator of moisture availability in semi-arid and arid regions (El-Moslimany, 1990; Leipe et al., 2014; Luo et al., 2010). The total pollen concentration is also a representative indicator of the regional climate. Using available fossil and published instrumental data, our study suggests a link between the North Atlantic warmer/colder temperatures and higher/lower atmospheric precipitation (or moisture availability) in southern Siberia at multidecadal to centennial scales.

3. Results

3.1. Grave 4 chronology

The male mummy (1 in Fig. 3) lay along the southern wall of the burial chamber. Next to the male mummy was found the first mannequin (2 in Fig. 3). The female mummy (3 in Fig. 3) was placed in the northern part of the chamber. Underneath the female mummy was found the second mannequin (4 in Fig. 3), whose preservation condition was relatively poor. Skeleton remains of a child (5 in Fig. 3) were found in the eastern part of the chamber. Various other objects, such as wooden sticks, ceramic pots and animal bones, were scattered on the floor (Fig. 3).

The grave chamber was made of pine and larch logs. The larch was mainly used to construct the walls of the chamber, whereas the ceiling was made mainly of pine logs. Thick strips of birch bark were used to cover the ceiling of the chamber; similar strips were found on the chamber floor. The calibrated age (no. 3 in Fig. 4) of the combined date on the birch bark cover of the burial chamber was chronologically estimated to 81–306 CE (99.7% probabilistic range).

The 'start' and 'end' boundaries date to 12 BCE–326 CE and 157–563 CE, respectively (Fig. 4). The most *conservative* age estimate for the use of the grave ranges therefore between 12 BCE and 563 CE. This chronological range is accurate as it encapsulates the probabilistic distributions of all modelled dates, but it is not precise or very informative. The *high probability density* range distributes between 254 and 306 CE, which gives a more precise age estimate for the use of the grave despite a reduced level of accuracy. In addition, these two dates are well consistent with the archaeological data. Thus, 306 CE represents the end of the 99.7% probability range of the dates obtained on the birch bark covering the burial chamber, which is archaeologically associated with the grave closing. This date makes all younger ages for the grave construction and use archaeologically and statistically unjustifiable. In turn, 254 CE points to the beginning of the 99.7% probability range of the date obtained on a woollen skirt from the female mummy (Table 1). Since we have no conclusive evidence that Grave 4 was opened several times, we accept this date as the earliest possible for the grave construction.

3.2. Animal remains from Grave 4

The results of fur identification summarised in Table 2 suggest a broad range of wild and domesticated animals that were used for making clothes and utensils found in Grave 4. Among the domesticated animals, sheep, goat and possibly dog and reindeer should be mentioned, while the group of the hunted wild animals includes Eurasian otter, sable, weasel, red squirrel, wolverine, brown bear, Siberian roe deer and possibly red deer (Vereshchagin, archive note), wolf and fox, i.e. species that are still present in the region (Alpat'ev et al., 1976). The most exotic species revealed by the analyses is reindeer (*Rangifer tarandus*), whose skin and hairs were found in at least four objects from Grave 4: the cushion, the outer coat of the male mummy, the coat of the second mannequin and the front part of the bow and arrow case model. Although the distribution area of reindeer has changed significantly as a result of human activities, both wild and domesticated forms are present today in the tundra and taiga regions of Siberia north and south of Oglakhty, for example, in the mountainous forests of the Eastern Sayan and Kuznetsky Alatau in Southern Siberia and at the border to Mongolia (Vainshtein, 1960; Rassadin, 2018).

The very good preservation of the plumage of the arrow shafts from Grave 4 made it possible to determine the species of birds whose feathers were used in the manufacture of arrows. Five arrow shafts (four shafts are 47 cm long and the fifth one with destroyed plumage is 39.5 cm long) with the tips removed were found in the gorytos – a miniature leather case, in the compartments of which the bow and whip models were also placed (Nikolaev and Pankova, 2017; Pankova, 2021). The four shafts have preserved the plumage of three blades, each of which is a half of a feather (6.5–7 cm long), glued to the shaft by the back part. The length of the shafts allows to consider them as models, since the normal length of arrows in Asian quivers reached 70 cm and more (Kubarev, 1981). However, the diameter of all shafts (0.7–0.8 cm) and carefully glued plumage suggest that real but cut arrows were used for placement in the grave. The white-brown pattern of the feathers is typical for birds of prey – Falconidae and Accipitridae. The first group can be excluded from consideration, since of the three species of large falcons, suitable for the size of the feathers, the white colour appears in a different pattern (i.e. parallel grey-white stripes on the tail feathers of the gyrfalcon, *Falco*

