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ORIGINAL PAPER

Siberia and neighboring regions in the Last Glacial Maximum: did people occupy northern Eurasia at that time?

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Abstract An updated analysis of Paleolithic sites in Siberia and the Urals ^{14}C-dated to the coldest phase of the Last Glacial Maximum (LGM), with its timespan currently determined as ca. 23,000–19,000 BP (ca. 27, 300–22,900 cal BP), is presented. It is demonstrated that people continuously occupied the southern and central parts of Siberia and the Russian Far East (up to 58° N latitude), and perhaps sporadically settled regions located even further north, up to 70° N, throughout the LGM. This is in accord with our previous data, but is now based on a larger dataset, and also on a paleoecological analysis of the major pre-LGM archaeological sites in Siberia and the Urals north of 58° N. It is clear that Paleolithic people in northern Eurasia were able to cope with the treeless tundra environment well in advance of the LGM, at least at ca. 34,000–26,000 BP (ca. 38,500–30,000 cal BP). Therefore, a high degree of adaptation to cold conditions allowed people to survive in Siberia during the LGM.

Keywords Last Glacial Maximum · Paleolithic · Radiocarbon dating · Adaptation · Siberia · Urals

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Introduction

The issue of human presence in northern Eurasia—Western/Central Europe north of the Alps, northern part of Eastern Europe, and Siberia—during the Last Glacial Maximum (LGM), has been intensely debated in the last 15–20 years. The LGM was originally determined as centered around 18, 000 radiocarbon years ago (BP) (e.g., COHMAP 1988) when environmental conditions in the Northern Hemisphere were the most cold and dry for the last 60,000 years, and possibly the last 130,000 years. In later studies, the duration of the LGM was set at ca. 22,000–16,000 BP corresponding to ca. 26,500–19,000 calendar years ago (cal BP) (Clark et al. 2009). This timespan includes several paleoclimatic events reflected in Greenland ice cores: Greenland stadials (GS) 3, 2.2, 2.1b, and 2.1c; and Greenland interstadials (GI) 2.2 and 2.1 (Rasmussen et al. 2014). The coldest conditions were observed during the GS-3 interval dated to ca. 27.5–23.3 thousand years ago (or ka b2k in Rasmussen et al. 2014), which on a radiocarbon time scale is equal to ca. 23,300–19,300 BP (Reimer et al. 2013).

Since the beginning of the discussion about the presence of Paleolithic humans in Siberia at the LGM in the late 1970s (Tseitlin 1979), there have been two groups of scholars with opposite opinions. "Pessimists" like Tseitlin (1979), Dolukhanov et al. (2002), Hoffecker (2002, 2005a), Goebel (1999, 2002), and Graf (2005, 2009a, b; but see Raghavan et al. 2014) concluded that humans were absent in Siberia at the LGM. "Optimists" like Velichko and Kurenkova (1990), and Kuzmin and co-authors (see Kuzmin 2008; Kuzmin and Orlova 1998; Kuzmin and Keates 2005, 2013; Fiedel and Kuzmin 2007) have argued that people occupied at least the southern part of Siberia at the LGM. The debates are still ongoing (e.g., Kuzmin 2009 vs. Graf 2009a), and here, we present updated information on this subject compared to our previous publications (Kuzmin and Keates 2005, 2013).

The question of human presence during the LGM in Siberia and neighboring regions such as the Urals, the Russian Far East, Mongolia, and Northern China is related to the broader issue of Upper Paleolithic adaptations to the harsh environment of the second part of the Late Pleistocene, as repeatedly discussed (e.g., Soffer 1990, 1993; Vasil'ev 2000, 2003; van Andel and Davies 2003; Pavlov et al. 2004; Hoffecker 2005b; Kuzmin 2008; Pitulko et al. 2012; Velichko et al. 2014). Keeping in mind the importance of the degree of Paleolithic capability to cope with natural challenges in northern Eurasia, including unresolved issues related to human existence in Siberia during the LGM (e.g., Graf 2005, 2009a; Kuzmin 2008, 2009), the analysis presented here seems to be timely.

Material and methods

The basic source for this study is the review by Kuzmin (2008) on Siberia at the LGM. The sites selected for this analysis are shown in Fig. 1. An important addition to this dataset is the series of pre-LGM sites from Siberia and the neighboring Urals region (Fig. 2) which were the subject of investigations since the 1960s (e.g., Pavlov et al. 2001, 2004; Svendsen and Pavlov 2003; Pitulko et al. 2004, 2012; Pavlov 2008; Svendsen et al. 2010; Slimak et al. 2011; Heggen et al. 2012), and the results were recently summarized (Velichko et al. 2014). In our opinion, without an understanding of pre-LGM human adaptations to the extreme continental climate and Pleistocene faunal resources of the European-Siberian region of the Palearctic, it is impossible to determine the peculiarities of existence for Upper Paleolithic populations in Siberia and adjacent territories during the LGM.

We have employed the most recent research results on the duration and environment of the LGM, especially for Siberia and Eastern Europe (Clark et al. 2009; Rasmussen et al. 2014; Kotlyakov et al. 2014). According to the latest analysis of Greenland ice cores (Rasmussen et al. 2014), we determined the duration of the coldest phase of the LGM (GS-3) as the interval of ca. 23,000–19,000 BP corresponding to ca. 27,300–22,900 cal BP (Reimer et al. 2013) for this study. This is in general accord with the majority of current views (see review: Hughes and Gibbard 2015). For this study, we selected archaeological sites in Siberia and the Russian Far East associated with this LGM sensu stricto timespan.

In this paper, we refer to updated summaries on the archaeology of LGM-associated sites in northern Eurasia (Abramova et al. 1991; Kasparov 1998; Derevianko et al. 1998, 2003; Akimova et al. 2001, 2005; Tarasov et al. 2002; Stepanov et al. 2003; Boeskorov 2003; Kuzmin et al. 2005, 2011; Graf 2009b; see also Kuzmin 2008, and references therein). These data are supplemented by information on the pre-LGM sites in Siberia and the Urals north of 58° N latitude (Pavlov et al. 2001, 2004; Pitulko et al. 2004, 2012; Pavlov 2008; Svendsen et al. 2010; Slimak et al. 2011; see also Kotlyakov et al. 2014).

