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CHRONOLOGY OF THE MIS 3 MEGAFAUNA IN SOUTHEASTERN WEST SIBERIA AND THE POSSIBILITY OF LATE SURVIVAL OF THE KHOZARIAN STEPPE MAMMOTH (*MAMMUTHUS TROGONTHERII CHOSARICUS*)

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ABSTRACT. We report a new series of radiocarbon (^{14}C) dates on the MIS 3 megafauna for a previously poorly studied region of southeastern West Siberia. Some species, like woolly mammoth and woolly rhinoceros, and Pleistocene bison and horse, existed throughout the MIS 3 (ca. 29–59 ka cal BP); cave hyaena is dated to ca. 46,400 cal BP. The very late ^{14}C dates on Khozarian steppe elephant (*Mammuthus trogontherii chosaricus*), ca. 45,100–45,400 cal BP, may indicate the survival of this species in Siberia up to MIS 3. More work is needed to confirm or reject this suggestion. Previously, Khozarian steppe elephant was known in Siberia only at the beginning of the Late Pleistocene (MIS 5e).

KEYWORDS: Khozarian steppe elephant (*Mammuthus trogontherii chosaricus*), megafauna, MIS 3, radiocarbon dating, West Siberia.

INTRODUCTION

During the last several decades, significant progress has been made in the development of a Late Pleistocene megafaunal chronology in Eurasia, based on radiocarbon (^{14}C) dating results (e.g., MacDonald et al. 2012; Stuart 2015). While the majority of these ^{14}C dates come from bones and tusks of woolly mammoth (e.g., Stuart et al. 2002; Guthrie 2004; Kuzmin and Orlova 2004; Vartanyan et al. 2008; Kuzmin 2010; Nikolskiy et al. 2010; Puzachenko et al. 2017), they also include several other megafaunal species (e.g., Orlova et al. 2004; Stuart et al. 2004; Pacher and Stuart 2009; Kuzmin 2010; Stuart and Lister 2011, 2012, 2014; Markova et al. 2015; Kosintsev et al. 2019; Lister and Stuart 2019).

However, some regions remain relatively poorly studied, and the southeastern part of the West Siberian Plain (Figure 1) is one such area. In the last 10–20 years, new data has been accumulated in this area, and here we present the latest information on the chronology and environment of the large mammals that existed during MIS 3 (i.e. before the Last Glacial Maximum), and discuss the possibility of survival of some species which were previously considered to be extinct in Siberia and in Europe, by the mid-Late Pleistocene.

The MIS 3 in Siberia can be dated to ca. 25–56 ka BP, or ca. 29–59 ka cal BP (e.g., Swann et al. 2005). In Siberia it is referred to as the Karginsky interstadial (e.g., Volkova 2002: 134–139), and it is equal to the Middle Weichselian interstadial in Europe.

MATERIAL AND METHODS

For this study, we used data collected during the last two decades in the basins of the Ob and Chulym rivers (Shpansky 2018). Classic paleontological methods of identification and description were applied to the Late Pleistocene mammalian fossils, recovered from both *in situ* positions and surface collections on the riverbanks. Almost all of the localities in southeastern West Siberia that contain mammal fossils are of the subaquatic type, and

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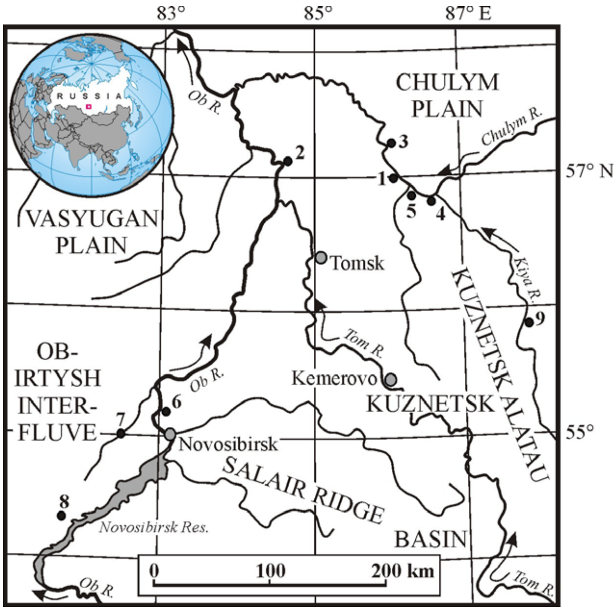

