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The Late Pleistocene megafauna of the Chulym River basin, southeastern West Siberian Plain: chronology and stable isotope composition

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ABSTRACT: New data were obtained for the Chulym River basin in the southeastern part of the West Siberian Plain, one of the understudied parts of Siberia in terms of age and composition of carbon and nitrogen stable isotopes for Late Pleistocene megafauna. The ^{14}C dates from the Sergeevo outcrop, the most complete section of Late Quaternary deposits in the region, are mostly greater than ~30 550 BP. Other localities yielded ^{14}C values in the range from >44 500 to ~19 300 BP. The finite date of ~42 270 BP for the Khozarian steppe elephant (*Mammuthus trogontherii chosaricus*) from Asino is intriguing because previously it was not detected in the Late Pleistocene of Siberia after the last interglacial (Marine Isotope Stage 5e), ~115 000–130 000 years ago. Stable isotope data show both similarities and differences compared to the pre-Last Glacial Maximum megafaunal species in other parts of Siberia.

KEYWORDS: Chulym River; megafauna; radiocarbon dating; stable isotopes; Western Siberia

Introduction

The northern Eurasian radiocarbon (^{14}C) records for extinct Pleistocene megafauna are the best in the world (e.g. Stuart 2021), including several large ^{14}C datasets for individual species – woolly mammoth (e.g. Stuart *et al.*, 2004; Kuzmin, 2010; Arppe *et al.*, 2019; Kuitems *et al.*, 2019), woolly rhinoceros (e.g. Kuzmin, 2010; Stuart and Lister, 2012; Rey-Iglesia *et al.*, 2021), giant deer (Lister and Stuart, 2019), cave lion (Stuart and Lister, 2011), cave hyena (Stuart and Lister, 2014), cave bear (Pacher and Stuart, 2009; Terlato *et al.*, 2019), and Pleistocene bison and musk ox (Markova *et al.*, 2015). Nevertheless, the spatial distribution of ^{14}C-dated localities is patchy, and some regions – such as Western Siberia – have still not been adequately studied (see Shpansky and Kuzmin, 2021). This is also true for investigation of the stable isotope values (for carbon and nitrogen) for the Late Pleistocene megafauna. Research is quite active in northern Siberia (Yakutia and neighbouring regions) (see review: Kuzmin *et al.*, 2021), while in most of Siberia there is the dearth of information on this subject. In this paper, we present new ^{14}C and stable isotope data for the Chulym River basin.

Material and methods

The basin of the Chulym River is located in the southeastern part of the West Siberian Plain (Fig. 1), covered today by southern taiga forest which consists mainly of conifers (Siberian pine, fir and spruce), with an admixture of a small number of deciduous species (small leafed linden), and green-mosses (Suslov, 1961; Tishkov, 2002: 224). The landscape of this region is relatively flat, and the main features are watersheds (with an elevation up to ~150–180 m above the Baltic datum), and the valleys of the Chulym, Yaya and Kiya rivers (with a water level of ~80–100 m above the datum). Between the latter rivers, there is a low mountain ridge of the Kuznetsk Alatau (elevation of ~300–400 m) with southern taiga vegetation (Fig. 1).

There is only sparse information on the chronology and stable isotopes of the Pleistocene megafauna in the Chulym River basin and neighbouring territories (Shpasnky, 2006; Shpansky *et al.*, 2016; Shpansky and Kuzmin, 2021; Malikov *et al.*, 2020). In recent years, more materials have become available (Table 1). The main body of data was obtained from the Sergeevo outcrop (Fig. 1, no. 1; Fig. 2) which was preliminarily studied previously (Konovalova and Shpansky, 2005; Shpansky and Pecherskaya, 2009; Shpansky, 2021). Other localities in the Chulym River valley were also investigated (Fig. 1, nos. 2–5). In addition, the data from the Krasny Yar outcrop (Fig. 1, no. 6) were used for comparison.