The Siberian Paleolithic radiocarbon (^{14}C) database (Vasil'ev et al. 2002; Kuzmin et al. 2011) serves as the basic source of information about the LGM-related sites. It should be highlighted that the ^{14}C values included in this dataset underwent a reliability check also called "chronometric hygiene" (sensu Spriggs 1989). As for the frequency of Paleolithic occupation in Siberia, data published previously (Kuzmin and Keates 2005, 2013) were used.

The ^{14}C dates that belong to the LGM (a total of 43 values) are listed in Table 1. There are 13 values obtained by the accelerator mass spectrometry method, and 30 ages are determined by liquid scintillation counting. The material dated includes wood charcoal (24 values; 57 % of the total), animal bones (16 values; 38 % of the total), and human bones (2 values; 5 % of the total). We consider charcoal and human bone as the most reliable materials to establish the timing of human occupation because of problems in ^{14}C dating of animal bones related to (a) poor preservation of collagen, and (b) possible scavenging of the megafaunal osseous remains by Paleolithic humans. Both factors could distort the chronology of sites. Animal bones with clear cutmarks and/or other traces of human modification can be considered as a more reliable material compared to non-modified bones but use-wear and taphonomic studies in Russian archaeology are still quite rare, and for the sake of objectivity, we do not consider animal bones as suitable material in relation to charcoal and human bones. Charcoal is quite fragile and much less resistant to redeposition compared to unmodified animal bones, and therefore is more secure in terms of its in situ localization in a cultural layer.

Results and discussion

Evidence of human occupation of Siberia in the LGM

Based on data available as of the beginning of 2016, we have compiled a list of 28 Siberian archaeological sites and their ^{14}C dates within the LGM at ca. 23,000–19,000 BP (Table 1). The sites are located in different parts of northern Asia: Western Siberia (West Siberian Plain and Altai Mountains); Eastern Siberia (Yenisei River basin, Angara River basin, upper course of the Lena River, Transbaikal, and Yakutia); and the Russian Far East (Amur River Basin and Sakhalin Island). The sites cover all the major regions of the southern and central parts of Siberia (Fig. 1).

In Fig. 3, the calibrated ages of LGM-associated sites in Siberia are presented for each geographic region against the background of climatic phases. The majority of sites have been found in the Yenisei River Basin (12 sites; 43 % of the

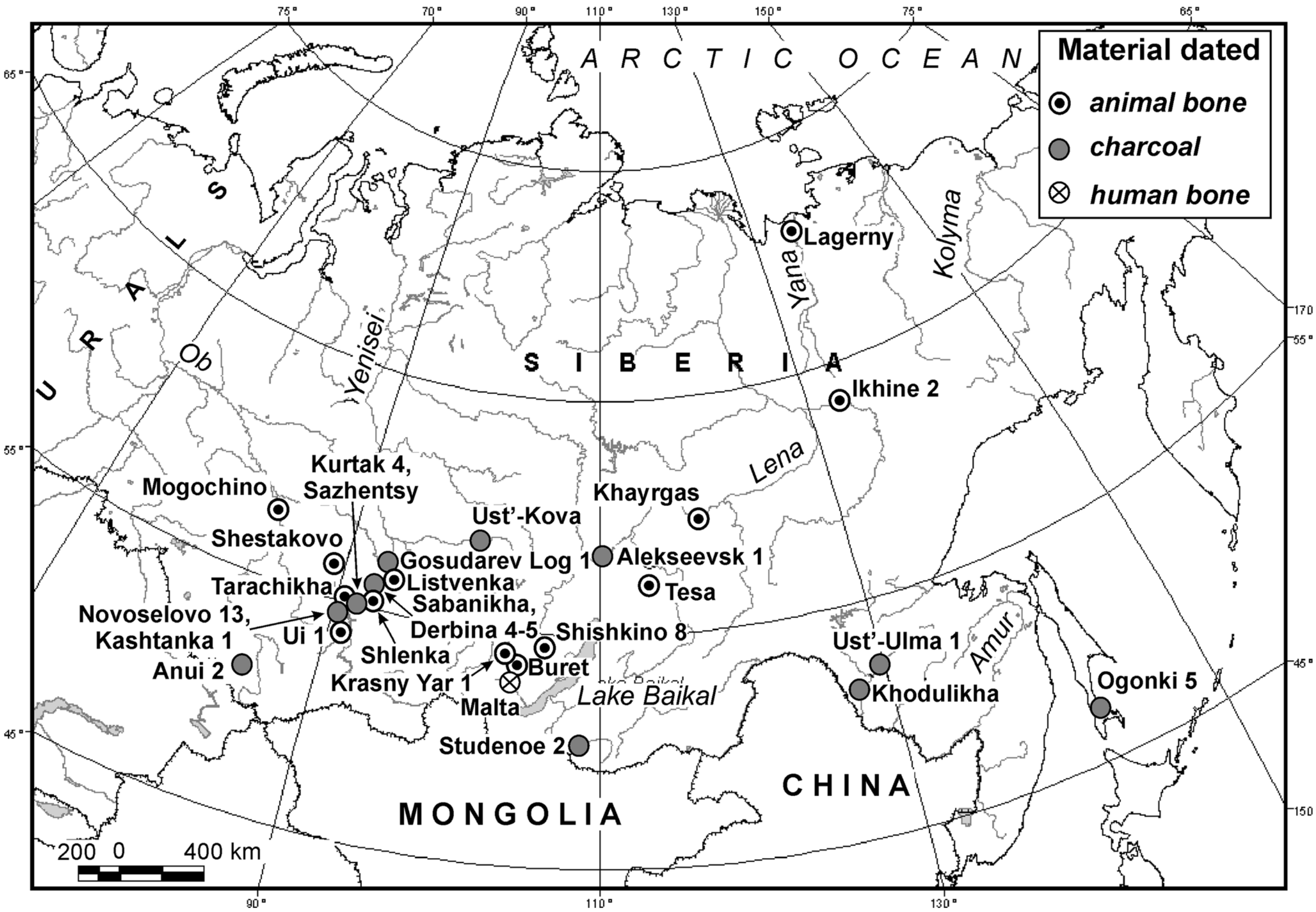

Fig. 1 The LGM sites in Siberia referred to in this study

total), and in the Angara River Basin and Cis-Baikal (six sites; 21 % of the total). The intermediate level of occupation is in Western Siberia (three sites; 11 % of the total) and the Russian Far East (three sites; 11 % of the total). The smallest number of sites was detected in the Transbaikal (two sites; 7 % of the total) and Yakutia (two sites; 7 % of the total).