Figure 1 The main localities of the MIS 3 megafauna in southeastern West Siberia: 1—Asino; 2—Krasny Yar (Tomsk Province); 3—Sergeevo; 4—Zyryanskoe; 5—Bolshedorokhovo; 6—Krasny Yar (Novosibirsk Province); 7—Chick River; 8—Orda River; 9—Shestakovo.

bones are embedded into sands and sandy loams of alluvial genesis or paleosols (Shpansky 2006, 2018). Only at the Shestakovo locality are bones situated in loess-like loams of aeolian origin (Zenin et al. 2000).

The measurements of proboscidean skulls were conducted according to methods developed by Dubrovo (1966), and of teeth according to Garutt and Foronova (1976), with precision up to 0.1 mm. For comparison, skulls of the steppe elephant species *Mammuthus trogontherii trogontherii* Pohlig and *Mammuthus trogontherii chosaricus* Dubrovo from localities in Western Siberia and Europe, including the holotype of *M. t. chosaricus* (PIN PM KP 4874) from the Cherny Yar in the lower stream of Volga River, were used. The comparison of the last change of M^3 teeth for woolly mammoth (*Mammuthus primigenius* Blum.) and two species of steppe elephants from the Middle–Late Pleistocene of West Siberia and Europe was also performed. The results are presented as a bivariate plot with the most important parameters for teeth—thickness of enamel, and frequency of plates per 10 cm.

The ^{14}C dating of mammalian fossils was conducted by both liquid scintillation counting (LSC; lab code SOAN) and accelerator mass spectrometry (AMS; lab codes UBA, GrA, and AA) (Tables 1–2). Methods of the pretreatment of bones are fully described in Kuzmin and Orlova (2004) for LSC; and in Zenin et al. (2000), Shpansky et al. (2016), and Kuzmin et al. (2018) for AMS. We applied the quality criteria for bone collagen suggested by van Klinken (1999) and Brock et al. (2012), with the determination of the collagen yield, C:N ratio, and stable isotopes (δ^{13}C and δ^{15}N) values whenever possible. Samples with a low collagen yield (less than 1% weight) and C:N ratios beyond the 2.9–3.6 range were excluded. Unfortunately, this information does not exist for LSC and some of the AMS dates.

RESULTS AND DISCUSSION

The list of mammalian species from the region includes ca. 20 taxa (Shpansky 2018). The most common among them are Pleistocene bison (*Bison priscus* Boj.) and horse (*Equus* ex gr. *gallicus* Prat), woolly mammoth, and woolly rhinoceros (*Coelodonta antiquitatis* Blum.).

The ^{14}C values on mammal bones vary from greater than ca. 48,600 BP to ca. 24,400 BP (Table 1). The best-studied outcrop is Krasny Yar in Tomsk Province (Figure 1). Here new ^{14}C dates were obtained from layers 5–6 (Figure 2), in the range of ca. 37,920 BP—greater than ca. 48,600 BP. Collagen parameters (yield and δ^{13}C) are within the reliable range. For Layer 3, the ^{14}C value is ca. 25,700 BP; also, a bone of Pleistocene bison was ^{14}C-dated to ca. 18,500 BP (Shpansky 2006). The age of cave hyaena (*Crocuta crocuta spelaea* Goldf.), ca. 43,140 BP, is noteworthy because no direct ^{14}C dates from this region were previously available (see Stuart and Lister 2014). Along with a ^{14}C value from Denisova Cave (Altai Mountains, southern Siberia) of ca. 42,300 BP (Stuart and Lister 2014, supplementary materials), this is one of the latest ^{14}C dates for cave hyaena in West Siberia.