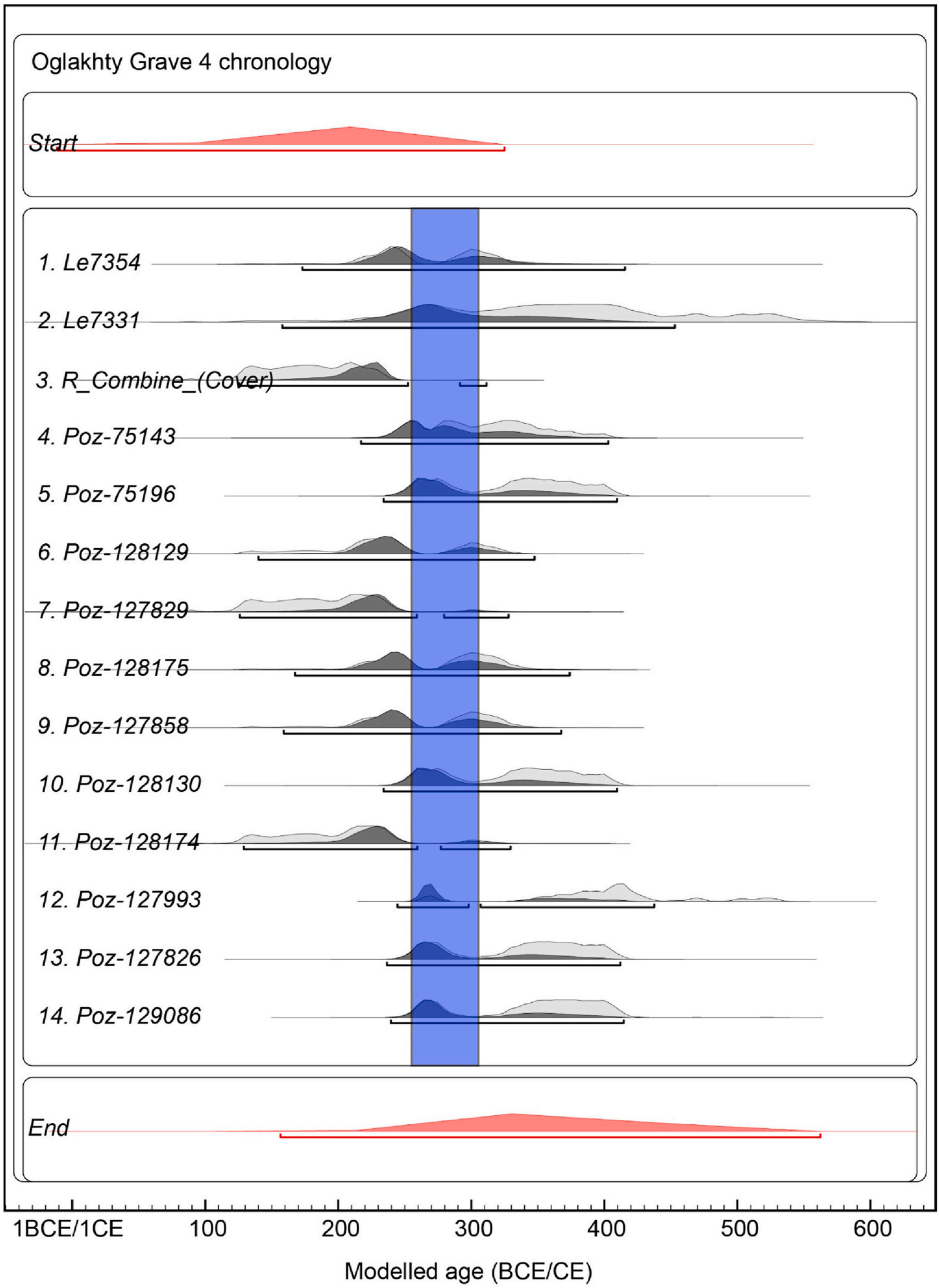

Fig. 4. Distribution of calibrated ages of archaeological ^{14}C dates (Table 1) from Grave 4 discussed in this study. The light grey areas represent unmodelled probability distributions of calibrated ^{14}C dates and dark grey areas represent their modelled probability distributions. R_Combine_(Cover) is a modelled combination of two ^{14}C dates, Poz-127827 and Poz-132852. The combination of the Start and End boundaries (square brackets below the red areas) provides a *conservative* range that encapsulates the distributions of modelled dates. The vertical blue band from 254 to 306 CE indicates the overlap amongst the 99.7% probabilistic ranges of all studied ^{14}C dates, i.e. the estimated *high probability density* range from construction to final closure of the grave. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

rusticolus) than on the arrows from Grave 4. The species diversity of representatives of Accipitridae with feathers of a certain size in the study area is not very large. In terms of pattern, colour and size, the Oglakhty feathers clearly belong to one of three species of buzzards. The upland buzzard (*Buteo hemilasius*) is the largest of them. It is characterized by black-reddish-white colours. The common buzzard (*Buteo buteo*) is the smallest in this group and has the darkest colour. The rough-legged buzzard (*Buteo lagopus*) has a rather light colouration with a characteristic combination of brown and off-white spots, the same as can be seen on the four well-preserved arrows. This species nests in the tundra, forest-tundra and northern taiga, but migrates to the southern regions of Siberia and Mongolia during the cold season (Rogacheva, 1988). In the study region, the rough-legged buzzard occurs from October to April and was probably hunted during this period in the past.

Analysis of food residue from the 16-cm-high ceramic pot indicates that the pot contained substances of lipid nature. According to existing approaches, the identification of the type of lipid substance is determined by the ratio of azelaic, palmitic and stearic acids present in the analysed sample as well as by the presence of biomarkers (Mills, 1966; Evershed et al., 2002).

In the analysed sample, azelaic acid is practically absent and the ratio of palmitic and stearic acids (P/S) is 0.9. This points to animal fat. The sample also contains biomarkers, such as odd-carbon-numbered straight-chain fatty acids (i.e. C15:0, C17:0, C19:0), which are typical for ruminant fat. This conclusion is also supported by the presence of several isomers of octadecenoic acid. Based on the above results, the pot originally contained food based on ruminant broth.

The samples analysed using the ZooMS method showed poor preservation of collagen, which resulted in low-quality spectra with no or few diagnostic markers of varying intensity. While eight samples gave

Table 2
Identifications of animal fur and skin samples from Grave 4, Oglakhty. Identifications done by N. Vereshchagin (Zoological Institute, USSR Academy of Sciences). The asterisk indicates the skin sample from the gorytus model analysed by E. Mikolaichuk (State Hermitage Museum, St. Petersburg).