In terms of the materials dated, regions with a high and intermediate density of human presence have a significant

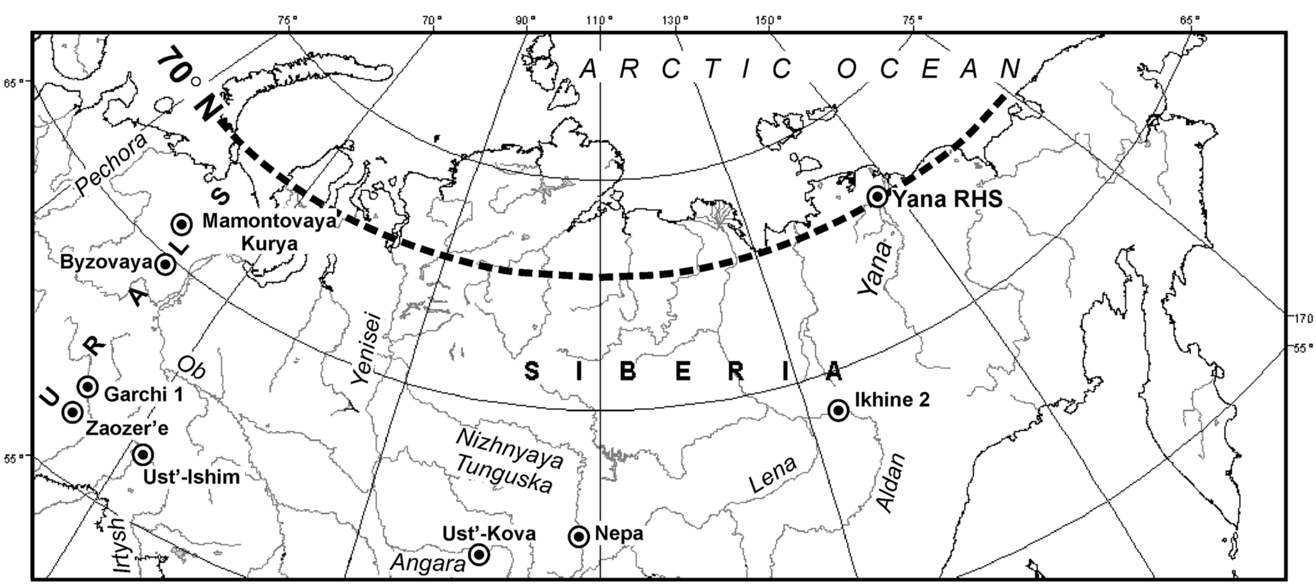

Fig. 2 The pre-LGM sites in Siberia and the Urals north of 58° N used in this study

Table 1 The LGM-associated sites in Siberia and their ^{14}C dates as of late 2015 (after Kuzmin 2008; Kuzmin et al. 2011; with additions)