Two bones of *Panthera* sp. (the ancestral form of cave lion) returned infinite ages of greater than ca. 46,200–48,600 BP. They were probably obtained from a redeposited context, and the true age could be older than MIS 3. Also, at the Zyryanskoe locality, a bone of *Panthera spelaea* Goldf. was ^{14}C-dated to greater than ca. 44,500 BP (Table 1). This is most probably a redeposited specimen that appeared in the MIS 3 sediments.

The Sergeevo locality in the Chulym River basin (Figure 1) has three ^{14}C dates on mammal bones. Layer 7 is dated to greater than ca. 44,900 BP; and Layer 4 to ca. 32,100–34,300 BP. Paleoenvironmental reconstruction for Layer 7, based on palynological and microfaunal (ostracods) analyses, show that the climate was cold and wet. The presence of a relatively large proportion of woolly rhinoceros in Layer 4 (ca. 12% of total bones), directly ^{14}C-dated to ca. 32,100 BP (Table 1), can be explained by favorable conditions for this species in the river valley.

New data on the chronology of woolly mammoth in West Siberia, ca. 25,800–28,700 BP, were obtained from the Orda River and Bolshedorokhovo localities (Table 1). They are similar to the Shestakovo locality where it was ^{14}C-dated to ca. 24,400–25,700 BP.

The most unexpected and intriguing ^{14}C dates were obtained from the Asino locality in the Chulym River valley (Figure 1; Table 2) where the skull of a Khozarian steppe elephant (*Mammuthus trogontherii chosaricus*) was discovered (Figure 3). Previously, the latest finds of this species in West Siberia were known from deposits of the last interglacial (MIS 5e), ca. 115,000–130,000 years ago (Vasiliev 2005; Shpansky 2018). The Asino skull is moderately well preserved, with some damages to the occipital bone, the left side of the parietal bone, the left alveoli of the tusk, and near the nasal opening. The left zygomatic arch is missing. The Asino skull is similar to two Khozarian steppe elephant skulls from Layer 6 of the Krasny Yar locality (Novosibirsk Province; Figure 1) (see Table S1 in supplementary materials). According to Vasiliev (2005), the age of the Krasny Yar skulls could be the beginning of the Late Pleistocene, MIS 5e.

A distinctive feature of the Ashino skull is the relatively narrow facial part with a sufficiently large length and height. This is reflected in the narrow nasal opening, minimum width of the forehead, width of the supraorbital processes, and other parameters (measurements 7, 10, 12,

Table 1 New radiocarbon dates of MIS 3 megafauna in southeastern West Siberia.

Locality	Species	^{14}C date (^{14}C yr BP)	Lab code	Collagen yield (%)	δ^{13}C (‰)
Krasny Yar (Tomsk Province)	*Mammuthus primigenius*	25,650 ± 420	SOAN-5201	—	—
	Bison priscus	> 44,930	UBA-25872	4.0	–20.0
	B. priscus	43,655 ± 1460	UBA-21202	6.7	—
	B. priscus	37,920 ± 915	UBA-25870	1.6	–20.9
	Panthera sp.	> 48,615	UBA-28337	8.9	–19.2
	Panthera sp.	> 46,115	UBA-30470	7.8	–18.8
	Crocuta crocuta spelaea	43,140 ± 2370	UBA-28335	4.2	–20.0
	Ursus savini rossicus	> 48,615	UBA-28336	11.4	–23.2
Sergeevo	*Coelodonta antiquitatis*	> 44,800	UBA-38452	9.3	–20.6
	C. antiquitatis	32,100 ± 390	SOAN-5552	—	—
	Panthera spelaea	34,280 ± 740	UBA-38455	7.7	–18.6
Zyryanskoe	*P. spelaea*	> 44,500	UBA-38456	6.8	–19.0
Orda River	*M. primigenius*	28,720 ± 560	SOAN-6384	—	—
Bolshedorokhovo	*M. primigenius*	25,800 ± 2200	AA-60031	—	–22.1
Shestakovo	*M. primigenius*	25,660 ± 200	GrA-13238	—	–21.2
	M. primigenius	24,360 ± 150	GrA-10935	—	–21.2