Sample affiliation	Studied object	Analysed part	Identified animal (common name)	Identified animal (Latin name)
Male mummy	inner coat	body part	domestic sheep or goat	*Ovis aries* or *Capra aegagrus hircus*
		edgings	wolf or dog	*Canis lupus* or *C. lupus familiaris*
	outer coat	body part	reindeer (adult)	*Rangifer tarandus*
	left mitten or a coat cuff		Eurasian otter	*Lutra lutra*
	trousers		domestic sheep or goat	*O. aries* or *C. aegagrus hircus*
	cap	upper part	young fox or dog	*Vulpes vulpes* or *C. lupus familiaris*
		face cover	sable	*Martes zibellina*
	chest cover (tiny pieces)	vertical edges on both sides	Siberian weasel or mountain weasel	*Mustela sibirica* or *M. altaica*
		face side, low edging	sable and otter (from stomach and paws)	*M. zibellina* and *L. lutra*
		face side, centre	Siberian weasel or short-tailed weasel	*M. sibirica* or *M. erminea*
		reverse side, centre	Eurasian red squirrel (stomach and sides)	*Sciurus vulgaris*
	pouch		Siberian weasel	*M. sibirica*
Female mummy	coat	body part	domestic goat	*C. aegagrus hircus*
		edgings	wolverine or brown bear	*Gulo gulo* or *Ursus arctos*
		narrow edgings	sable or young fox	*M. zibellina* or *V. vulpes*
First mannequin	coat	body part	Siberian roe deer (narrow pieces from the legs)	*Capreolus pygargus*
		left cuff	dog	*C. lupus familiaris*
	trousers		black domestic goat	*C. aegagrus hircus*
Second mannequin	coat	body part	domestic goat and adult reindeer	*C. aegagrus hircus* and *R. tarandus*
		edging	dog	*C. lupus familiaris*
	trousers		domestic goat	*C. aegagrus hircus*
	cushion stuffing	animal hair	reindeer	*R. tarandus*
	a model of a quiver	front side, outer surface	reindeer*	*R. tarandus*
Disarticulated find	cap	low side	domestic goat (white hairs)	*C. aegagrus hircus*

no identifications, one sample (O16), based on markers shared between several species, could be identified to a species within the families of Bovidae or Cervidae. For one sample (O12), the families of Bovidae and Cervidae could be ruled out based on the presence of marker B, COL1α2 484–498. Based on the geographical context and the use of skin, this sample most likely derives from a species of either Carnivora or Glires. The latter group also includes hares. The poor preservation of collagen was very surprising compared to the expectations for morphologically well-preserved samples from a cold archaeological environment. Samples from the left mitten had been conserved prior to sampling, whereas samples from the right mitten were taken before conservation. Given that the collagen preservation was similar in both mittens, this does not seem to explain the poor results.

3.3. Plant remains from Grave 4

The majority of the identified plant remains (Table 3) represent numerous wooden objects from the grave as well as logs of the burial chamber. The burial chamber was constructed using trunks of conifer tree species, larch (12 logs) and Scots pine (7 logs). Large pieces of birch bark were used for insulation and protection of the chamber and its content from ground water. Rather numerous wooden objects found in the chamber are made of birch (9), poplar (3), spruce (3), Scots pine (2) and larch (1) trees and of willow (14) and spirea (1) shrubs. Dry herbaceous plants used as the stuffing of the leather mannequins and pillows are represented by members of Poaceae, mainly different species of *Stipa* grass (Table 3).

4. Discussion

4.1. Chronological issues

The chronology of the ancient Oglakhty cemetery has been discussed since the first excavations and spectacular finds reported by A.V. Adrianov (e.g. Teploukhov, 1929; Sosnovskii, 1933; Tallgren, 1937). Earlier publications, which considered the absolute age of the Oglakhty burial ground and the best-preserved Grave 4, employed typological dating and a comparison of the burial tradition and burial items using the method of the closest analogues (see Pankova et al., 2010 for details and references). However, the ages proposed by different authors were ambiguous and covered a fairly wide time interval from the 1st century BCE to the middle of the 1st millennium CE (Vadetskaya, 1999; Azbelev, 2007; Pankova et al., 2010, 2020 and references therein). The first attempt of absolute age determination using ^{14}C dating and wiggle matching methods was applied to the set of samples from two wooden logs (Table 1) from the burial chamber of Grave 4 (Pankova et al., 2010). Due to the shape of the calibration curve during the early 1st millennium CE, the conversion of the obtained ^{14}C dates into calendar ages suggests two intervals (260–296 and 372–402 CE). However, the age of the timber provides information about the tree lifespan and year of the logging, but not necessarily the year of grave construction and final closing because it may have been used secondarily or prepared in advance. The same concern can be applied to the different burial objects, including furniture and silks, which could have been produced long before the funeral ceremony itself. Closest to the time of burial comes the age of short-lived materials such as herbaceous plant remains, thin twigs, seeds, remains of the plant food, etc. However, the picture can be even more complicated, if a burial was reopened and used several times (i.e. representing multiple burial phases), which was quite typical for Tashtyk graves (Vadetskaya, 1999; Zaitceva et al., 2021). In the case of Grave 4, however, the lack of clear evidence prevents us from going further on this topic, assuming that all burials occurred simultaneously or in a relatively short period of time, which cannot be determined using the ^{14}C dating method.

