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A REVIEW OF THE EVIDENCE FOR EXTINCTION CHRONOLOGIES FOR FIVE SPECIES OF UPPER PLEISTOCENE MEGAFAUNA IN SIBERIA

Lyobov A Orlova[1] • Yaroslav V Kuzmin[2] • Vyacheslav N Dementiev[1,3]

ABSTRACT. A review of the radiocarbon chronology of some late Upper Pleistocene mammals from Siberia is presented. Previously published data has been supplemented by new ^{14}C dates for 5 species (woolly mammoth, woolly rhinoceros, bison, horse, and muskox) to reconstruct chronological extinction patterns. The final extinction of woolly rhinoceros and bison in Siberia can be dated to approximately 11,000–9700 BP, but some megafaunal species (woolly mammoth, horse, and muskox) survived into the Late Holocene, about 3700–2200 BP.

INTRODUCTION

Determining the extinction patterns of Upper Pleistocene megafauna using radiocarbon dating was first conducted in Siberia in the early 1960s (Heintz and Garutt 1964, 1965; Heintz 1966). Since that time, the number of ^{14}C dates obtained directly from megafaunal species has significantly increased and now constitutes several hundred values. The majority of dates were obtained for such species as woolly mammoth (*Mammuthus primigenius* Blum.), woolly rhinoceros (*Coelodonta antiquitatis* Blum.), Pleistocene bison (*Bison priscus* Boj.), Pleistocene-type horse (*Equus caballus* L.), and muskox (*Ovibos moschatus* Zimm.). These data provide a basis for establishing the timing of the megafauna's final extinction in Siberia and the Russian Far East, and in the adjacent territories of Kazakhstan and Northeastern China. The aim of this paper is to present an extended data set which enhances our understanding of extinction patterns for the species and compare the data set to previous summaries (cf. Stuart 1991; Sulerzhitsky 1997; Vasil'chuk et al. 1997).

MATERIAL AND METHODS

We have compiled data from published sources (mainly from Sulerzhitsky 1997; Sulerzhitsky and Romanenko 1999; Vasil'chuk et al. 1997; Orlova et al. 2000; Stuart et al. 2002; MacPhee et al. 2002; Schirrmeister et al. 2002; Kuzmin et al. 2003), with new ^{14}C dates produced at the Institute of Geology, Siberian Branch of the Russian Academy of Sciences, Novosibirsk (Lab code SOAN). The number of ^{14}C dates known for extinct megafaunal species in Siberia is skewed towards woolly mammoth, with about 530 ^{14}C values from 230 localities. Of these, we have concentrated on only the "youngest" dates, less than about 12,000 BP, because they are directly related to the issue of extinction (Table 1; Figure 1). Other species have far fewer ^{14}C determinations; for example, there are 59 dates on bison from 51 localities, 55 dates on horse from 33 localities, 41 dates on woolly rhinoceros from 35 localities, and 29 dates on muskox from 19 localities (Tables 2–5; Figures 2–3).

The dating of megafaunal remains was conducted mainly using bone collagen as the source of carbon. Dates produced in Russian laboratories, located in Moscow, Novosibirsk, and St Petersburg, comprise 85% of the total ^{14}C values discussed in this paper. The main technique of collagen extraction for bone dating in Russian laboratories since the late 1960s is the dissolution of the mineral part of the bone in weak hydrochloric acid (HCl) (Arslanov and Svezhentsev 1993; Sulerzhitsky 1997;

[1]Institute of Geology, Siberian Branch of the Russian Academy of Sciences, Koptuyg Ave. 3, Novosibirsk 630090, Russia. Email: orlova@uiggm.nsc.ru.
[2]Pacific Institute of Geography, Far Eastern Branch of the Russian Academy of Sciences, Radio St. 7, Vladivostok 690041, Russia. Email: ykuzmin@tig.dvo.ru.
[3]Email: dementev@uiggm.nsc.ru.

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see detailed description in Vasil'ev et al. 2002:505–7). Slow dissolution of the mineral part of whole pieces of bone in diluted HCl makes it possible to extract non-contaminated collagen and to see the degree of preservation of the initial fiber-like internal collagen structure after demineralization. The reliability of the slow dissolution technique for collagen extraction is also supported by good agreement of results of parallel dating on the same pieces of bone conducted in Russian, US, and European laboratories (Vartanyan et al. 1995; Vasil'chuk et al. 2000; Kuzmin et al. 2001; MacPhee et al. 2002).

The date of final extinction was estimated using the latest ^{14}C date available for a particular species, an approach employed in similar studies (cf. Stuart et al. 2002; MacPhee et al. 2002; Guthrie 2003). The extent of the species' habitats (i.e. the natural home or environment of an organism) were assumed by the geographic distribution of their fossil remains (cf. Kuzmin et al. 2003:223–5) and are listed in Tables 1–5 by latitude and longitude, given as decimal values (e.g. 70.50 N means 70°30′ northern latitude), as per the US Defense Mapping Agency Operational Navigation Charts (scale of 1:1,000,000). GIS ArcView 3.2 software was used for map generation.

RESULTS AND DISCUSSION

Woolly Mammoth

As previously noted, we selected 56 of the latest ^{14}C dates from 26 localities covering the Late Glacial and the Holocene, about 12,000–3700 BP (Table 1; Figure 1). As for earlier times, about 50,000–12,000 BP, it is clear that the woolly mammoth habitat extended through all of Northern Asia-Siberia, the Russian Far East, northeastern China, and northern Kazakhstan (cf. Sulerzhitsky 1997; Kuzmin et al. 2003). The distribution pattern appears to have changed significantly, by about 12,000–10,000 BP (Figure 1). The mammoth habitat was substantially reduced in size and located mainly in arctic Siberia, including the lower part of the Indigirka River basin, the Taymyr, Yamal, and Gydan peninsulas, the Severnaya Zemlya archipelago, and Wrangel Island. The Taymyr Peninsula mammoths have the youngest ^{14}C dates in continental Siberia of about 9800–9700 BP. New ^{14}C dates obtained in 2000–2002 also reveal several mammoth sites in the temperate belt of Siberia dated to approximately 11,980–10,210 BP, including the central and southern West Siberian Plain (Volchya Griva, Sosva River, and Lugovskoe) and the Upper Yenisei River basin (Konzhul) (Table 1; Figure 1). In our opinion, these localities represent the "patchy" nature of the mammoth habitat in Siberia after about 12,000 BP, with few isolated "pockets" outside of the High Arctic. Finally, in the Middle Holocene, about 7700–3700 BP, smaller mammoths (a subspecies, *M. primigenius vrangeliensis*; Averyanov et al. 1995) existed only on Wrangel Island.