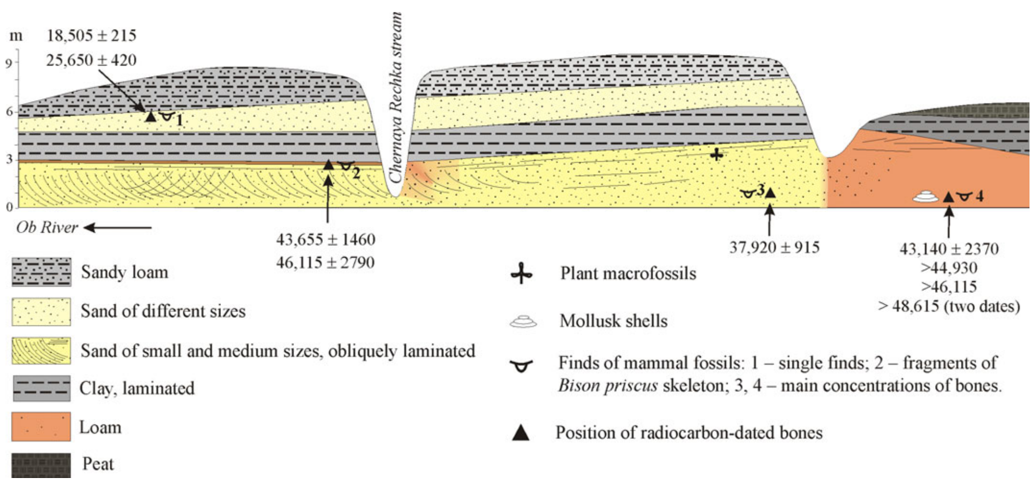

Figure 2 Krasny Yar (Tomsk Province) locality, with ^{14}C-dated fossils.

19, and 21; see Table S1 as well as Siegfried 1956; Baigusheva and Garutt 1987; Shpansky et al. 2015). The Asino skull has M^3 teeth of moderate wear. The plates are very short, with parallel surfaces and without any bulges. In the anterior part of the crown, heavily worn plates are divided in half. The thick enamel is presented in rough folds. In the crowns, 15 plates are

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Table 2 Radiocarbon dates for the Khozarian steppe elephant (*Mammuthus trogontherii chosaricus*) from southeastern West Siberia.

Locality	^{14}C date (BP)	Lab code	Collagen yield (%)	C:N ratio	δ^{13}C (‰)	δ^{15}N (‰)	Calendar date (cal BP)[1]
Asino	41,865 ± 1990	UBA-38453	7.7	3.25	–21.6	10.3	42,360–47,880
	42,670 ± 1310	UBA-39395	11.8	3.08	–21.9	9.4	43,150–47,600

[1]Calib Rev 8.1 software was used (available at http://calib.org/calib/); with ± 2 σ.

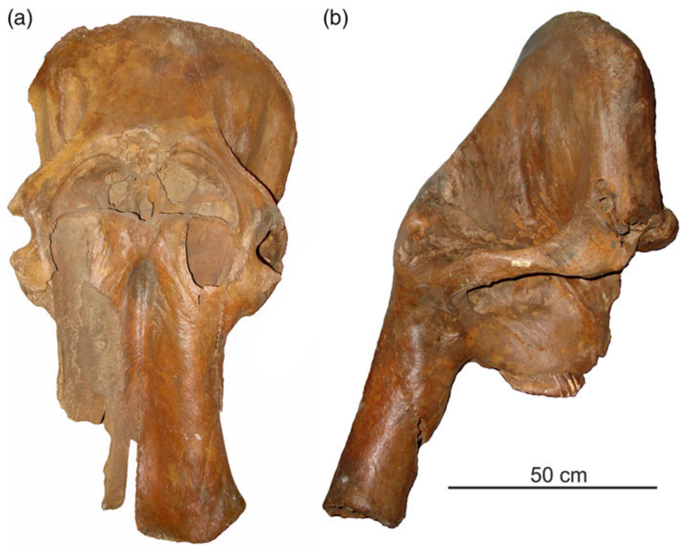

Figure 3 Skull of Khozarian steppe elephant (*Mammuthus trogontherii chosaricus*) from the Asino locality: (a) frontal view; (b) lateral view.

preserved in the right tooth, and 13 plates in the left one. It can be assumed that at least 5 plates were lost in each tooth as a result of abrasion. The last plates are at the very early stage of abrasion, and their surface was damaged in recent years in the museum.