Site no.	Coordinates[a]	Site name and cultural layer no.	^{14}C date, BP[b]	Calendar date, cal BP[c]	Material dated	Lab code	Reference
1	57.75, 83.52	Mogochino	20,150 ± 240	23,650–24,950	Animal bone	SOAN-1513	Kuzmin (2008)
2	51.30, 84.60	Anui 2, layer 3	**21,280 ± 440**	24,440–26,430	Charcoal	SOAN-3007	Kuzmin et al. (2011)
		Anui 2, layer 4	**21,500 ± 585**	24,420–27,080	Charcoal	IGAN-1431	Kuzmin et al. (2011)
3	55.90, 87.95	Shestakovo, layer 5	21,560 ± 100	25,660–26,040	Animal bone	GrA-13234	Zenin et al. (2000)
		Shestakovo, layer 6	22,340 ± 180/-170	26,150–27,120	Animal bone	GrA-13240	Zenin et al. (2000)
4	55.01, 90.95	Sabanikha	**22,900 ± 480**	26,110–27,870	Charcoal	LE-4700	Kuzmin et al. (2011)
			22,930 ± 350	26,420–27,760	Charcoal	LE-3611	Kuzmin et al. (2011)
5	55.08, 91.00	Tarachikha, locality 1, layer 2	19,850 ± 180	23,450–24,330	Animal bone	LE-3821	Kuzmin (2008)
6	55.09, 91.00	Novoselovo 13, layer 3	**22,000 ± 700**	24,790–27,630	Charcoal	LE-3739	Vasil'ev et al. (2002)
7	55.13, 91.42	Kashtanka 1, layer 1	**20,800 ± 600**	23,570–26,180	Charcoal	GIN-6968	Vasil'ev et al. (2002)
			21,800 ± 200	25,700–26,490	Charcoal	IGAN-1049	Vasil'ev et al. (2002)
8	55.15, 91.57	Sazhentsy	**22,175 ± 195**	26,000–26,990	Charcoal	SOAN-7439	Kuzmin et al. (2011)
9	55.17, 91.58	Kurtak 4, layer 1	**20,690 ± 240**	24,300–25,530	Charcoal	AA-72146	Graf (2009a)
			21,270 ± 160	25,250–25,900	Charcoal	AA-72147	Graf (2009a)
10	55.20, 92.05	Shlenka	19,700 ± 200	23,170–24,200	Animal bone	GIN-2861	Kuzmin (2008)
			20,100 ± 100	23,900–24,430	Animal bone	GIN-2863	Kuzmin (2008)
11	55.92, 92.33	Listvenka, layer 20	20,610 ± 380	23,940–25,680	Animal bone	SOAN-4795	Kuzmin et al. (2011)
12	52.93, 91.50	Ui 1, layer 2	19,280 ± 200	22,690–23,730	Animal bone	LE-4257	Kuzmin (2008)
			22,830 ± 530	26,000–27,890	Animal bone	LE-4189	Vasil'ev et al. (2005)
13	55.33, 92.50	Derbina 5	**20,460 ± 465**	23,570–25,700	Charcoal	SOAN-4796	Kuzmin et al. (2011)
			21,100 ± 120	25,160–25,720	Charcoal	SOAN-4346	Kuzmin et al. (2011)
			21,320 ± 300	24,900–26,180	Charcoal	SOAN-4346a	Kuzmin et al. (2011)
			21,440 ± 450	24,540–26,660	Charcoal	SOAN-4797	Kuzmin et al. (2011)
14	55.33, 92.52	Derbina 4	**21,930 ± 220**	25,760–26,700	Charcoal	SOAN-4955	Kuzmin et al. (2011)
15	56.05, 93.23	Gosudarev Log 1	**22,870 ± 380**	26,300–27,740	Charcoal	SOAN-4315	Kuzmin et al. (2011)
16	58.33, 100.33	Ust'-Kova, middle complex	**19,540 ± 90**	23,210–23,850	Charcoal	SOAN-1900	Kuzmin (2008)
17	52.95, 103.42	Buret	21,190 ± 100	25,260–25,770	Animal bone	SOAN-1680	Kuzmin et al. (2011)
18	53.00, 103.50	Malta[d]	**19,880 ± 160**	23,520–24,320	Human bone	OxA-7129	Richards et al. (2001)
			20,240 ± 60	24,090–24,520	Human bone	UCIAMS-79666	Raghavan et al. (2013)
19	53.30, 103.37	Krasny Yar 1, layer 6	19,100 ± 100	22,690–23,380	Animal bone	GIN-5330	Kuzmin (2008)
21	54.13, 105.58	Shishkino 8	21,190 ± 175	25,150–25,870	Animal bone	AA-8882	Kuzmin et al. (2011)
22	57.83, 108.33	Alekseevsk 1	**22,410 ± 480**	25,830–27,550	Charcoal	LE-3931	Kuzmin et al. (2011)
22	50.18, 108.50	Studenoe 2, layer 8	**20,620 ± 90**	24,490–25,180	Charcoal	CAMS-90971	Buvit et al. (2004)
23	57.50, 112.50	Tesa	20,040 ± 765	22,460–25,800	Animal bone	SOAN-4419	Kuzmin (2008)
24	59.93, 117.47	Khayrgas, layer 7	21,500 ± 755	24,090–27,330	Animal bone	SOAN-4249	Kuzmin et al. (2011)
25	50.33, 127.66	Khodulikha, layer 1	**22,530 ± 320**	26,120–27,430	Charcoal	SNU 03-365	Kuzmin et al. (2011)
26	51.83, 129.58	Ust'-Ulma 1, layer 2b	**19,360 ± 65**	23,050–23,560	Charcoal	SOAN-2619	Kuzmin (2008)
27	63.17, 133.75	Ikhine 2	19,695 ± 100	23,440–24,010	Animal bone	SOAN-3186	Kuzmin (2008)
			20,080 ± 150	23,770–24,510	Animal bone	SOAN-3185	Kuzmin (2008)
28	70.63, 135.42	Lagerny	22,040 ± 100	26,000–26,540	Ivory	Beta-362949	Pitulko et al. (2015)
29	46.77, 142.40	Ogonki 5, horizon 3	**19,320 ± 145**	22,890–23,650	Charcoal	AA-20864	Kuzmin (2008)
			19,380 ± 190	22,870–23,840	Charcoal	Beta-115986	Kuzmin (2008)
			19,440 ± 140	23,010–23,790	Charcoal	Beta-115987	Kuzmin (2008)

[a] Latitude (N) and longitude (E); in decimal values

[b] Dates run on charcoal and human bones are in bold

[c] IntCal13 dataset (Reimer et al. 2013) is used for calibration; with ±2 sigma, and all calibration intervals rounded to the next 10 years and combined