Pankova et al. (2020) used two new AMS ^{14}C dates obtained on the grass sample from the first mannequin's stuffing (Poz-75143) and on the leather sample from the mannequin's 'skin' (Poz-75196) together with the two published tree ring sequences from Pankova et al. (2010) for reanalysis using OxCal v.4.3 (Bronk Ramsey, 1995) and IntCal13 as the calibration curve. The results were used in a Bayesian model in OxCal v.4.3 with an integrated 'SSimple' model (Bronk Ramsey, 2009) in order to reduce the influence of possible outliers. The default 'D-sequence' model (Bronk Ramsey, 2008) was used for wiggle matching of the tree ring sequences. The two data from the short-lived material were combined with the 'R_Combine' command (Lienkaemper and Bronk Ramsey, 2009). The results of this experiment provided an approximate age for the short-lived material of 251–380 CE (95.4% probability), while the outermost 10 tree rings of the larch log were dated to 167–241 CE and the outermost 6 rings of the pine log dated to 237–268 CE (95.4% probability). The modelling demonstrated that the age interval obtained

Table 3
Identifications of wooden objects from Grave 4, Oglakhty. Wood objects and burial chamber logs were analysed by M. Kolosova and A. Stepanova (sample D 4556 marked with an asterisk) from the State Hermitage Museum, St. Petersburg) and stuffing grass from the two mannequins and pillows was analysed by A. Kalinina (former Botanical Institute of the USSR Academy of Sciences, Leningrad).

Laboratory number	Inventory number	Studied object	Identified plant
D 4536	2864/8	Bowl	Birch (*Betula* sp.)
D 4537	2864/9	Small platter	Birch (*Betula* sp.)
D 4538	2864/10	Platter	Birch (*Betula* sp.)
D 4539	2864/11а	Stick	Willow (*Salix* sp.)
D 4540	2864/11б	Stick	Willow (*Salix* sp.)
D 4541	2864/12	Platter	Poplar (*Populus* sp.)
D 4542	2864/13	Ladle	Birch (*Betula* sp.)
D 4543	2864/14	Ladle	Birch (*Betula* sp.)
D 4544	2864/15	Whisk (rod)	Poplar (*Populus* sp.)
D 4545	2864/21а	Bow case rib	Willow (*Salix* sp.)
D 4546	2864/21б	Model of bow	Spirea (*Spiraea* sp.)
D 4547	2864/21в	Arrow shaft	Birch (*Betula* sp.)
D 4548	2864/23	Model of cheekpiece	Willow (*Salix* sp.)
D 4549	2864/25	Model of cheekpiece	Willow (*Salix* sp.)
D 4550	2864/27а	Model of cheekpiece	Birch (*Betula* sp.)
D 4551	2864/27б	Model of horse trapping device	Birch (*Betula* sp.)
D 4552	2864/37	Head rest	Scots pine (*Pinus sylvestris*)
D 4553	2864/38	Head rest	Spruce (*Picea* sp.)
D 4554	2864/39	Round applique	Willow (*Salix* sp.)
D 4555	2864/42	Small plank	Willow (*Salix* sp.)
D 4556*	2864/45	Stick	Birch (*Betula* sp.) *
D 4557	2864/46	Rod	Spruce (*Picea* sp.)
D 4558	2864/47	Stick	Spruce (*Picea* sp.)
D 4559	2864/50	Rod	Willow (*Salix* sp.)
D 4560	2864/51	Rod	Willow (*Salix* sp.)
D 4561	2864/43	Small plank	Willow (*Salix* sp.)
D 4562	2864/44	Small plank	Poplar (*Populus* sp.)
D 4563	2864/49	Stick with forked ending	Willow (*Salix* sp.)
D 4564	2864/54	Pointed stick	Willow (*Salix* sp.)
D 4565	2864/53а	Flat fragment	Larch (*Larix* sp.)
D 4566	2864/53 б	Flat fragment	Scots pine (*Pinus sylvestris*)
D 4567	2864/56б	Plank	Willow (*Salix* sp.)
D 4568	2864/56а	Plank	Willow (*Salix* sp.)
D 4934	Log 1	Burial chamber, long wall	Larch (*Larix* sp.)
D 4935	Log 2	Burial chamber, long wall	Larch (*Larix* sp.)
D 4936	Log 3	Burial chamber, long wall	Larch (*Larix* sp.)
D 4937	Log 4	Burial chamber, long wall	Larch (*Larix* sp.)
D 4938	Log 5	Burial chamber, short wall	Scots pine (*Pinus sylvestris*)
D 4939	Log 6	Burial chamber, short wall	Scots pine (*Pinus sylvestris*)
D 4940	Log 7	Burial chamber, short wall	Larch (*Larix* sp.)
D 4941	Log 8	Burial chamber, short wall	Larch (*Larix* sp.)
D 4942	Log 9	Burial chamber, short wall	Larch (*Larix* sp.)
D 4943	Log 10	Burial chamber, short wall	Larch (*Larix* sp.)
D 4944	Log 11	Burial chamber, ceiling, 1 mark	Larch (*Larix* sp.)
D 4945	Log 12	Burial chamber, ceiling, 2 marks	Scots pine (*Pinus sylvestris*)
D 4946	Log 13	Burial chamber, ceiling, 3 marks	Scots pine (*Pinus sylvestris*)
D 4947	Log 14	Burial chamber, ceiling, 4 marks	Larch (*Larix* sp.)
D 4948	Log 15	Burial chamber, ceiling, 5 marks	Scots pine (*Pinus sylvestris*)
D 4949	Log 16	Burial chamber, ceiling, 6 marks	Scots pine (*Pinus sylvestris*)
D 4950	Log 17	Burial chamber, ceiling, 7 marks	Scots pine (*Pinus sylvestris*)
D 4951	Log 18	Burial chamber, ceiling, 8 marks	Larch (*Larix* sp.)
D 4952	Log 19	Burial chamber, ceiling, no marks	Larch (*Larix* sp.)
		Effigies 1 and 2, stuffing, plant leaves	Grasses (Poaceae, mainly *Stipa rubens* with admixture of *Stipa joannis*)
		Pillow, stuffing, plant leaves	Grasses (Poaceae, *Stipa krylovii*)

for the short-lived samples, likely representing the time of burial, does not or partially overlap with those of the larch and pine logs. This could be a sign that at least some of the trees for the burial chamber could have been felled a few years to decades before the construction of the tomb. To verify this suggestion, all logs of the chamber should be systematically analysed using dendrochronological analysis, wiggle matching approaches and AMS ^{14}C dating of the outermost rings.