These data suggest that the final extinction of woolly mammoth in Siberia and elsewhere in the Northern Hemisphere occurred at about 9700 BP in the continental part (Taymyr Peninsula), and at about 3700 BP in the insular part (Wrangel Island). Our extended data set presented here indicates mammoth survival in temperate Siberia after shrinking and fragmentation of its habitat at about 12,500–12,000 BP. Based on this, it is possible to assume that even after approximately 12,000 BP some mammoth populations survived outside of arctic regions in a few places in continental Eurasia (Western Siberia, north Russian Plain in Eastern Europe) until the beginning of the Holocene (Stuart et al. 2002; Lõugas et al. 2002).

Woolly Rhinoceros

The distribution of woolly rhinoceros ^{14}C dates indicates its habitat covered Northeastern Siberia and the southern parts of Western and Eastern Siberia (Figure 2) in the late Upper Pleistocene, from

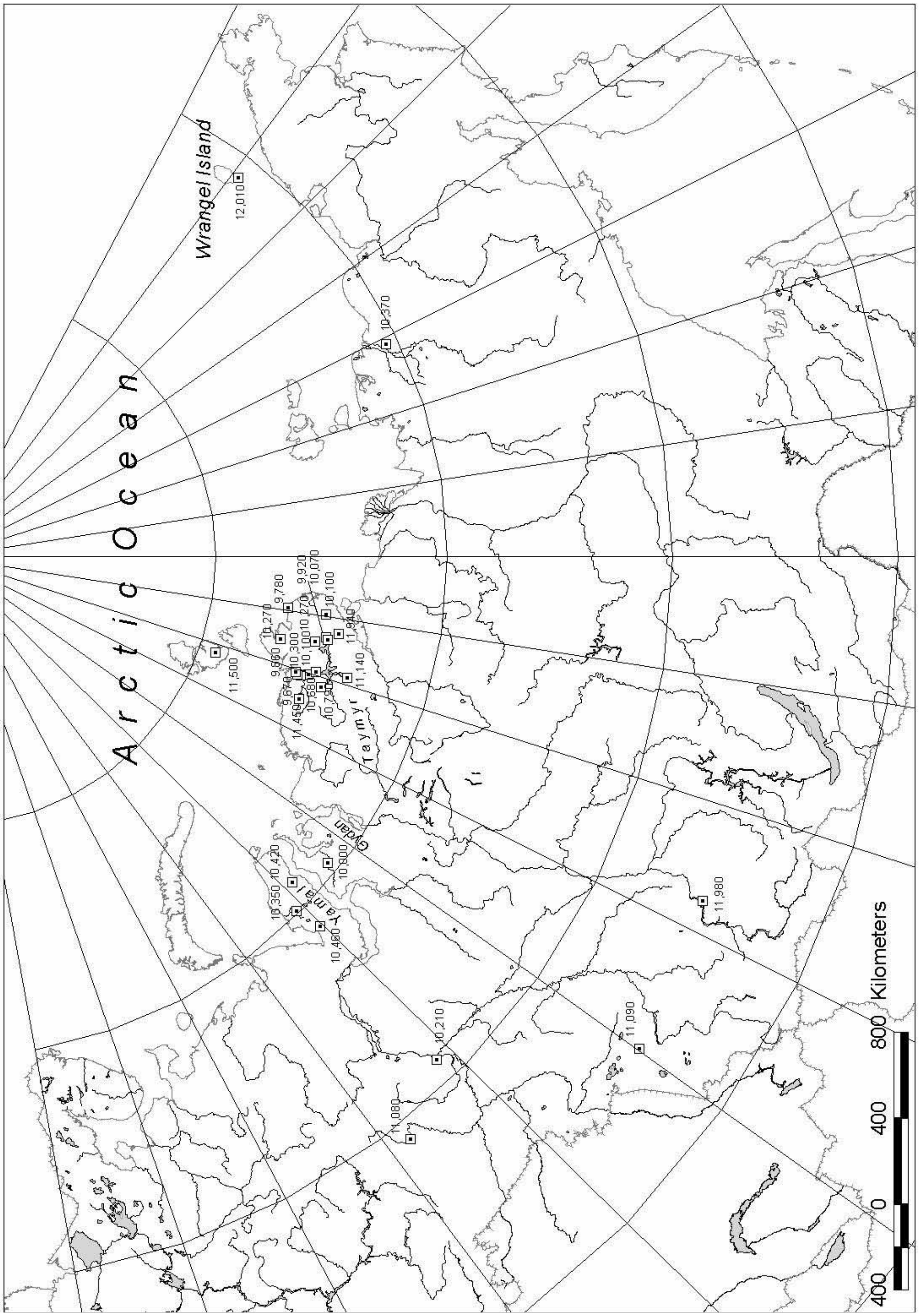

Figure 1 Location of ^{14}C-dated woolly mammoth remains for the Late Glacial and Holocene (about 12,000–3700 BP) in Siberia