[d] The Malta 1 skeleton was ^{14}C-dated

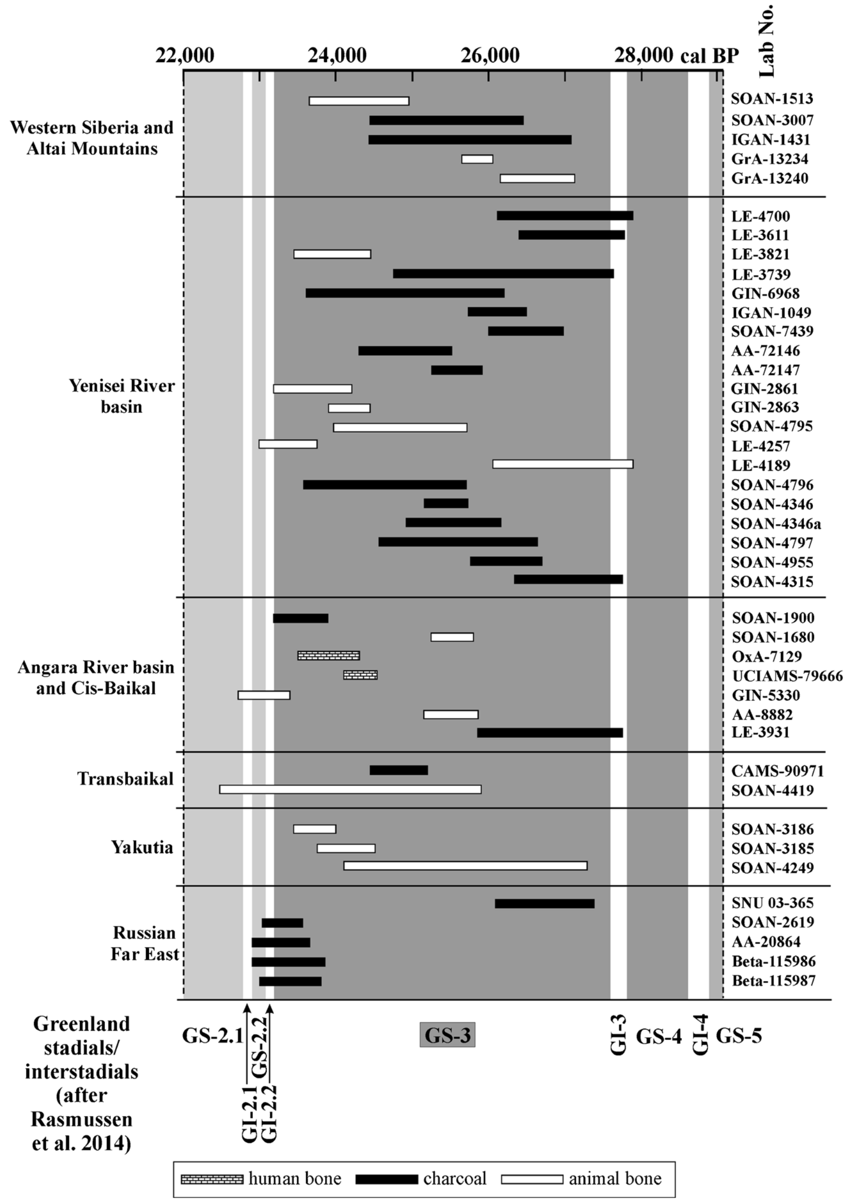

Fig. 3 Plot of LGM-associated calibrated ^{14}C dates from Siberian sites (see also Table 1). The *dark gray* intervals represent the coldest conditions, and the *light gray* intervals correspond to slightly warmer conditions; the *white intervals* are climatic ameliorations (after Rasmussen et al. 2014). The longest cold interval, GS-3, is *highlighted*

ratio of charcoal/human bone dates compared to regions with the smallest density (68 vs. 20 %) (see Fig. 3; Table 1). This is solid data in favor of human existence at the LGM in Western Siberia, the Yenisei River basin, the Angara River basin and Cis-Baikal, and the Russian Far East. In regions of low density (Transbaikal and Yakutia), however, the majority of dates were run on the bone, and they deserve additional screening (see below). In general, evidence on human presence in the two latter regions at the LGM is weak; for the Transbaikal, similar conclusion is recently made by Buvit et al. (2015).

In her discussion of the reliability of bone ^{14}C dates in Siberia, Graf (2009a: 695) considers the bone as a much less secure material for ^{14}C dating compared to charcoal because "Bone is inherently porous with high potential for contamination by recent carbon." We agree that the bone is a less reliable material for ^{14}C dating than charcoal, but this is due to collagen preservation and not contamination by recent carbon (e.g., van Klinken 1999; Brock et al. 2012). Contamination can easily be overcome by thorough pretreatment with removal of young carbonates and humic acids (e.g., Brock et al. 2010). The preservation of organic material in the bone, usually expressed as collagen yield (e.g., Brock et al. 2012), is the major criterion for sample selection. When the amount of collagen in the bone is 1 % weight or more, this is usually a good material for producing reliable ^{14}C dates (e.g., Brock et al. 2010, 2012). Therefore, the ^{14}C values obtained on well-preserved bone collagen can be considered as relatively secure. Although quantitative information in terms of collagen yield was not provided by Russian radiocarbon laboratories, the preservation of it at Siberian archaeological and paleontological sites is usually good (e.g., Kuzmin and Orlova 1998; Sulerzhitsky 2004).

However, the possibility of dating osseous material which was introduced to a site by ancient humans as a result of scavenging fossil bones, and re-deposition of older bones into younger sediments (including cultural layers) makes the bone a less reliable medium to establish the timing of human occupation. In this case, wood charcoal found at archaeological sites, especially in hearths or in direct association with artifacts, is on a conservative assumption the most secure material for ^{14}C dating. The same is true for ^{14}C values run on human remains (e.g., Street et al. 2006; Kuzmin and Keates 2014). Accepting this, we did not include sites with bone ^{14}C dates in the final analysis (see below).

A critical evaluation of the Paleolithic ^{14}C records in the Yenisei River basin: continuous occupation vs. gaps

In the course of the discussion on the ^{14}C dates from the Yenisei River basin, Kuzmin (2009: 2732) mentioned that "… another analysis of the Upper Paleolithic ^{14}C data corpus from the Yenisei River valley should now be conducted in order to avoid incomplete datasets, biases, factual mistakes, and unjustified interpretations as presented by Graf (2009a)." Here, we compare the results generated by Graf (2009a) and by us, in light of the LGM human occupation of the Yenisei River valley as one of the key regions (Fig. 3). An analysis of ^{14}C values from the Yenisei region that belong to the time interval of ca. 26,000–17,000 BP is presented in this paper, using data for the following sites: Ui 1, Sabanikha, Novoselovo 13, Tarachikha, Kurtak 4, Kashtanka 1, Shlenka, and Listvenka (cultural layers 20–15) (Fig. 4).