The morphology and morphometrics of the skull and teeth (Tables 3 and S1; Figures 3 and 4) testifies that this is the Khozarian steppe elephant and not a woolly mammoth. On the graph of the main morphometric parameters for M^3 teeth of *M. t. chosaricus*, one can clearly see that the teeth from the Asino have the thickest enamel, while the frequency of plates per 10 cm is within the range of variability of this taxon (Figure 5). For comparison, the data on M^3 teeth for woolly mammoth from Layer 4 of the Sergeevo locality is presented (Table 3). It is clearly different from the Asino *M. t. chosaricus*, and correlates with the typical Late Pleistocene woolly mammoth. At the same time, the ^{14}C dates of the Asino and Sergeevo localities are very close (see Tables 1–2), and the distance between these sites along the Chulym River is about 20 km (Figure 1).

Two ^{14}C dates were generated for the same specimen of the Khozarian steppe elephant (Table 2), and according to the criteria for the quality of collagen they can be considered

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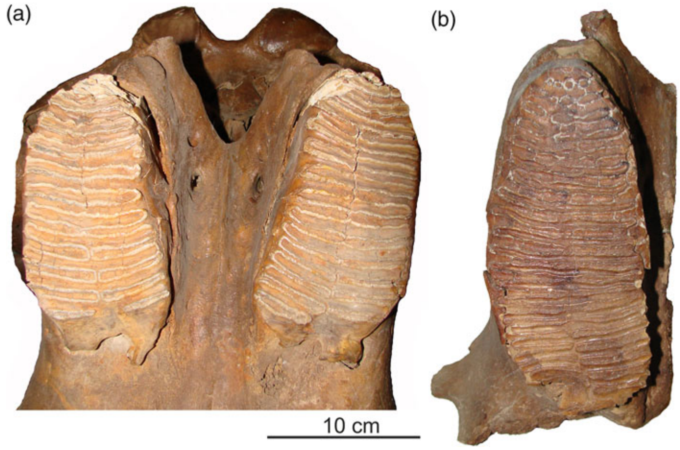

Figure 4 Occlusal view of the M^3 teeth: (a) Khozarian steppe elephant from the Asino locality (TOKM 10300/3); (b) woolly mammoth from the Sergeevo locality (PM TSU 18/140).

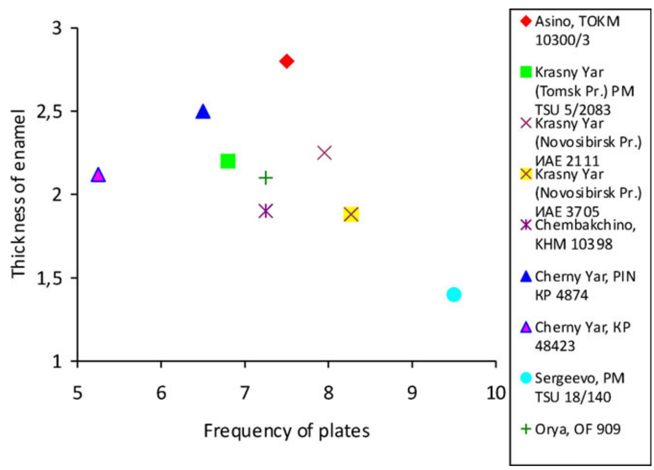

Figure 5 Bivariant diagram of the M^3 teeth of Khozarian steppe elephant and woolly mammoth (see original data in Table 3).

as reliable. If true, the age of steppe elephant at Asino can be estimated as ca. 41,900–43,700 BP, or ca. 45,700–46,200 cal BP (median values of calibrated dates).