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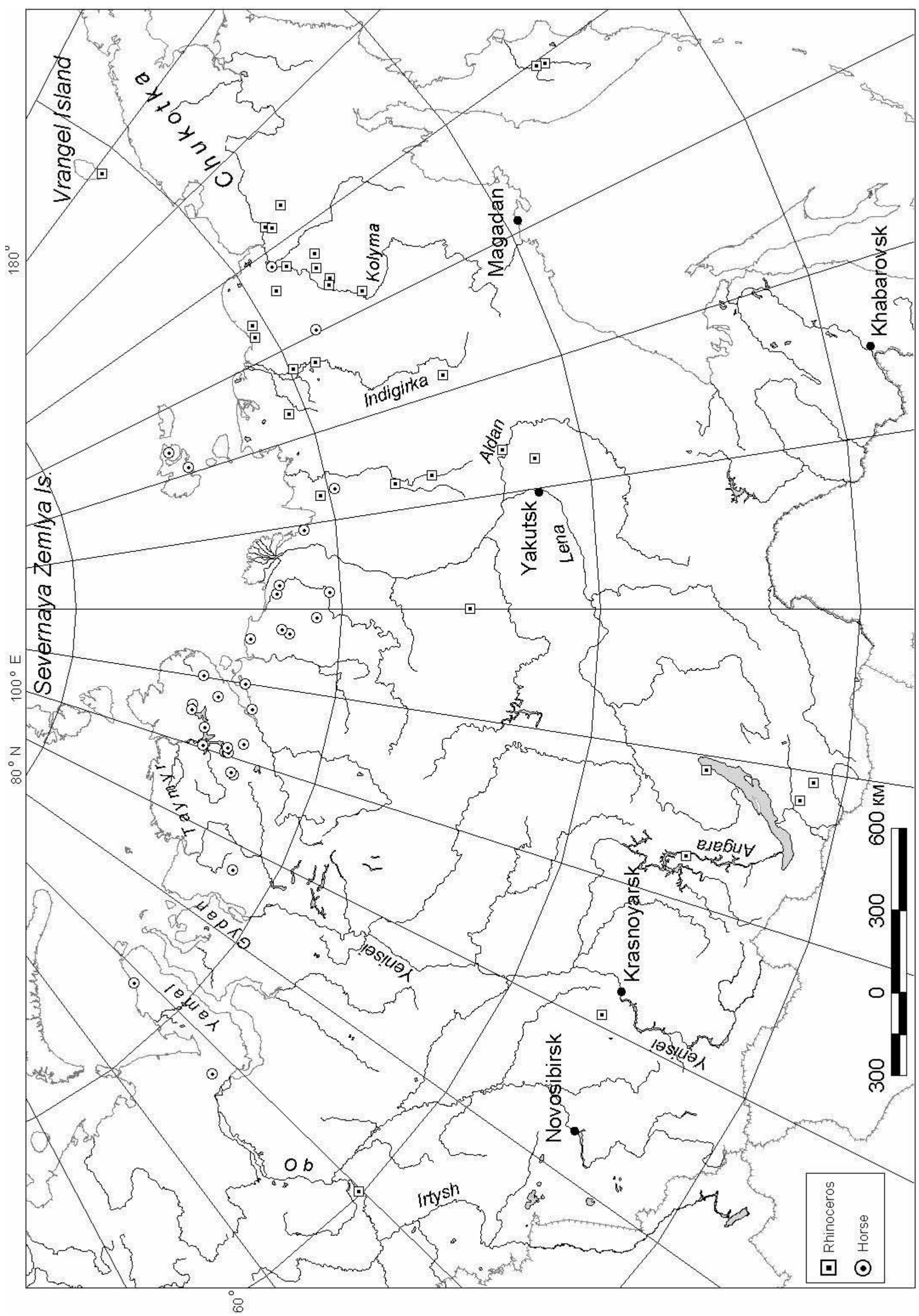

Figure 2 Location of ^{14}C-dated woolly rhinoceros and horse remains in Siberia

about 49,000 BP, as well as the Russian Far East (without direct ^{14}C dates). In the northern parts of Western and Eastern Siberia (Putorana Plateau, and the Taymyr, Gydan, and Yamal peninsulas), no remains of woolly rhinoceros have been recovered, perhaps indicating that these areas were not part of its natural habitat as was earlier assumed by R-D Kahlke (1998). The latest ^{14}C dates for the species are from the Bolshoi Khomus-Yuriakh River, Yakutia (about 15,130 BP); Yukagir Plateau, Northeastern Siberia (about 14,260 BP); Zlatoustovka, Ashkadar River, southern Trans-Urals (about 12,330 BP); and Lugovskoe, central Western Siberia (about 10,770 BP) (Table 2). It is worthwhile highlighting that the ^{14}C dates from temperate Siberia (Zlatoustovka and Lugovskoe) are significantly younger than those from arctic regions.

With the new ^{14}C date from the Lugovskoe locality, the final extinction of woolly rhinoceros could be as late as the end of the Late Glacial (about 10,800 BP), rather than as suggested at approximately 14,000–12,000 BP by Vereshchagin and Baryshnikov (1984:497–9). Further study is thus necessary on this ^{14}C chronology in Siberia to confirm/reject the 10,800 BP age for its final extinction, especially in the areas with the youngest dates such as Western Siberia and the Trans-Urals.

Bison

The bison habitat in the late Upper Pleistocene extended throughout all of the Siberian and the Russian Far Eastern territory (Figure 3). In most of Siberia, bison were extinct by approximately 15,000–11,600 BP (Table 3). Bison persisted only in a few places into the Holocene. The latest bison ^{14}C date, about 8860 BP, comes from the Popigai River basin, northern Eastern Siberia, next to the Taymyr Peninsula (MacPhee et al. 2002). At the Sushikha locality, southern West Siberian Plain, the tentative age of bison occupation, about 9320 BP, requires further study due to only a single ^{14}C value obtained so far from this locality and the fragmentary nature of the fossils. Similar aged bison remains are known from the Ust-Belaya site (layers 3–4) at the Angara River headwaters, southern Eastern Siberia, with an associated ^{14}C bone date of 8960 ± 60 BP (GIN-96) (Kuzmin and Orlova 1998:18; MacPhee et al. 2002:1033). Nevertheless, no details are available about the association of ^{14}C-dated bone and the bison remains, and this value should, therefore, be treated with caution. The existence of *Bison priscus* in southern Siberia in the Early Holocene is still in doubt and requires additional study.