Graf (2009a: 702–703) rejected the ^{14}C dates produced on bone material found on the surface of the Tarachikha site (i.e., not in situ); the excavators, however, accepted them because they correspond well to the general scheme of Paleolithic cultural complexes in the Yenisei River (e.g., Abramova 1983; Lisitsyn 2000: 33–34). The same skepticism was expressed by Graf (2009a: 703) on two ^{14}C dates from the Shlenka site, despite the fact that one of the ^{14}C values (GIN-2861; see Fig. 4b) was obtained on a projectile point made of mammoth bone. Some ^{14}C dates are disqualified by Graf (2009a) due to large sigma, >750 years: among them is the value LE-4155 for the Kurtak 4 site (cultural layer 1). Even though the calendar age of this value has quite a large range (Fig. 4b), in our opinion, it is still possible to keep it as a reliable ^{14}C date for this cultural component (e.g., Kuzmin 2009: 2731). Some ^{14}C dates are omitted without any explanation, for example, the ^{14}C value SOAN-4795 from cultural layer 20 of the Listvenka site, although the excavators tentatively accepted it because it fits the general site stratigraphy and chronology (Akimova et al. 2005: 36–37).

As was mentioned previously (Kuzmin 2009: 2371), Graf (2009a) rejected several ^{14}C dates which do not create tight clusters within the ±2 sigma interval. For example, she does not include several ^{14}C values (AA-72146, AA-72147, and AA-68670) from the Kurtak 4 site (cultural layer 1) and from Kashtanka 1 site (SOAN-2853) (see Fig. 4b). According to our opinion (e.g., Kuzmin and Keates 2005; Kuzmin 2009), the wide deviation of ^{14}C dates within the single cultural component is a common phenomenon, and one cannot simply delete values which do not overlap within the ±2 sigma timespan.

Graf (2009a: 696) considered the disturbed stratigraphy at the Ui 1 site as the reason to reject ^{14}C dates of ca. 17,690–16,760 BP. In fact, cultural layer 2 of this site is not as badly damaged by permafrost as Graf (2009a) believes. According to the latest study of the site's stratigraphy and chronology (Vasil'ev et al. 2005: 34), ice wedges in this component are small and are not "… penetrating the cultural layer from above …" as stated by Graf (2009a: 703).

The real problem with Graf's (2009a) interpretation of the Yenisei Paleolithic chronology, in our opinion, is that she uses criteria for choosing ^{14}C dates as reliable values very selectively, in order to eliminate practically all LGM-related ^{14}C age determinations. This is why two ^{14}C dates from the Tarachikha site (ca. 19,850 BP and ca. 18,930 BP), and three ^{14}C values from the Shlenka site (ca. 20,100 BP, ca. 19,700 BP, and ca. 17,660 BP) are not accepted by Graf (2009a). After that, a single LGM-associated ^{14}C date, ca. 19,280 BP from the Ui 1 site, remains (Fig. 4a). On the contrary, our analysis shows that there are several sites in the Yenisei River basin which are directly associated with the LGM, either in its revised timespan (sensu Clark et al. 2009) or within the duration of the previous "southern Siberian LGM?" (sensu Graf 2009a) (Fig. 4b).

In order to justify additionally her conclusion that people were not able to cope with the LGM environment of Siberia, recently, Graf (2015) argued that there were not enough animal food resources at that time: "Though large megafauna did not go extinct until the very end of the Pleistocene, their numbers were quite low during the climatic minimum." (Graf 2015: 520) and "The extreme cold and dry conditions of the LGM decreased faunal populations …" (Graf 2015: 521). This contradicts factual data based on hundreds of direct ^{14}C dates on Siberian megafaunal representatives, especially woolly mammoth and woolly rhinoceros (Kuzmin and Orlova 2004; Nikolskiy et al. 2011; Stuart and Lister 2012; MacDonald et al. 2012). Megafauna was abundant in the Late Pleistocene in all parts of Siberia, including the High Arctic, before its rapid disappearance began at ca. 12,000 BP (e.g., Kuzmin 2010).

To conclude the analysis of Paleolithic ^{14}C records for the Yenisei River basin, it should be highlighted that biased views as expressed by Graf (2009a, 2015) cannot help to evaluate the existing data and select the most reliable age determinations, especially concerning the LGM occupation of this region. The critical remarks about the flaws in K. Graf's