Preparation for ^{14}C dating of bones and measurements of stable isotopes was carried out at the Laboratory of Radiocarbon Dating and Electron Microscopy, Institute of Geography, Russian Academy of Sciences, Moscow (laboratory index $IGAN_{AMS}$). Collagen extraction was conducted by slow dissolution of the mineral part of the bone in a 0.2 M solution of HCl, rinsing, treatment with 0.1 M NaOH, rinsing again, dissolution of the extract in weak HCl at 80 °C, and centrifuging. This pretreatment allowed us to remove all contamination from collagen, soils, charcoal, plant remains and other kinds of organic matter (e.g. Shpansky and Kuzmin, 2021; see also Solomina *et al.*, 2022; Sedov *et al.*, 2022). The material obtained was dried and used for analyses. Graphitization of collagen was performed using the AGE3 system combined with an Elementar varioIsotope Cube. The resulting graphites were compressed into the target with a pneumatic press. ^{14}C age measurements for graphite were carried out at the Center for Applied Isotopic Research, University of Georgia, Athens, GA, USA. The ^{14}C/^{13}C ratio in graphite was measured on an 0.5-MeV tandem system accelerator mass spectrometer (1.5SDH-1 Pelletron). All measurements were made against the OXII standard; the ^{14}C age was calculated using the Libby half-life of 5568 years. The resulting dates were adjusted for natural isotopic fractionation. Calibration was performed using Calib Rev 8.1.0 software (http://calib.org/calib/), following the

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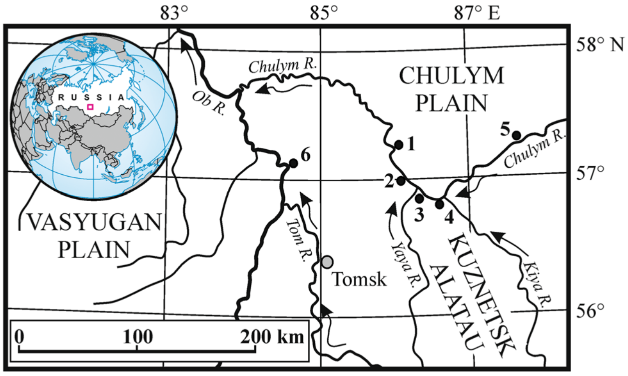

Figure 1. Localities with megafauna of the Chulym River basin and neighbouring areas. 1 – Segreevo; 2 – Asino; 3 – Bolshedorokhovo; 4 – Zyryanskoe; 5 – Krasnoyarskaya Kurya; 6 – Krasny Yar (Tomsk Province). [Color figure can be viewed at wileyonlinelibrary.com]

IntCal20 calibration curve (Reimer *et al.*, 2020). The measurements of $\delta^{13}C$ and $\delta^{15}N$ were conducted on an Isoprime PrecisION IRMS coupled with the varioIsotope Cube, against IAEA-600, B2155 and B2159 standards. The analytical precision is 0.2‰ for both $\delta^{13}C$ and $\delta^{15}N$. The C/N_{atom} ratios for all animal collagen samples are within the range of 2.9–3.6 (Table 1).

Results and discussion

The major part of the new data was obtained from the Sergeevo outcrop of the third terrace of the Chulym River where bones were collected *in situ*. The total thickness of alluvial deposits (layers 3–9) and terrestrial cover of loess-like loam (Layer 2) is ~21 m (Fig. 2). Megafaunal remains belong to 13 species, with horse (*Equus* ex gr. *gallicus*), Pleistocene bison (*Bison priscus*), woolly mammoth (*Mammuthus primigenius*) and woolly rhinoceros (*Coelodonta antiquitatis*) being predominant.

The bone of woolly rhinoceros from the bottom of Layer 7 is dated to more than 44 800 BP. The largest concentration of animal bones is in Layer 4, along with numerous pieces of tree logs. Here several megafaunal species – woolly rhinoceros, elk, bison, reindeer, musk ox, giant deer and cave lion – are ^{14}C dated to ~30 545–41 595 BP. A single ^{14}C value of ~15 770 BP was obtained for a small horse (unidentified to species) from Layer 2.

Based on the ^{14}C dates and the results of palynological and ostracod analyses (see Konovalova and Shpansky, 2005), Layer 7 can be dated to Marine Isotope Stage (MIS) 4 (cold environmental conditions), and Layer 4 to MIS 3 (warmer than MIS 4 but colder than today). The top of the section (Layer 2) was created during and soon after the Last Glacial Maximum (LGM; MIS 2). In Layer 4, there is a relatively high concentration of bones belonging to horse, bison, woolly mammoth and woolly rhinoceros, and this can be explained by the existence of waterlogged soil that acted as an natural trap. The deposits show a change in the sedimentation regime from channel (sands of Layer 5 and bottom of Layer 4) to floodplain (clays and loams, middle and upper parts of Layer 4) (Fig. 2).