Horse

Although there are many Upper Pleistocene findings of horse fossils in Siberia (cf. Vangengeim 1977; Vereshchagin and Baryshnikov 1984; Markova et al. 1995), ^{14}C-dated localities are known mostly from the northern parts of Western, Eastern, and Northeastern Siberia (Figure 2). Most of the youngest dates correspond to the Late Glacial and the Pleistocene-Holocene boundary, about 15,300–9010 BP (Table 4). However, in the Holocene, small populations of horse existed on the Laptev Sea coast and the Taymyr Peninsula. At the Bykovsky Peninsula locality, on the Laptev Sea coast near the modern town of Tiksi, a ^{14}C date of 4610 ± 40 BP was obtained; and on the Bolshoi Lyakhovsky Island (Novosibirsk archipelago), the value of 2200 ± 50 BP was generated (Kuznetsova et al. 2001). On the Taymyr Peninsula, ^{14}C dates of 3250 ± 60 BP (Agapa River basin) and 2150 ± 200 BP (Bolshaya Balakhnya River basin) have been previously reported (MacPhee et al. 2002). These dates support that horse existed in arctic Siberia into the Late Holocene.

The data shows an extinction pattern which illustrates a disappearance of horse in Siberia at about 11,700–9000 BP, but an apparent reappearance in arctic Siberia at about 4600 BP, and finally becoming extinct throughout the region at about 2200 BP. The cause of the hiatus in the existence of horse in this region between approximately 9000 and 4600 BP is not clear (MacPhee et al. 2002: 1034–40).

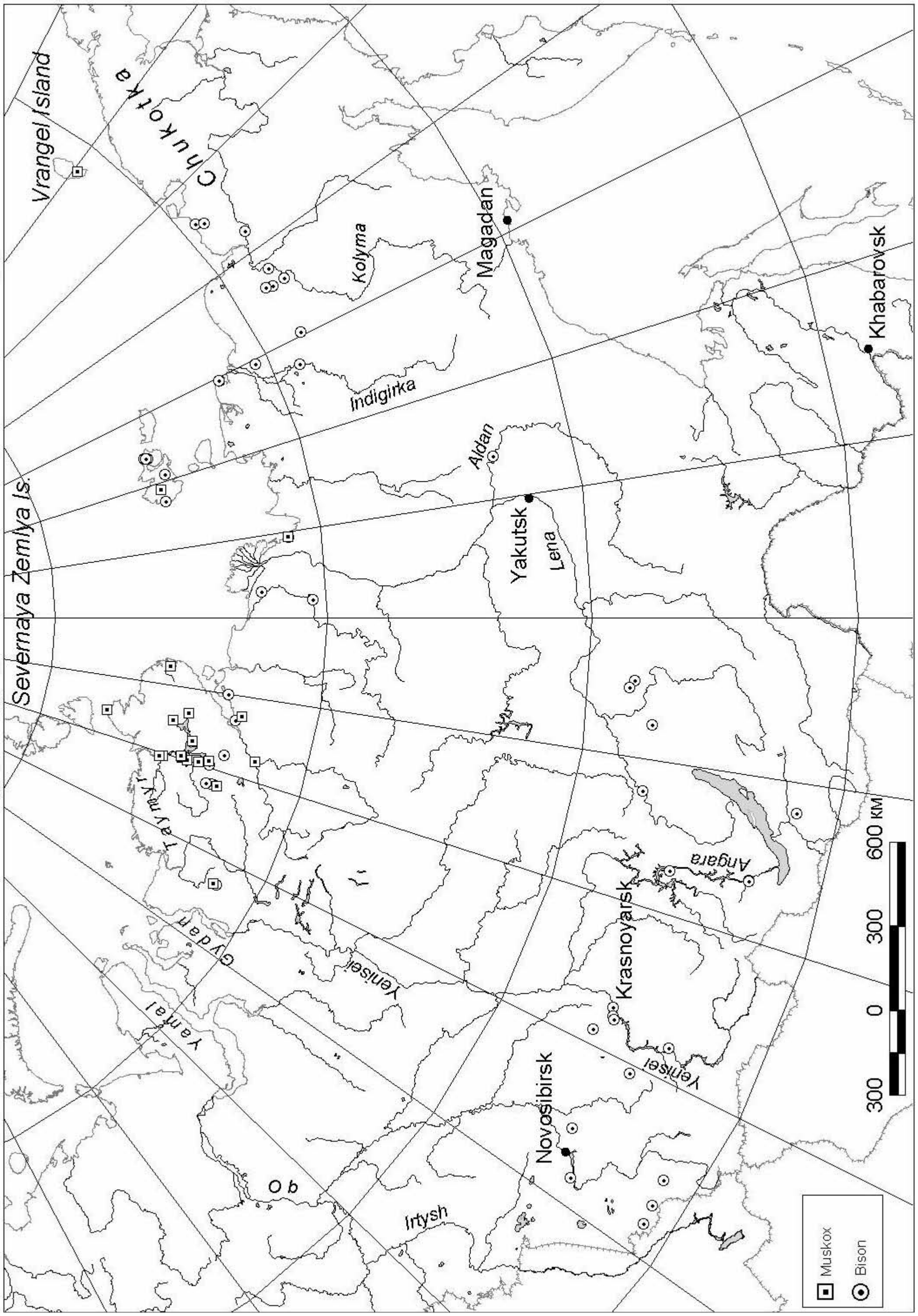

Figure 3 Location of ^{14}C-dated bison and muskox remains in Siberia

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Muskox

Fossils of muskox are rare in Siberia and are concentrated mainly in what are today arctic regions, from where ^{14}C-dated remains are found (Figure 3). The highest concentration of dates is on the Taymyr Peninsula (MacPhee et al. 2002). The majority of the latest ^{14}C dates run on muskox belong to the Late Glacial, about 12,150–10,750 BP (Table 5). However, in the Late Holocene, muskox reappeared on the Laptev Sea coast and the Taymyr Peninsula at about 3200–2900 BP, and continued to exist until about 2700 BP (Sulerzhitsky and Romanenko 1999; Kuznetsova et al. 2001). This pattern is similar to the Holocene dynamics of horse in the same region, with a significant hiatus on the Taymyr Peninsula from approximately 12,150 BP to 2900 BP (MacPhee et al. 2002:1030–3).