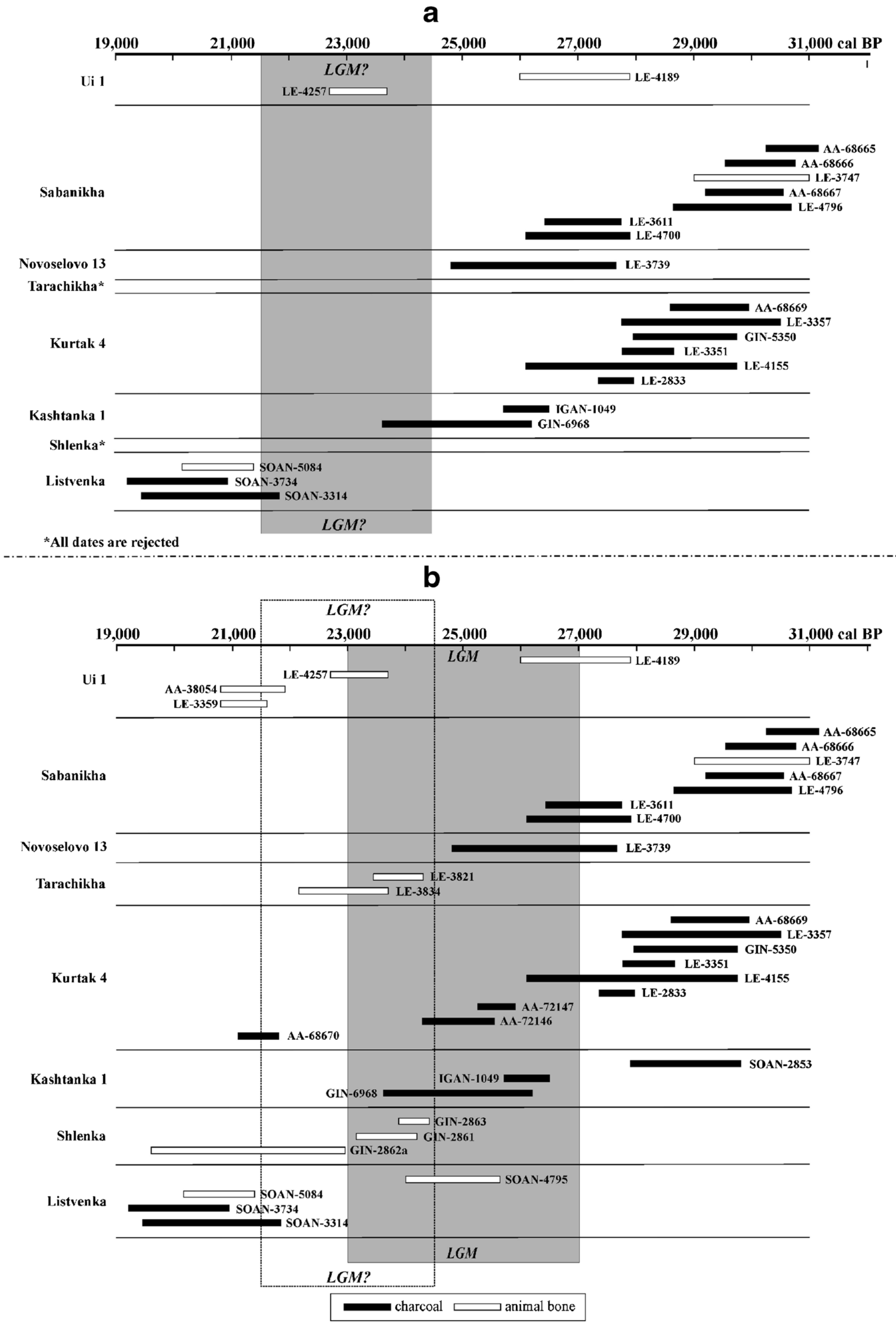

Fig. 4 Calibrated ^{14}C dates from the selected Paleolithic sites in the Yenisei River basin: **a** accepted by Graf (2009a), with "southern Siberian LGM?" interval in *gray*; and **b** used by Vasil'ev et al. (2002), Kuzmin (2008), and Kuzmin et al. (2011); with LGM timespan in *gray*, and Graf's (2009a) LGM [see part a)] as a *dashed contour*

methodology were repeatedly published (see Kuzmin 2008, 2009; Kuzmin and Keates 2013, 2014), but ignored by her.

The pre-LGM occupation of Siberia and the Urals: a brief overview

The question of presence/absence of humans in Siberia during the LGM is closely related to the problem of human adaptation to Arctic-type conditions in the Paleolithic. Even though the pre-28,000 cal BP climate in Siberia was warmer than during the LGM (e.g., Anderson and Lozhkin 2001; Haesaerts et al. 2005; Andreev et al. 2011), tundra and forest-tundra landscapes existed throughout the central and northern parts of Siberia and the northern Russian Plain (Pitulko et al. 2007; Velichko et al. 2014). Therefore, knowledge of the environment in which pre-LGM inhabitants of northern Eurasia lived is essential for understanding the possibility of human survival in Siberia in the LGM. Below, we present the most reliable evidence on pre-LGM Upper Paleolithic sites in Siberia and the Urals north of 58° N (Fig. 2). Overall, nine localities were selected.

Ust'-Ishim in Western Siberia is the oldest locality in northern Eurasia with evidence of occupation by anatomically modern humans before the LGM. The complete genome was identified in the partial femur bone discovered at the site; two direct ^{14}C dates are ca. 41,400 BP (Fu et al. 2014). Despite Goebel's (2015) skepticism that this bone was found on the surface and is lacking archaeological context, this is the earliest direct trace of modern human presence in the central part of Western Siberia. At that time, the region was covered by conifer forest (Fig. 5) and had a continental climate with very cold winters.

Discoveries of pre-LGM human activity have been made in the Urals region at four sites. The Mamontovaya Kurya site was found in alluvial sediments, and cultural material was redeposited within the 1.40-m-thick stratum (e.g., Svendsen et al. 2010). A series of ^{14}C determinations with the youngest age at ca. 32,000 BP sets up the upper chronological limit of human presence there (Svendsen and Pavlov 2003). Initial microscopic studies of an incised mammoth tusk indicate human modification soon after death of the animal; this artifact is ^{14}C-dated to ca. 33,980–36,630 BP (Pavlov et al. 2001; Svendsen and Pavlov 2003). The youngest of these values suggests human occupation of the site at around 34,000 BP; the incised mammoth tusk could be a more accurate date if the microscopic analyses are confirmed.

At the Byzovaya river terrace site, mammalian fossils and lithic artifacts were recovered from 2.00 to 2.50 m of sandy gravels. The mean age is ca. 28,450 BP, when discarding 12 (of the original 33) ^{14}C dates "with large uncertainties" on mammalian bones, teeth, tusks, and antlers (Slimak et al. 2011: 842). While the cultural remains are not in situ, transport distance is inferred to have been brief with the majority of archaeological materials found in good condition (see Slimak et al. 2011, Fig. 3). Several fossils show cutmarks (Svendsen et al. 2010; Slimak et al. 2011).

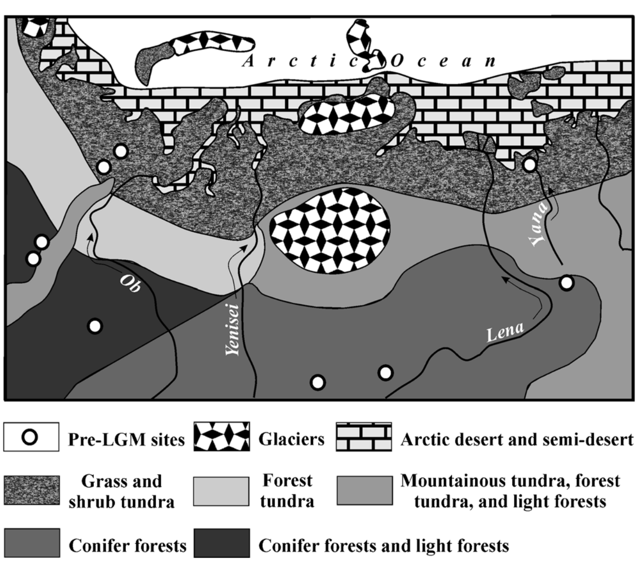

Fig. 5 The pre-LGM landscapes and sites in Siberia and the Urals north of 55° N (after Velichko et al. 2014, modified)

At the Zaozer'e site found on a terrace (ledge) of the Chusovaya River exposed in the Kama Reservoir, lithic artifacts and mammalian fossils, as well as hearths, were excavated within an 0.40-m-thick humic-rich loam, in primary context (Pavlov et al. 2004; Svendsen et al. 2010). From the cultural layer, nine ^{14}C dates on bone range from ca. 30,100 BP to ca. 35,140 BP; and one ^{14}C date on charcoal is ca. 30,140 BP (Pavlov et al. 2004; Svendsen et al. 2010).