Several ^{14}C dates were acquired for bones of woolly mammoth in the Chulym River valley, in the range ~19 670–25 800 BP (Table 1). The cave lion from Zyryanskoe is dated to more than 44 500 BP. The chronology of the Khozarian steppe elephant (*Mammuthus trogontherii chosaricus* Dubrovo) from Asino remains to be resolved. Its ^{14}C age (based on non-ultrafiltered collagen) was determined as ~42 270 BP (average value of two measurements). According to previously received data on Pleistocene megafauna in Western Siberia, this species went extinct at the last interglacial (MIS 5e), ~115 000–130 000 years ago (see Shpansky and Kuzmin, 2021). Judging from collagen quality parameters, its preservation seems to be satisfactory (e.g. van Klinken, 1999; Brock *et al.*, 2012). Additional measurements of ^{14}C age at another well-known laboratory, as well as independent dating of tooth enamel by U-series (U–Th) methodology, are needed to either confirm or reject these ^{14}C values, and this is an urgent task for the near future.

Morphologically, the Asino find is very close to the typical Khozarian steppe elephant from the lower course of the Volga River dated to the end of the Middle Pleistocene, MIS 6–7 (see details: Shpansky and Kuzmin, 2021). For typical *M. trogontherii trogontherii*, which is considered the older species and is associated with the early Middle Pleistocene, the frequency of plates over 10 cm on molar M^3 is ~5.6–6.5, and the enamel thickness is ~3.2 mm. For *M. trogontherii chosaricus*, these parameters are ~6.5–7.5 and ~2.4–2.7, respectively (Shpansky *et al.*, 2008, 2015). The holotype of the Khozarian steppe elephant from the Cherny Yar locality in the lower coarse of the Volga River has a frequency of plates over 10 cm on molar M^3 of 6.8–7.0, and the thickness of enamel is 1.9–2.5 mm (Dubrovo, 1966; Titov and Golovachev, 2017).

In Fig. 3, new stable isotope data for the Chulym River basin are plotted (see also Table 1). Unfortunately, due to the small number of measurements for each megafaunal species, it is currently impossible to use statistical methods for comparison with other information on stable isotopes from Siberia; therefore, we present our new data in qualitative fashion. Because almost all samples are of pre-LGM age (except for $IGAN_{AMS}$-9263), the results are fully compatible with $\delta^{13}C$ and $\delta^{15}N$ values for Siberia, especially for the Ust'-Ishim region of Western Siberia (see Kuzmin *et al.*, 2021 for original data and information taken from other publications). For cave lion, the data are similar to northern Siberia ($\delta^{13}C$ = –19.6‰; $\delta^{15}N$ = 10.9‰). The same pattern is observed for four other species. For woolly mammoth, $\delta^{13}C$ = –20.8 ± 0.1‰, $\delta^{15}N$ = 6.6 ± 0.3‰ for Ust'-Ishim; and –21.9‰ and 9.4‰ for northern Siberia. For bison, $\delta^{13}C$ = –19.0 ± 0.1‰, $\delta^{15}N$ = 5.8 ± 0.7‰ for Ust'-Ishim; and –20.1‰ and 6.9‰ for northern Siberia. The values for elk are similar to those for Ust'-Ishim ($\delta^{13}C$ = –19.2‰, $\delta^{15}N$ = 1.4‰). The same is observed for reindeer: $\delta^{13}C$ = –18.8‰, $\delta^{15}N$ = 3.4‰ for Ust'-Ishim. The composition of stable isotopes for the Khozarian steppe elephant is similar to woolly mammoth (Fig. 3).

Regarding woolly rhinoceros, the Chulym value is similar to northern Siberia ($\delta^{13}C$ = –19.9‰ and $\delta^{15}N$ = 6.0‰) but different from the Ust'-Ishim region (–19.6‰ and 2.6‰). For musk ox, the $\delta^{15}N$ value from the Chernilshchikovo site near the city of Tomsk is lower than for Ust'-Ishim (5.6 ± 1.4‰) and northern Siberia (5.9‰). The same is observed for saiga antelope: 3.8‰ for the pre-LGM sample from Krasny Yar *vs.* 6.7‰ for Ust'-Ishim and 8.9‰ for Siberia and Eastern Europe. The small number of measurements for woolly rhinoceros and musk ox and well-known significant stable isotope variations for these species (e.g. Raghavan *et al.*, 2014; Rey-Iglesia *et al.*, 2021) do not allow us currently to draw definite conclusions.