CONCLUSION

From the data presented, we conclude that the major extinction of the Pleistocene fauna representatives in continental Siberia can be dated to approximately 11,000–9700 BP. In the insular territories, (for example, Wrangel Island), a few species such as woolly mammoth survived until the Late Holocene, about 3700 BP. Some species, such as horse and muskox, reappeared in continental arctic Siberia in the Holocene. Thus, the dynamics of the megafaunal species was quite complex and "mosaic-like" in their geographic and chronological patterns, with hiatuses in the ^{14}C age distribution for some species, possibly reflecting the re-colonization after a long absence.

Our data also allows us to assume that the central and southern parts of the West Siberian Plain contained several apparent refuge areas for Pleistocene species, including mammoth (until about 10,200 BP), woolly rhinoceros (until about 10,800 BP), and possibly bison (until about 9000 BP). The existence of isolated megafaunal populations beyond the Arctic after about 12,000 BP is at odds with current Pleistocene extinction models, but will provide an interesting challenge for future research.

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Table 1 ^{14}C dates for Late Glacial and Holocene (about 12,000–3700 BP) woolly mammoth in Siberia (after Sulerzhitsky 1997; Sulerzhitsky and Romanenko 1999; Vasil'chuk et al. 1997; MacPhee et al. 2002; Kuzmin et al. 2003) (*, **, *** = dates were run on the same sample).

Nr	Site name, location	Latitude, N	Longitude, E	^{14}C date, BP	Sigma (± σ)	Lab code and nr
1	Wrangel Island	71.00	179.00	3685	60	Ua-13366
2	Wrangel Island	71.00	179.00	3730	40	LU-2741
3	Wrangel Island	71.00	179.00	3920	30	GIN-6980
4	Wrangel Island	71.00	179.00	4010	50	LU-2798
5	Wrangel Island	71.00	179.00	4040	30	LU-2808
6	Wrangel Island	71.00	179.00	4370	70	GIN-8249
7	Wrangel Island	71.00	179.00	4400	40	LU-2756
8	Wrangel Island	71.00	179.00	4410	50	LU-2768
9	Wrangel Island	71.00	179.00	4740	40	LU-2556
10	Wrangel Island	71.00	179.00	4900	40	LU-2740
11	Wrangel Island	71.00	179.00	5110	40	LU-2794
12	Wrangel Island	71.00	179.00	5200	30	LU-2745
13	Wrangel Island	71.00	179.00	5250	40	LU-2744
14	Wrangel Island	71.00	179.00	5310	90	LU-2742
15	Wrangel Island	71.00	179.00	5480	50	LU-2535
16	Wrangel Island*	71.00	179.00	6260	50	LU-2799
17	Wrangel Island*	71.00	179.00	6360	60	AA-11529
18	Wrangel Island	71.00	179.00	6610	50	LU-2558
19	Wrangel Island**	71.00	179.00	6750	30	GIN-6990
20	Wrangel Island**	71.00	179.00	6760	50	LU-2736
21	Wrangel Island	71.00	179.00	6890	50	LU-2810
22	Wrangel Island	71.00	179.00	7040	60	LU-2746
23	Wrangel Island***	71.00	179.00	7250	60	LU-2809
24	Wrangel Island***	71.00	179.00	7295	95	AA-11530
25	Wrangel Island	71.00	179.00	7360	50	LU-2559
26	Wrangel Island	71.00	179.00	7710	40	GIN-6995
27	Nizhnaya Taymyra River	75.25	99.73	9670	60	GIN-1828
28	Pronchischev Coast	76.75	110.50	9780	40	GIN-8256
29	Nizhnaya Taymyra River	75.25	99.73	9860	50	GIN-1495
30	Bikada River	74.92	106.58	9920	60	GrA-17350
31	Yuribey River (Gydan Peninsula)	68.92	71.00	10,000	70	LU-1153
32	Nyengatiatari	74.83	106.17	10,070	60	GIN-10508
33	Engelgardt Lake	75.10	110.30	10,100	100	GIN-1489
34	Kupchiktakh Lake	73.58	101.13	10,200	40	GIN-11138a
35	Lugovskoe	61.05	68.57	10,210	135	SOAN-4752
36	Goltsovaya River	76.80	104.58	10,270	40	Beta-148640
37	Nyunkarakutari River	75.35	105.50	10,270	120	GIN-10507
38	Nizhnaya Taymyra River	75.25	99.73	10,300	100	GIN-1828k
39	Mutnaya Seyakha River	70.15	69.00	10,350	50	GIN-6386
40	Berelekh	70.55	149.05	10,370	70	SOAN-327
41	Sabettayakha River	71.15	71.33	10,420	130	AA-27378
42	Yuribei River (Yamal Peninsula)	68.92	69.70	10,460	120	AA-27378
43	Nganasanskaya River	74.40	99.41	10,680	70	GIN-3768

Table 1 ^{14}C dates for Late Glacial and Holocene (about 12,000–3700 BP) woolly mammoth in Siberia (after Sulerzhitsky 1997; Sulerzhitsky and Romanenko 1999; Vasil'chuk et al. 1997; MacPhee et al. 2002; Kuzmin et al. 2003) (*, **, *** = dates were run on the same sample). *(Continued)*

Nr	Site name, location	Latitude, N	Longitude, E	^{14}C date, BP	Sigma (± σ)	Lab code and nr
44	Krasnaya River	74.57	98.50	10,790	100	GIN-10552
45	Lugovskoe	61.05	68.57	10,820	170	SOAN-4943
46	Sosva River	59.16	62.08	11,080	160	SOAN-4842
47	Volchya Griva	54.50	80.20	11,090	120	SOAN-4921
48	Taymyr Lake	74.05	93.10	11,140	180	GIN-3067
49	Lugovskoe	61.05	68.57	11,310	380	SOAN-4755
50	Mamont River	75.15	96.00	11,450	250	T-297
51	Oktyabrskoi Revolutsii Island	78.82	97.67	11,500	60	LU-610
52	Lugovskoe	61.05	68.57	11,840	95	SOAN-4753
53	Arilakh Lake	74.42	107.58	11,940	40	Beta-148663
54	Konzhul	55.33	92.47	11,980	155	SOAN-4953
55	Berelekh	70.55	149.05	12,000	130	LU-149
56	Wrangel Island	71.00	179.00	12,010	110	LU-2823

Table 2 ^{14}C dates for woolly rhinoceros in Siberia (after Heintz and Garutt 1965; Latypova and Yakheemovich 1993; Kuzmin and Orlova 1998; Sulerzhitsky and Romanenko 1999; Garutt and Boeskorov 2001).