The results obtained in the current study (Fig. 4), using a larger set of consistently analysed AMS ^{14}C dates representing different types of material from Grave 4 (Table 1) date the interval of the grave chamber building and use to between 254 and 306 CE at a 99.7% probability level. This interval includes the early range (260–296 CE) reported by Pankova et al. (2010), but excludes the later range (372–402 CE), which was initially regarded as the most probable.

A robust chronology helps to better understand the place of the Oglakhty population in the Iron Age history of Eurasia and their possible contacts to other peoples of Central Asia. It has already been suspected that the Tashtyk culture was ethnically heterogeneous (e.g. Debets, 1948; Alekseev, 1961; Keyser et al., 2009) and that the introduction of cremation went hand in hand with the immigration of a new population (e.g. Nikolaev and Pankova, 2017). Most of the approximately 300 Tashtyk graves uncovered today contain ceramic vessels and small bone and metal objects, from which neither the origin of these migrants nor the time can be easily read. Some graves contain glass beads, lacquer objects and silk fabrics that have yet to be analysed (Pankova et al., 2020).

The reconstructed age of Grave 4 postdates the Eastern Han Dynasty (25–220 CE), but overlaps with the last years of the Cao Wei State

(220–265 CE) and with most of the Western Jin (265–316 CE). From the 3rd century CE political and cultural life in Central Asia acquired a new dynamic. The time of the Scythians and Xiongnu was over; great empires such as the Kushan and Han disintegrated into many short-lived rival states; formerly prosperous oases in the south of the Tarim Basin, such as Niya and Loulan, suffered from water shortage and desertification; in the north, at the foothills of the Tian Shan mountains, new centres of trade and Buddhist religion emerged as caravan routes that also followed Buddhism spread, moved there (Millward, 2007, 2013).

There are no texts or images in the tombs of Oglakhty that indicate Buddhism. What indicates a connection to places with early Buddhist communities in the Tarim Basin, however, are some funeral rituals (i.e. cremation) and fragments of Chinese silk that were found in Oglakhty (Riboud and Loubo-Lesnichenko, 1973; Pankova and Mikolaychuk, 2019; Pankova, 2020b). Buddhism called for the soul to be detached from the dead body through cremation. But according to Chinese as well as local Siberian tradition, the body was needed for continuing life in the hereafter. The way out of this dilemma was a full-fledged imitation of a human body with ashes, the 'essence' of a deceased person, placed inside a mannequin (Shen, 2006; Pankova et al., 2020; Pankova and Shirobokov, 2021). Polychrome *jin* silks (such as those found in Grave 4; Pankova and Mikolaichuk, 2019) were produced in eastern China during the Eastern Han and the Wei and Jin periods (Li, 2012). As the payment to officers in Chinese garrisons, trade goods or diplomatic gifts, these silks came to the oasis cities in the Tarim Basin in the west and to the Xiongnu in the north (Millward, 2013). Textile fragments that correspond to those from Grave 4 were found in graves near Niya and Loulan (Pankova and Mikolaychuk, 2019 and references therein). These two city-states in the Tarim Basin are not only important trading centres and Chinese garrisons known through the 1st century BCE to the 4th century CE but also as places through which Buddhism was spread eastwards from northern India under the influence of the Kushan (Millward, 2007). Later, monasteries were built in mountain caves on the northern edge of the Tarim basin at Kucha and Turfan, which have been expanded for centuries from then on. In the Tarim Basin, *jin* silk was used in the context of Buddhism and nothing contradicts contacts between this region and the Minusinsk Basin in the Yenisei valley. After the fall of the Han Empire in 220 CE, *jin* silk continued to be produced in eastern China, albeit for other rulers, whose core area was the steppe and forest-steppe regions of southern Siberia and Mongolia (Parzinger, 2006) and who definitely had contacts to the valley of the Yenisei (Pankova et al., 2020). These are just two of the possible scenarios which explain appearance of Chinese silks in the Oglakhty burials and should be tested within the scope of future research.

4.2. Use of plant and animal resources

The results of archaeological excavations as well as archaeozoological and archaeobotanical analyses of organic remains from Grave 4 give an idea of the plants and animals that were available to the Oglakhty people and an important part of their economy in the 3rd century CE. Wood was the readily available and common resource used for the construction of solid grave chambers (and most likely houses) as well as for making many other objects, such as household items, working tools, weapons and furniture (e.g. Sosnovskii, 1933; Pankova et al., 2010; Nikolaev and Pankova, 2017). The woody objects identified in Grave 4 are made of birch, pine, larch and spruce as well as poplar and willow, which are still common in the region today (Alpat'ev et al., 1976). Grave 4 is not an exception (Pankova et al., 2021). A.V. Adrianov also left a description of the grave chamber lined from outside with birch bark and made of carefully cut and hewn thick larch trunks with ceiling logs being ca. 22 cm in diameter and some of the wall logs up to 45 cm in diameter (Sosnovskii, 1933). Enclosed burial chambers (170–240 cm long, 97–165 cm wide, 57–160 cm deep) made of thick larch and pine logs with rounded ends were also found in the other excavated graves. These wooden frames were carefully lined with 10–13 layers of birch bark with a total thickness of up to 18 cm (Sosnovskii, 1933).