This information looks unusual, considering all previously known data on steppe elephant in Eurasia (e.g., Titov and Golovachev 2017). Very late dates on steppe elephant, ca. 24,900–33,900 years ago (i.e., equal to cal BP), were reported from China (Wei et al. 2010). However, they should be treated with caution because re-dating of several supposedly late finds of Pleistocene megafauna from China returned much older ages (Turvey et al. 2013). On the other hand, a recent direct ^{14}C dating campaign for giant rhinoceros *Elasmotherium sibiricum* showed that it survived in West Siberia and the Urals until ca. 33,300–34,400 BP (or ca. 37,500–38,900 cal BP) (Kosintsev et al. 2019). This unexpected conclusion clearly

Table 3 Sizes (in mm) of the M^3/m^3 teeth for the Khozarian steppe elephant from West Siberia and Eastern Europe, and the woolly mammoth from Sergeevo locality. The upper values are for dex, and the lower for sin.

Locality, collection no., reference	Length of crown	Width of crown	Height of crown	Number of plates	Average length of plate	Frequency of plates per 10 cm	Thickness of enamel
Asino (TOKM 10300/3), (M^3), dex; sin	210*; 200	98.5; 99	—	ca. 15; 13	13.5; 14.5	7.5; 7	2.2–[2.8]–3.2
Krasny Yar (Tomsk Pr.), M^3 (PM TGU 5/2083)	311	92.0	ca. 210	22	13.8	6.8	2.2
Krasny Yar (Novosibirsk Pr.), M^3 (IAE 2111) (Vasiliev 2005)	216	83	—	ca. 15	12.84	7.95	2–[2.25]–2.5
Krasny Yar (Novosibirsk Pr.), M^3 (IAE 3705) sin/dex (Vasiliev 2005)	–/340	107/105	–/215	–/24	11.82/12.64	8.27/8.17	1.5–[1.88]–2.1 1.6–[1.83]–2.1
Krasny Yar (Novosibirsk Pr.), M^2 (PM TGU 33/2) (Shpansky 2018)	224	115	113	ca. 11	15	7	2.2
Chembakchino** (KHM-10398) M^3/m^3, dex; sin (Kosintsev et al. 2004)	278 315	85.7; 80 80	178; 181 145.3	20 22	13.4; 12.9 16.7	7.25; 7.5 5.75	— 1.9
Cherny Yar*** (PIN PM KP 4874) M^3/m^3, dex; sin (Dubrovo 1966)	— 258; 252	105; 106 98; 97	—	20 18	—	7; 6.5 6; 5.5	2.5 2.5
Cherny Yar (KP 48423), m^3, dex; sin (Titov and Golovachev 2017)	C230; C240	99; 96.5			20.75; 19.3	5.0; 5.25	2.02; 2.12
Orya River**** (OF-909) m^3, dex; sin (Garutt 1972)	ca. 190; ca. 195	ca. 84; ca. 75	—	13+?	—	6.5–8	1.8–2.1
Sergeevo (PM TGU 18/140) M^3, sin (Shpansky and Pecherskaya 2009)	ca. 260	111.6		ca. 24	10.8	9.5	1.4

*Teeth are not completely erupted; measurements were made using the available part.

**Lower part of the Irtysh River basin (West Siberia).

***Lower part of the Volga River basin (Eastern Europe).

****Cis-Urals region, Kama River basin (Eastern Europe).

demonstrates that our knowledge of the age of Late Pleistocene megafauna in Siberia is still limited. Obviously, more direct ^{14}C and other dates (for example, U-series) are needed for the Asino fossils.

CONCLUSIONS

New data on the MIS 3 megafauna of southeastern West Siberia and its chronology has allowed us to increase the dataset of the ^{14}C values on fossil mammals of Eurasia. While for some species—woolly mammoth and rhinoceros, and Pleistocene bison and horse—the chronological patterns are in the general range established earlier for northern Eurasia, the very late age of the Khozarian steppe elephant (*Mammuthus trogontherii chosaricus*), ca. 45,100–45,400 cal BP, allowed us to suggest the possibility of its late survival in Siberia.

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SUPPLEMENTARY MATERIAL

To view supplementary material for this article, please visit https://doi.org/10.1017/RDC.2021.6.

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