Nr	Site name, location	Latitude, N	Longitude, E	^{14}C date, BP	Sigma (± σ)	Lab code and nr
1	Lugovskoe	61.05	68.57	10,770	250	SOAN-4757
2	Zlatoustovka	52.97	55.32	12,330	120	BashGI-107
3	Yukagir Plateau	67.00	157.17	14,260	150	GIN-6007
4	Bolshoi Khomus-Yuriakh River	71.16	153.45	15,130	50	GIN-6023
5	Bolshoi Khomus-Yuriakh River	71.16	153.45	15,130	90	GIN-6024
6	Indigirka River	69.87	147.58	15,850	80	GIN-6020
7	Churapcha	62.00	132.50	19,500	120	GIN-9594
8	Zhuya River	58.15	115.51	19,610	670	SOAN-4732
9	Ikhine	63.17	133.75	20,080	150	SOAN-3185
10	Khroma River	70.70	143.00	20,400	200	GIN-6021
11	Kamchatka Peninsula	55.50	159.50	20,800	200	GIN-3400
12	Rel River	55.38	109.00	25,880	350	SOAN-829
13	Ikhine 2	63.17	133.75	26,030	200	IM-239
14	Kozlovka	56.35	90.77	26,620	240	SOAN-3158
15	Kolyma River	68.20	157.67	26,900	400	GIN-6005
16	Maly Anui River	68.00	162.17	27,300	300	GIN-6018
17	Maly Anui River	68.00	162.17	27,300	300	GIN-3209
18	Wrangel Island	71.00	179.00	29,800	340	GIN-8259a
19	Wrangel Island	71.00	179.00	>30,000	—	GIN
20	Lugovskoe	61.05	68.57	30,090	800	SOAN-4756
21	Bolshoi Khomus-Yuriakh River	71.16	153.45	>30,400	—	GIN-6023a

Table 2 ^{14}C dates for woolly rhinoceros in Siberia (after Heintz and Garutt 1965; Latypova and Yakheemovich 1993; Kuzmin and Orlova 1998; Sulerzhitsky and Romanenko 1999; Garutt and Boeskorov 2001). *(Continued)*

Nr	Site name, location	Latitude, N	Longitude, E	^{14}C date, BP	Sigma (± σ)	Lab code and nr
22	Varvarina Gora	51.62	108.12	30,600	500	SOAN-850
23	Bolshoi Khomus-Yuriakh River	71.16	153.45	30,900	200	GIN-6022
24	Emige	70.40	133.00	31,500	300	GIN-6013
25	Ozernaya Balya	55.45	103.05	31,860	780	SOAN-4251
26	Achchagy-Allaikha	69.00	147.30	>32,000	—	GIN-6017
27	Khalbui River	67.50	132.67	>33,000	—	T-172
28	Irelyakh-Sien River	66.17	151.67	33,100	400	GIN-6010
29	Varvarina Gora	51.62	108.12	>34,050	—	AA-8875
30	Tolbaga	51.25	109.33	34,860	2100	SOAN-1522
31	Bolshaya Chukochya River	69.03	156.00	37,100	1100	GIN-6009
32	Elga River	64.58	141.50	>38,000	—	T-173
33	Dzhelon-Siene	67.27	155.87	39,900	500	GIN-6011
34	Yana River headwaters	66.02	132.75	40,000	500	GIN-6012
35	Bourdakh	67.02	154.30	41,600	800	GIN-6006
36	Khetechan	67.80	161.67	>42,300	—	GIN-6014
37	Baltagai	67.17	153.75	>42,300	—	GIN-6015
38	Tyung River	65.08	120.00	>43,000	—	GIN-5926
39	Bolshaya Chukochya River	69.03	156.00	43,700	1000	GIN-6008
40	Kamchatka Peninsula	55.83	159.67	46,700	1200	GIN-3424
41	Bolshoi Anui River	66.98	163.00	>49,000	—	GIN-6014

Table 3 ^{14}C dates for bison in Siberia (after Kuzmin and Orlova 1998; Sulerzhitsky and Romanenko 1999; Schirrmeister et al. 2002; MacPhee et al. 2002).

Nr	Site name, location	Latitude, N	Longitude, E	^{14}C date, BP	Sigma (± σ)	Lab code and nr
1	Popigai River	72.83	107.42	8860	40	Beta-148623
2	Sushikha	54.37	81.70	9320	95	SOAN-4568
3	Krasnoyarsk	56.10	92.90	11,610	110	SOAN-1683
4	Keremensit River	70.50	149.50	12,800	60	GIN-4038
5	Listvenka, layer 10	55.95	92.40	13,200	110	SOAN-5083
6	Birusa, layer 3a	55.87	92.20	14,480	400	LE-3777
7	Malta, layers 9.1–9.2	52.83	103.55	14,720	190	GIN-8476
8	Kolyma River	68.30	157.70	14,800	250	GIN-3208a
9	Kozhevnikov Bay	73.50	110.00	16,390	120	GIN-5727
10	Shlenka	53.55	92.00	17,660	700	GIN-2862a
11	Ust-Mashinka 3	51.05	82.00	17,910	265	SOAN-4570
12	Ikhine	63.12	133.62	19,695	100	SOAN-3186
13	Tesa River	57.50	112.50	20,040	765	SOAN-4419
14	Malta, layer 8	52.83	103.53	21,600	170	GIN-8475
15	Kudelin	55.33	84.50	23,050	255	SOAN-3633