In contrast to the trees representing patchy watershed and riparian forests, several species of herbaceous plants (i.e. *Stipa rubens*, *S. joannis*, *S. krylovii*) identified in the stuffing of pillows and mannequins are common in the regional steppe vegetation predominated by *Stipa* and *Festuca* species with an admixture of diverse meadow plants in the wetter environments (Alpat'ev et al., 1976). Among the identified woody plants from Grave 4, spirea (*Spiraea* sp. used for the bow model) represents a genus of deciduous shrub species in the family Rosaceae. They are widespread in the shrubby mountain steppe and forest-steppe of the region and very resistant to the cold and dry climate (Alpat'ev et al., 1976).

Without doubts the list of the plants used in the economy of the Tashtyk population of Oglakhty is much longer than that presented in this study (Table 3) based on a single grave. Multidisciplinary studies of the other graves carried out recently or planned in the near future along with the application of systematic water flotation and plant aDNA analyses of soil samples from the cultural layers will help to get more information. Chemical analyses of the organic dyes used in textile making and for painting the masks, wooden vessels, ladles, arrow shafts and other objects may also provide important information about the plants that were collected or cultivated by the ancient populations and illuminate their contacts with other regions (e.g. Polosmak and Barkova, 2005; Kramell et al., 2014, 2016; Schmidt et al., 2020).

The economy of the Tashtyk culture and the population of Oglakhty was described as complex, based on animal husbandry and agriculture complemented by hunting, fishing and gathering of wild resources (e.g. Sosnovskii, 1933; Parzinger, 2006; Kyzlasov, 1969, 1992; Pankova et al., 2010). Although there is no direct evidence of cultivated plants in Grave 4, a pilot isotopic study of hair and braided hairpieces of three individuals from this grave and from Grave 1 of Adrianov's excavation at Oglakhty suggested that C_4 plants (probably millet) contributed to their diet as well as fish, C_3 plants, meat and dairy products (Shishlina et al., 2016). 'Millet glumes' from Grave 4 were noted in the field report, but poor preservation did not allow to confirm this (Kyzlasov, 1970). Millet grains were also mentioned in the reports of earlier archaeological excavations at Oglakhty (Sosnovskii, 1933). Later scientific analysis of the seeds from Adrianov's excavation made at the Moscow State University approved this finding and identified the seeds as broomcorn millet (*Panicum miliaceum*) (Kyzlasov, 1960). In the early 1st millennium CE, millet was already cultivated in many regions of northern Asia, including eastern Kazakhstan, the northern and western parts of China, Trans-Baikal and Primorye (e.g. Leipe et al., 2019; Kradin et al., 2021 and references therein). A recent review of millet spread across the steppe regions of Eurasia (Svyatko et al., 2021) emphasises that the earliest isotope-based evidence of millet consumption in southern Siberia and the Minusinsk Basin can be dated back to the 14th century BCE. However, in the absence of directly dated millet fossils, the role of agriculture and millet cultivation for the Tashtyk population of Oglakhty remains an important topic for upcoming research.

The animal remains identified in Grave 4 are numerous and diverse (Table 2), indicating that the people of Oglakhty were engaged in animal husbandry and hunting for different purposes, including food, clothing and tool making. The bones of domesticated sheep and cattle found on the floor of the burial chamber (i.e. 6 and 7 in Fig. 3) are the remains of ritual food offering and direct evidence of sheep and cattle husbandry. Fragments of miniature iron bits with wooden cheekpieces clearly indicate the use of horses in the local economy. This is supported by the reports of Adrianov's excavations saying that the bones of domesticated horse, cattle and sheep were found in the graves with the deceased. Most often sheep shoulder blades and ribs and occasionally ribs and ankles of cattle were found in the burials (Sosnovskii, 1933). Together with the evidence for the use of sheep skins and wool for clothing (Table 2) and textiles (Pankova, 2020a, 2020b), this may indicate a greater role of sheep than cattle in the local economy.

The wild animal remains demonstrate a broad spectrum of habitats, both close to the site (i.e. forest-steppe and steppe) and more distant (i.e. mountain taiga), available seasonally or throughout the whole year. This feature may indicate exchange with hunter-gatherer groups from the mountain taiga region located upstream of the Yenisei River, but also the existence of a class of professional hunters. The use of horses would have facilitated both long-distance exchange and hunting. The identification of reindeer reported in this study (Table 2) is the earliest evidences of reindeer skin and hair use in the Minusinsk Basin, albeit stuffing made from reindeer hair was used in saddle pillows found in the kurgan burials of the Pazyryk culture in the Altai mountains dated to the late 1st millennium BCE (e.g. Gryaznov, 1950; Rudenko, 1953). In the rock carvings of the Tagar culture at Boyary site dated to the end of the 1st millennium BCE, a reindeer herd is depicted within a 'settlement', which led to the hypothesis of their domestication in the Minusinsk Basin already at that time (Devlet, 1965). The earliest evidence of reindeer husbandry in the Sayan Mountains are wooden figurines of reindeer with harness straps, found in a burial of the 5–7 centuries CE in the southern part of the Republic of Khakassia (Kyzlasov, 1960).

Last but not least, we are aware that a burial complex, even as rich and informative as Grave 4 discussed here, is a deliberate choice of materials and objects that does not reflect the entire environment of the area. Natural archives, including pollen (e.g. Litt et al., 2009), plant macrofossils (Kienast et al., 2005) and ancient DNA records (e.g. Willerslev et al., 2014) stored in lacustrine and peat sediments, can provide a more detailed and objective picture of the plant and animal communities that prevailed in the study region in the past.