Malikov *et al.* (2020) explain the variation between Pleistocene musk ox in southern Siberia and modern musk ox from Greenland by the higher consumption of lichen in pre-LGM and LGM times by the former individuals. Data for the Ust'-Ishim region of central Western Siberia ($\delta^{13}C$ = –19.8 ± 0.7‰, $\delta^{15}N$ = 5.6 ± 1.4‰) are consistent with northern Siberia (–20.4‰ and 5.9‰) but different from southern Siberia

Table 1. Radiocarbon and stable isotope data for megafauna of the Chulym River basin and neighbouring regions, Western Siberia.

Region, site, layer, species	^{14}C date (BP)	Lab. code	Calendar date (cal BP) (average)	δ^{13}C (‰)	δ^{15}N (‰)	% C	% N	C/N ratio	Reference
Chulym River basin									
Sergeevo, Layer 7, *Coelodonta antiquitatis*	>44 800	UBA-38452	>47 100	–20.6	7.2	–	–	3.18	Shpansky (2021)
Sergeevo, Layer 4, *C. antiquitatis*	32 100 ± 390	SOAN-5552	36 430	–	–	–	–	–	Shpansky and Kuzmin (2021)
Sergeevo, Layer 4, *Alces alces*	30 545 ± 95	$IGAN_{AMS}$-9258	34 940	–20.1	2.5	51.49	19.11	3.16	This paper
Sergeevo, Layer 4, *Bison priscus*	41 595 ± 240	$IGAN_{AMS}$-9259	44 480	–20.6	5.0	50.96	18.78	3.17	This paper
Sergeevo, Layer 4, *Rangifer tarandus*	33 220 ± 115	$IGAN_{AMS}$-9260	37 940	–18.5	3.6	47.60	17.43	3.19	This paper
Sergeevo, Layer 4, *Ovibos moschatus**	33 175 ± 120	$IGAN_{AMS}$-9261	37 860	–19.5	11.4	49.69	18.64	3.12	This paper
Sergeevo, Layer 4, *Megaloceros giganteus*	34 890 ± 130	$IGAN_{AMS}$-9262	40 070	–20.3	3.5	44.07	16.32	3.16	This paper
Sergeevo, Layer 4, *Panthera spelaea*	34 280 ± 740	UBA-38455	39 050	–18.6	10.3	–	–	3.20	Shpansky (2021)
Sergeevo, Layer 2, *Equus* sp. (small)	15 770 ± 40	$IGAN_{AMS}$-9263	19 110	–20.6	1.4	50.25	18.86	3.11	This paper
Asino†, *Mammuthus trogontherii chosaricus*	41 865 ± 1990	UBA-38453	45 120	–21.6	10.3	–	–	3.25	Shpansky and Kuzmin (2021)
Asino†, *M. trogontherii chosaricus*	42 670 ± 1310	UBA-39395	45 370	–21.9	9.4	–	–	3.08	Shpansky and Kuzmin (2021)
Bolshedorokhovo, *Mammuthus primigenius*	25 800 ± 2200	AA-60031	30 160	–22.1	–	–	–	–	Shpansky and Kuzmin (2021)
Zyryanskoe, *P. spelaea*	>44 500	UBA-38456	>46 840	–19.0	9.7	–	–	3.20	This paper
Zyryanskoe, *M. primigenius*	19 290 ± 280	AA-60034	23 220	–21.2	–	–	–	–	This paper
Krasnoyarskaya Kurya, *M. primigenius*	20 020 ± 80	Beta-426078	24 040	–21.4	8.9	–	–	–	Seuru *et al.* (2017)
Krasnoyarskaya Kurya, *M. primigenius*	19 670 ± 120	GIN-12876	23 590	–	–	–	–	–	Maschenko (2010)
Krasnoyarskaya Kurya, *M. primigenius*	19 780 ± 180	GIN-12877	23 770	–	–	–	–	–	Maschenko (2010)
Neighbouring regions of Western Siberia									
Tomsk, *Saiga tatarica*	16 445 ± 80	OxA-22641	19 840	–19.1	4.2	41.40	14.10	3.40	Jürgensen *et al.* (2017)
Krasny Yar (Tomsk Prov.), *S. tatarica*	16 560 ± 75	OxA-22520	19 950	–19.2	4.3	46.10	15.90	3.40	Jürgensen *et al.* (2017)
Krasny Yar (Tomsk Prov.), *S. tatarica*	23 270 ± 160	OxA-22612	27 510	–18.8	3.8	45.70	16.00	3.30	Jürgensen *et al.* (2017)
Krasny Yar (Tomsk Prov.), *Castor fiber*	39 200 ± 190	$IGAN_{AMS}$-9264	42 710	–20.7	3.5	46.01	17.05	3.16	This paper
Chernilshchikovo, *O. moschatus*	29 605 ± 450	UBA-38454	34 070	–19.0	3.2	–	–	3.26	Malikov *et al.* (2020)
Ust'-Ishim, *O. moschatus*‡	–	–	–	–19.8 ± 0.7	5.6 ± 1.4	–	–	–	Kuzmin *et al.* (2021)