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Table 3 ^{14}C dates for bison in Siberia (after Kuzmin and Orlova 1998; Sulerzhitsky and Romanenko 1999; Schirrmeister et al. 2002; MacPhee et al. 2002). *(Continued)*

Nr	Site name, location	Latitude, N	Longitude, E	^{14}C date, BP	Sigma (± σ)	Lab code and nr
16	Yuzhny	55.83	102.83	23,400	455	SOAN-3155
17	Western Chukotka	69.50	166.00	23,590	1560	GIN-8251
18	Tobol River	56.00	66.00	24,600	300	SOAN-3849
19	Balyshevo 3	57.48	107.77	25,100	940	LE-3950
20	Faddeevsky Island	75.70	144.20	26,100	300	GIN-4329
21	Vacha River	58.24	115.31	27,140	330	SOAN-4734
22	Logata River	73.20	98.15	27,600	400	GIN-3814
23	Mylakchyn	69.00	147.50	29,500	100	SOAN-1007
24	Ust-Karakol	51.38	84.68	28,700	850	SOAN-2614
25	Belkovsky Island	75.50	135.83	30,500	400	GIN-8222
26	Bykovsky Peninsula	71.28	129.42	>31,300	—	GIN
27	Logata River	73.30	98.20	31,800	500	GIN-3825
28	Agapa River	71.60	87.10	31,900	500	GIN-3241
29	Vacha River	58.24	115.31	32,170	250	SOAN-4733
30	Faddeevsky Island	75.60	144.05	32,200	600	GIN-8228
31	Logovo Gieny Cave	51.25	83.05	32,700	2800	SOAN-110
32	Bykovsky Peninsula	71.28	129.42	32,800	400	GIN
33	Bolshoi Kuduskit	58.33	115.50	>33,000	—	GIN-8877
34	Vacha River	58.50	115.00	>33,000	—	GIN-9069
35	Faddeevsky Island	75.65	144.05	33,100	320	GIN-8231
36	Logata River	73.50	98.00	33,750	1200	GIN-3824
37	Lopatka Peninsula	72.00	149.67	33,800	1200	GIN-8235
38	Duvanny Yar	68.45	150.45	34,700	400	GIN-8235
39	Maly Anui River	68.20	162.17	>35,300	—	GIN-7308
40	Varvarina Gora, layer 3	51.63	108.17	>35,300	—	AA-8993
41	Bederbo-Tarida	73.16	102.20	35,800	800	GIN-3100/1
42	Olenek River	70.55	122.10	36,800	500	GIN-6097
43	Kolyma River	68.00	156.00	37,100	500	GIN-3207
44	Kolyma River	68.50	156.00	38,400	800	GIN-5711
45	Western Chukotka	69.20	165.50	>39,000	—	GIN-8239
46	Bolshaya Balakhnya River	73.60	100.50	39,200	800	GIN-2764a
47	Bykovsky Peninsula	71.28	129.42	39,200	900	GIN
48	Sabler Cape (Lake Taymyr)	74.53	100.50	39,760	870	Beta-148624
49	Proskuryakov Grotto	54.45	89.47	40,595	875	SOAN-1518
50	Proskuryakov Grotto	54.45	89.47	40,690	1150	SOAN-1517
51	Proskuryakov Grotto	54.45	89.47	40,770	1075	SOAN-1519
52	Malta	52.83	103.53	41,100	1500	GIN-7707
53	Olenek River	70.55	122.10	41,300	800	GIN-6098
54	Olenek River	72.45	123.20	41,700	1500	GIN-6428
55	Kolyma River	68.75	156.20	42,800	700	GIN-5710
56	Kotelny Island	75.20	141.00	43,400	2200	GIN-8253
57	Birusa River	55.55	97.90	>45,000	—	SOAN-3157
58	Duvanny Yar	68.45	150.45	45,400	1200	GIN-3860
59	Talalakh Lake	73.07	106.83	45,320	1740	Beta-148625

Table 4 ^{14}C dates for horse in Siberia (after Sulerzhitsky and Romanenko 1999; Kuznetsova et al. 2001; Schirrmeister et al. 2002; MacPhee et al. 2002).