4.3. Palaeoenvironments

Palaeoenvironmental records from the region are still rare (e.g. van Geel et al., 2004; Blyakharchuk et al., 2014), while dating quality and insufficient resolution create additional problems for the reconstruction of past environments and climate. A pollen record from Lake Shira (Hildebrandt et al., 2015) is one of the closest to the cemetery of Oglakhty (Fig. 1B) and covers the discussed interval including the Grave 4 construction phase (Fig. 5). The pollen data summarised in Fig. 5 shows the co-dominance of arboreal and non-arboreal taxa, which reflects the forest-steppe landscape during the millennium between 400 BCE and 600 CE. Birch (*Betula*) and pine (mainly *P. sylvestris*) are major contributors of arboreal pollen, suggesting spread of these trees in the region. The other arboreal taxa, such as willow (*Salix*), larch (*Larix*), spruce (*Picea*) and fir (*Abies*), are minor pollen contributors, which however can be explained by different reasons. Pollen grains of willow and larch are poorly dispersed and therefore better indicate presence/absence of these plants in the local vegetation close to the pollen sampling site (i.e. Tarasov et al., 1998; Müller et al., 2010 and references therein). Their presence in the pollen spectra normally reflects their local growth. Spruce and fir produce large pollen grains, which are not subject to long-distance air transport. Presence of these boreal evergreen conifer taxa in the pollen assemblage indicates their growth in the region, likely in sufficiently moist environments protected from direct sunshine, e.g. in the patchy forests of mountain or/and river valleys. Among the non-arboreal pollen taxa, wormwood (*Artemisia*) and grasses (Poaceae) predominate, although numerous minor herbaceous taxa are detected in the pollen assemblage. Such pollen composition reflects the modern plant composition of the wormwood-grassland steppe and meadow-steppe in the region (Gerasimov, 1964; Alpat'ev et al., 1976). Comparison of the fossil assemblage composition (Fig. 5) with the surface pollen sample composition representing the modern vegetation near Lake Shira (Hildebrandt et al., 2015) demonstrates higher birch percentage values due to the tree planting activities started in the 1960s.

In attempt to evaluate the climate conditions in the study region during the Tashtyk culture period (Fig. 6G) and the construction of Grave 4, we summarised here some of the regional moisture indicators (Fig. 6A–C; Hildebrandt et al., 2015), extra-regional records of temperature from the Altai Mountains in southern Siberia (Fig. 6D; Aizen et al., 2016) and from Greenland (Fig. 6E; Svensson et al., 2008) and the North Atlantic Oscillation (NAO) record of moisture variability (Fig. 6F; Olsen et al., 2012). The available palaeoenvironmental records from Lake Shira suggest somewhat drier conditions during the 4th to 1st centuries BCE, partly corresponding to a colder and dryer phase in the North Atlantic region. The regional pollen and isotope records demonstrate a weak trend towards wetter and warmer climate during the following five centuries when the Tashtyk culture thrived.

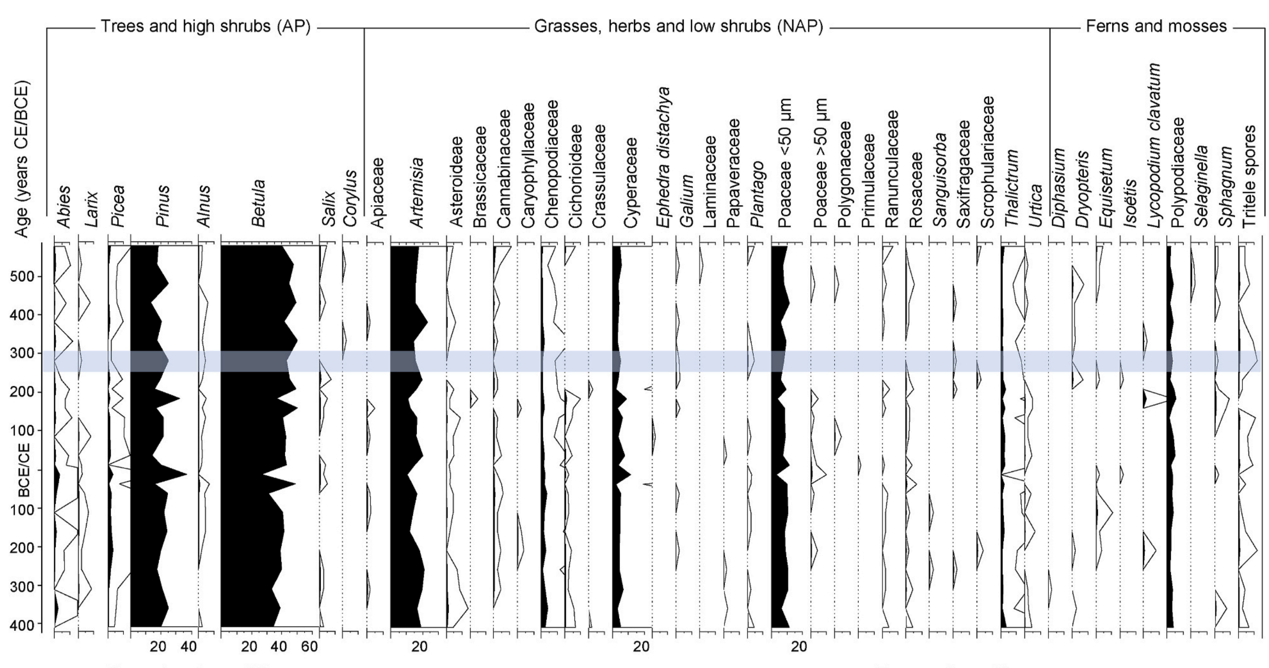

Fig. 5. Percentage diagram representing the lower part of the LS9 pollen record from Lake Shira (after Hildebrandt et al., 2015, with modifications) plotted against the age axis. Horizontal band indicates the estimated range from construction to final closure of Grave 4 (254–306 CE; see Fig. 4 for details).