*The δ^{15}N value for this sample is probably an outlier; it is not included in Fig. 2.
†The same individual was analysed.
‡Individual stable isotope values are given in Kuzmin *et al.* (2021, Supplement); all ^{14}C dates are pre-LGM.

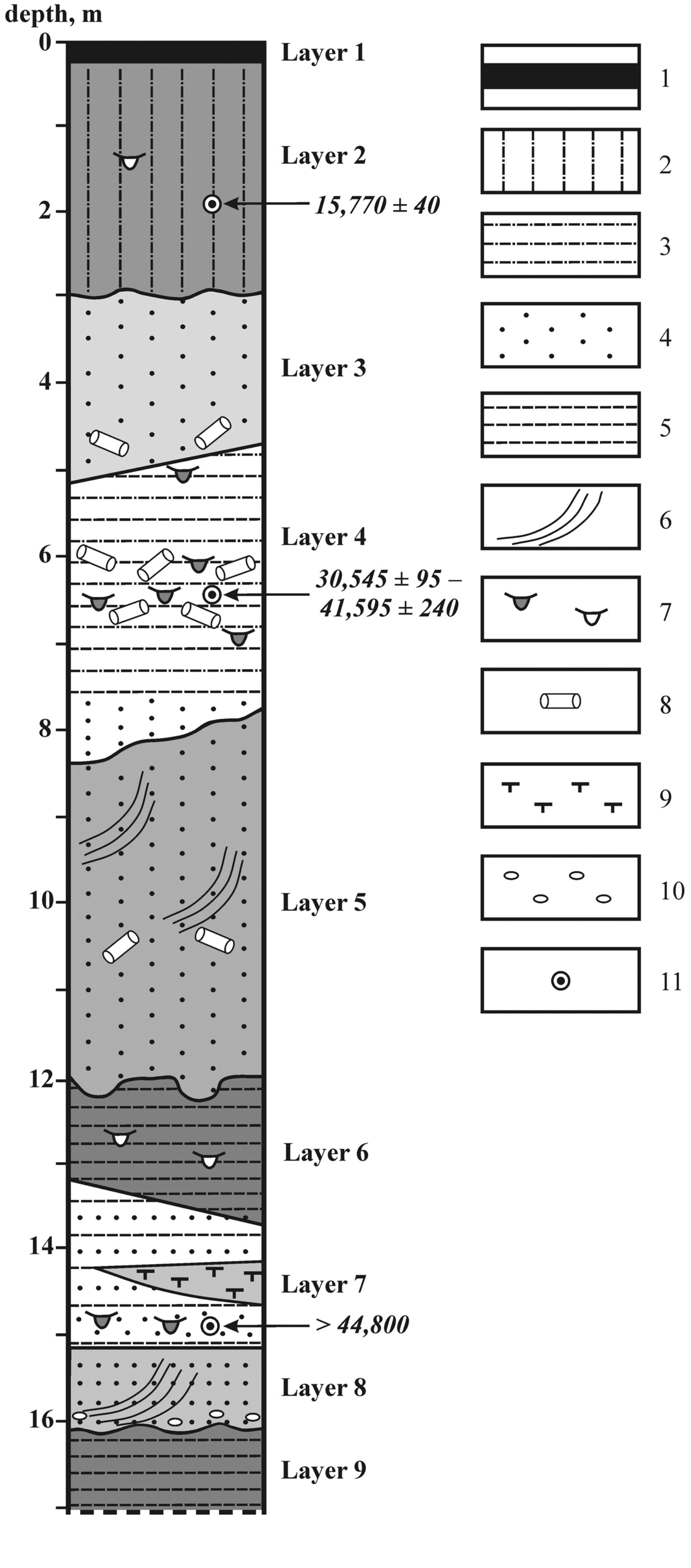

Figure 2. Cross-section of the Sergeevo outcrop, with position of ^{14}C-dated samples. 1 – modern soil; 2 – loess-like loam; 3 – loam; 4 – sand; 5 – clay; 6 – lamination; 7 – animal fossils; 8 – wood; 9 – peat; 10 – pebbles; 11 – position of ^{14}C-dated bones.

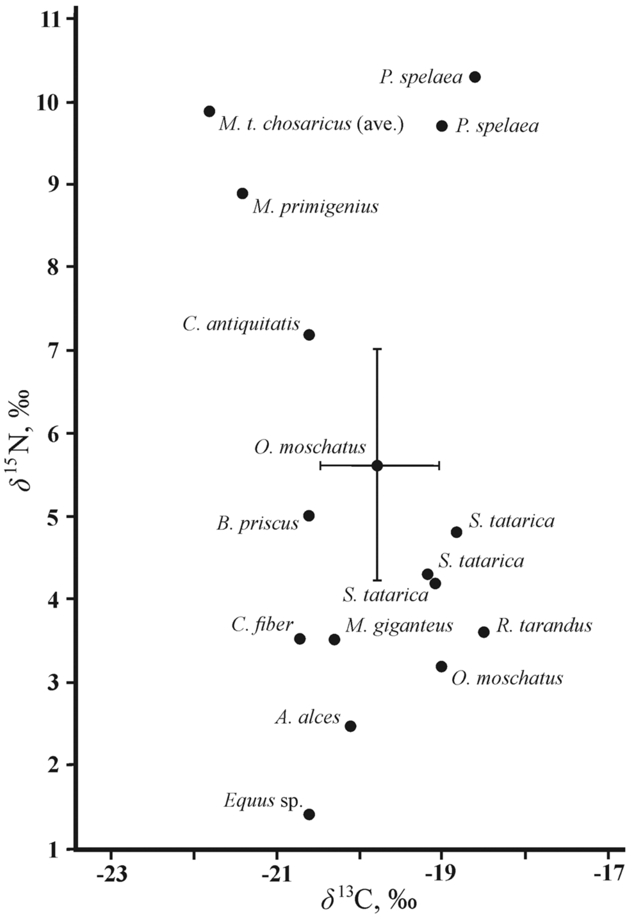

Figure 3. δ^{13}C vs. δ^{15}N plot for megafauna in the Chulym River basin and neighbouring areas (see Table 1).

(Minusinsk Depression) and southeastern Siberia (Chulym River basin) (Fig. 3). Regional patterns in the composition of stable isotopes for different parts of northern Eurasia in pre-LGM times are clear (e.g. Bocherens, 2015; Rey-Iglesia *et al*., 2021), and additional material for western and eastern (central) parts of Siberia is needed.

Conclusions

New stable isotope data for one of the understudied regions in Siberia – the Chulym River basin – show both similarities and divergences with neighbouring and distant parts of Siberia. It appears that variations in δ^{13}C and δ^{15}N for the pre-LGM megafauna in this region depended on several factors, including global environmental changes (MIS 4 and MIS 3), regional and local vegetation, and microclimate. Additional stable isotope data for West Siberian megafauna are urgently needed to understand the main features of stable isotope composition in Late Pleistocene mammal remains beyond the Siberian Arctic.

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Author contributions—**Yaroslav V. Kuzmin**: Conceptualization (equal); Formal analysis (equal); Funding acquisition (lead); Investigation (equal); Writing – original draft (lead); Writing – review & editing (lead). **Andrei V. Shpansky**: Conceptualization (equal); Formal analysis (equal); Investigation (equal); Writing – original draft (supporting); Writing – review & editing (supporting).

Abbreviations. LGM, Last Glacial Maximum; MIS, Marine Isotope Stage.

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