Nr	Site name, location	Latitude, N	Longitude, E	^{14}C date, BP	Sigma (± σ)	Lab code and nr
1	Bolshaya Balakhnya River	73.65	100.48	2150	200	GIN-2744
2	Bolshoi Lyakhovsky Island	73.63	143.10	2200	50	GIN
3	Agapa River	71.62	87.00	3250	60	GIN-3243
4	Bykovsky Peninsula	71.28	129.42	4160	40	GIN
5	Nyunkarakutari River	75.30	105.75	9010	140	GIN-10509
6	Olenek River	72.50	122.00	11,660	450	GIN-6427
7	Logata River	73.10	98.00	14,100	160	GIN-3823a
8	Olenek River	70.50	122.00	14,560	250	GIN-6096
9	Omolon River mouth	68.67	158.50	15,300	60	GIN-5371
10	Bykovsky Peninsula	71.28	129.42	16,380	120	GIN
11	Bolshaya Balakhnya River	73.53	100.49	17,000	150	GIN-11133
12	Taymyr Lake	74.66	103.00	17,950	60	Beta-148659
13	Arilakh Lake	74.43	107.58	18,090	80	GrA-17351
14	Bolshaya Balakhnya River	73.55	100.45	18,300	200	GIN-3140b
15	Kotelny Island	75.00	141.00	19,100	120	GIN-8252
16	Duvanny Yar	68.45	150.45	19,480	100	GIN-3868
17	Sabler Cape (Taymyr Lake)	74.53	100.50	20,700	500	GIN-3241a
18	Bederbo-Tarida River	73.06	102.16	21,500	200	GIN-2744
19	Bykovsky Peninsula	71.28	129.42	23,850	700	GIN
20	Bolshaya Balakhnya River	73.54	100.50	23,900	400	GIN-11132
21	Olenek River	70.50	122.00	24,000	400	GIN-6426
22	Sabler Cape	74.53	100.50	24,690	110	Beta-148660
23	Engelgardt Lake	75.10	110.30	25,200	200	GIN-1817a
24	Sabler Cape	74.53	100.50	26,400	300	GIN-2142b
25	Shchuchya River	67.40	67.90	27,360	170	GIN-6448a
26	Bykovsky Peninsula	71.28	129.42	27,500	400	GIN
27	Sabler Cape	74.53	100.50	27,900	300	GIN-3841b
28	Anabar-Olenek watershed	72.00	117.00	28,180	270	GIN-8219
29	Kozhevnikov Bay	73.50	110.00	28,300	400	GIN-5732
30	Bykovsky Peninsula	71.28	129.42	28,400	300	GIN
31	Bykovsky Peninsula	71.28	129.42	29,000	450	GIN
32	Bykovsky Peninsula	71.28	129.42	29,000	900	GIN
33	Faddeevsky Island	75.50	144.00	29,100	400	GIN-4330
34	Sabler Cape	74.53	100.50	29,700	700	GIN-3141a
35	Pavel-Saiyngi-Yuriakh River	41.00	119.00	29,800	1200	GIN-5047
36	Kupchiktakh Lake	73.61	101.15	>30,000	—	GIN
37	Bykovsky Peninsula	71.28	129.42	31,100	400	GIN
38	Bykovsky Peninsula	71.28	129.42	>31,300	—	GIN
39	Sabler Cape	74.53	100.50	32,000	1000	GIN-3141c
40	Bykovsky Peninsula	71.28	129.42	32,000	1000	GIN
41	Bykovsky Peninsula	71.28	129.42	33,000	400	GIN
42	Bykovsky Peninsula	71.28	129.42	34,000	400	GIN
43	Bykovsky Peninsula	71.28	129.42	34,800	700	GIN
44	Bykovsky Peninsula	71.28	129.42	>34,600	—	GIN
45	Bykovsky Peninsula	71.28	129.42	35,800	500	GIN
46	Bykovsky Peninsula	71.28	129.42	>35,800	—	GIN
47	Anabar-Olenek watershed	72.30	117.50	36,300	640	GIN-8221

Table 4 [14]C dates for horse in Siberia (after Sulerzhitsky and Romanenko 1999; Kuznetsova et al. 2001; Schirrmeister et al. 2002; MacPhee et al. 2002). *(Continued)*

Nr	Site name, location	Latitude, N	Longitude, E	^{14}C date, BP	Sigma (± σ)	Lab code and nr
48	Bolshaya Balakhnya River	75.30	105.00	36,300	900	GIN-3119
49	Bykovsky Peninsula	71.28	129.42	35,900	600	GIN
50	Talalakh Lake	73.07	106.83	36,770	610	Beta-148622
51	Olenek River	72.40	123.00	38,100	800	GIN-6430
52	Kular Ridge	69.83	133.50	38,700	1000	GIN-4965
53	Anabar-Olenek watershed	73.50	116.00	39,600	500	GIN-3519
54	Western Yamal Peninsula	72.00	68.67	>40,000	—	GIN-8544
55	Logata River	73.20	98.15	40,200	1200	GIN-3823

Table 5 [14]C dates for muskox in Siberia (after Sulerzhitsky and Romanenko 1999; Kuznetsova et al. 2001; Schirrmeister et al. 2002; MacPhee et al. 2002).

Nr	Site name, location	Latitude, N	Longitude, E	^{14}C date, BP	Sigma (± σ)	Lab code and nr
1	Logata River	73.12	98.03	2700	70	GIN-3803
2	Pronchishchev Bay	75.73	112.83	2900	60	GIN-10529
3	Cheluskin Cape	77.72	104.25	2920	50	GIN-2945
4	Bykovsky Peninsula	71.28	129.42	3180	100	GIN
5	Bykovsky Peninsula	71.28	129.42	3200	80	GIN
6	Kotelny Island	75.50	139.00	10,750	90	LU-1666
7	Bolshaya Balakhnya River	74.00	100.40	12,150	40	GIN-3131
8	Wrangel Island	71.08	179.50	15,250	60	GIN-8248
9	Sabler Cape (Lake Taymyr)	74.53	100.50	15,800	50	Beta-148653
10	Agapa River	71.70	87.00	16,080	100	GIN-3239
11	Nizhniya Taymyra River	75.30	99.70	17,800	300	GIN-1815
12	Sabler Cape	74.53	100.50	17,800	160	GIN-3140c
13	South of Sabler Cape	74.50	100.40	18,370	70	Beta-148628
14	Sabler Cape	74.53	100.50	19,310	80	Beta-148627
15	Bolshaya Balakhnya River	75.30	105.00	19,710	70	Beta-148654
16	Taymyr Lake	74.42	100.17	20,770	180	GrA-17500
17	Yalutarida River	74.42	102.83	21,190	90	Beta-148629
18	Khatanga	71.97	102.42	21,330	70	Beta-148658
19	Popigai River[a]	72.83	107.42	21,500	100	Beta-148655
20	Popigai River[a]	72.83	107.42	22,530	220	GrA-17605
21	Taymyr Lake	74.42	100.17	22,370	80	Beta-156194
22	Taymyr Lake	74.42	100.17	22,610	100	Beta-148652
23	Nizhniya Taymyra River	75.45	99.50	24,660	110	Beta-148657
24	Bykovsky Peninsula	71.28	129.42	>27,000	—	GIN
25	Bolshaya Balakhnya River	73.60	100.50	27,440	150	Beta-148656
26	Bolshaya Balakhnya River	73.60	100.50	32,540	150	GrA-17349
27	Bikada River	74.80	106.50	36,700	700	UtC-10156
28	Bolshaya Balakhnya River	73.60	100.50	>39,000	—	GIN-11130
29	Sabler Cape	74.53	100.50	42,680	1240	Beta-148626

[a]Dates were run on same sample

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