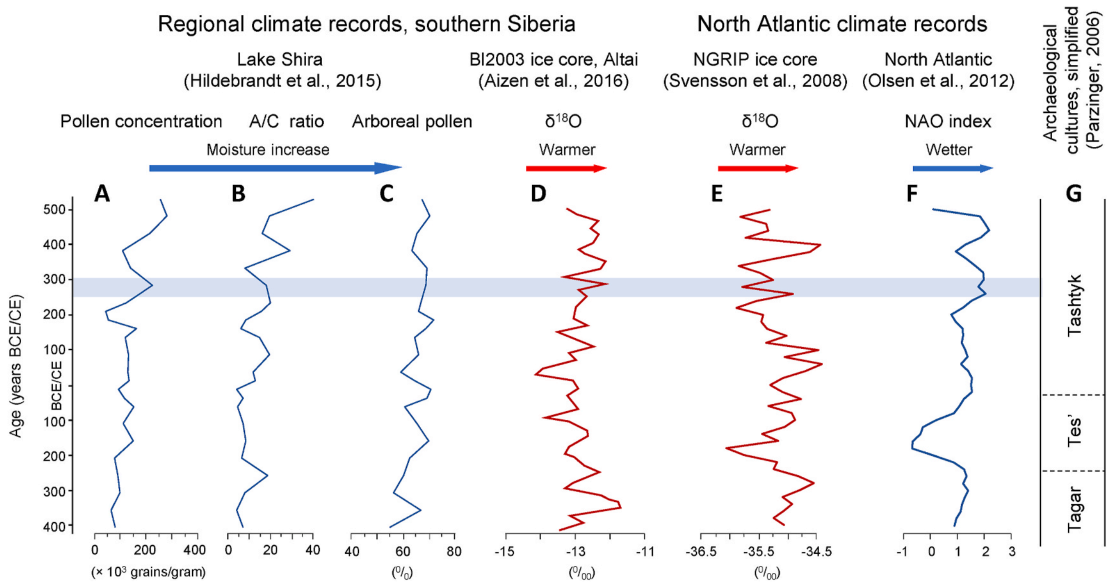

Fig. 6. Selected vegetation and climate proxy records discussed in the text. Changes in pollen concentrations (A), *Artemisia*/Chenopodiaceae (A/C) pollen ratio (B) and percentages of arboreal pollen (AP) taxa (C) in the LS9 pollen record from Lake Shira (after Hildebrandt et al., 2015, with modifications); (D) BI2003 ice core $\delta^{18}O$ record from the Altai Mountains (Aizen et al., 2016); (E) NGRIP ice core $\delta^{18}O$ record from Greenland (Svensson et al., 2008) resampled to the GICC05 time scale (Vinther et al., 2006); (F) lake sediment-based North Atlantic Oscillation (NAO) reconstruction (Olsen et al., 2012). The estimated range from construction to final closure of the studied Grave 4 (horizontal band) and (G) regional cultural periods (simplified from Parzinger, 2006) are shown for comparison.

5. Conclusions

An extensive set of ^{14}C, archaeobotanical and zooarchaeological data from Grave 4, Oglakhty burial ground, improves our understanding of the natural environments and way of life in this remote region of Central Asia during the early 1st millennium CE.

Our results show that a reasonable number of ^{14}C dates on different materials help to narrow the most probable funeral time period to an interval between 254 and 306 CE, which sets the time frame for discussing possible contacts between the Tashtyk people and their neighbours during the 3rd century CE.

The archaeological records of the well-preserved Grave 4 excavated in 1969 demonstrate that the Oglakhty cemetery as a whole has a great potential for better understanding the key aspects of the Tashtyk culture and the local people's lifestyle based on multi-species animal husbandry supplemented by plant cultivation and extensive use of natural plant and animal resources provided by the diverse landscapes of the Minusinsk Basin and the Yenisei River valley with its numerous tributaries.

The archaeological records from Oglakhty suggest that sheep were probably the most important component of the local economy in the early 1st millennium CE, while goats, cattle and horses were also part of the livestock. The use of horses facilitated long-distant exchange and contacts with communities further south or east of the study region, as indicated by the *jin* silks produced in eastern China. Answering the question of whether reindeer in the Oglakhty area were wild or domesticated requires further study.

The role of climate in the life and economy of the local populations during the past millennia is still poorly understood and requires further in-depth investigation using potentially available environmental records stored in lake sediments and dendrological archives. Considering the large amount of wood used for grave (and possibly house) construction and the diverse agropastoral practices of the local people, studying the potential human impact on the environment is another important task of the ongoing geoarchaeological research in Oglakhty.

Author contributions

Conceptualisation, S.V.P, P.E.T., M.W.; Material and data collection, S.V.P, P.E.T., M.W., I.L.K.; Methodology, P.E.T., T.L., K.B.K., A.V.P., L.Ø. B.; Analysis, T.L., P.E.T., S.V.P, K.B.K., A.V.P., L.Ø.B.; Writing (original draft), P.E.T., S.V.P, M.W., T.L., C.L.; Writing (review and editing), all authors; Visualization, P.E.T., C.L., T.L., S.V.P.

Data availability

All data generated during this study are included in this article.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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