At the Garchi 1 site, located on the shore of the Kama Reservoir, excavations yielded lithic artifacts, two hearths, and "poorly preserved" animal fossils in a less than 0.20-m-thick layer of paleosol (Svendsen et al. 2010: 3145, Fig. 8). A ^{14}C date on charcoal is ca. 28,750 BP (Pavlov 2008; Svendsen et al. 2010).

In Northeastern Siberia, two sites have evidence of pre-LGM occupation. Excavations at the Yana RHS site in the High Arctic recovered in situ lithic artifacts and animal fossils in mostly good condition in loamy sand of 0.20-m thickness (Pitulko et al. 2004, 2012). The ^{14}C dates have a range of ca. 28,500–27,140 BP and are mostly on the bone (Pitulko and Pavlova 2010). The exceptional array of items found (including ornaments, decorated ivory vessels, engraved mammoth tusks, and eye needles), of the, thus far, earliest activity site in the Siberian High Arctic, indicates that humans before the LGM were well adapted to cold conditions (Pitulko et al. 2012).

The site of Ikhine 2 is on a terrace of the Aldan River in Yakutia. Two artifacts and animal bones were found in alluvial loams in the lower part of cultural layer IIc (0.20–0.30-m thick) according to Mochanov (2009 [1977]: 43). There are four ^{14}C dates from the middle part of cultural layer IIc; the value of ca. 26,030 BP is considered the most reliable because it is on the bone and not on wood which could have been re-deposited (Vasil'ev et al. 2002; see also Abramova 1979; Yi and Clark 1985). We do not include the Ust'-Mil 2 site in Yakutia in this study because all the ^{14}C dates are on wood, and may therefore not be reliable (Abramova 1979; Vasil'ev et al. 2002).

The most recent discovery of human-butchered mammoth carcass at the Sopochnaya Karga site (ca. 72° N) near the Yenisei River mouth dated to ca. 44,650 BP (Pitulko et al. 2016) gives additional evidence of human presence in pre-LGM times in the far north of Siberia. Another find of wolf bone with human-made injury at the Bunge-Toll paleontological locality (ca. 69° N) south of the Yana RHS site, dated to ca. 45,000 BP (Pitulko et al. 2016:261), may represent another trace of human existence in High Arctic well in advance of the LGM.

In Eastern Siberia, two sites can be securely assigned to pre-LGM times (Fig. 2). The site of Ust'-Kova was found on a terrace of the Angara River in loam and in a generally disturbed context (ice wedges and solifluction textures). Layers 7 and 5 (0.40- and 0.30-m thick, respectively) are dated to ca. 34,300–28,050 BP on charcoal (Kuzmin et al. 2011). At the Nepa site, the 0.15-m-thick cultural layer with artifacts and animal bones was discovered on a terrace of the Nizhnaya Tunguska River. There are two ^{14}C dates on the bone: ca. 26,065 BP and ca. 33,100 BP (e.g., Goebel 2004).

Paleoenvironmental information is available for several selected pre-LGM sites. Data for the Mamontovaya Kurya, Byzovaya, Ikhine 2, and Yana RHS sites in the arctic regions of Siberia and the Urals allow us to reconstruct treeless tundra steppe vegetation around these sites (Savvinova et al. 1996; Pitulko et al. 2007; Svendsen et al. 2010), with a harsh continental-type cold and dry climate at ca. 34,000–26,000 BP. According to the oxygen isotope data from ice wedges at the Yana RHS site, the average January temperature at ca. 28,000–27,500 BP was −47.8 °C, which is 10 °C colder than today (Pavlova et al. 2015). For the Zaozer'e site in the central Urals, a landscape of conifer forests with meadows and bogs at ca. 35,000–30,000 BP is revealed based on palynological data (Gribchenko 2014).

This corresponds well to the latest environmental reconstruction for northern Eurasia at ca. 40,000–25,000 BP. According to Velichko et al. (2014), people occupied different landscapes during the pre-LGM timespan, including tundra and forest tundra, and light forests (Fig. 5). It appears, therefore, that people in northern Eurasia were well adapted to the cold conditions of the Arctic and sub-Arctic well before the LGM. The northernmost pre-LGM site, Yana RHS, is situated at 70° N (Fig. 2).

Did people live in Siberia during the LGM?

The distribution of LGM-associated sites in Siberia, with ^{14}C dates run on animal bone, charcoal, and human bone, shows that humans occupied mainly the southern and central parts of western and eastern Siberia, the Russian Far East, and Northeastern Siberia (Yakutia) (Fig. 1). According to a conservative analysis of the ^{14}C dates, the ^{14}C values on charcoal and human bone are considered as the most reliable evidence for the age of sites. As a result, there are still 16 sites, which have either charcoal or human bone ^{14}C dates (Fig. 6; Table 1). These sites occupy the southern part of Western Siberia (Anui 2 site, Altai Mountains), the southern and central parts of Eastern Siberia (Gosudarev Log 1, Sabanikha, Derbina 4 and 5, Kurtak 4, Kashtanka 1, Sazhentsy, and Novoselovo 13 in the Yenisei River Basin; Mal'ta in the southern part of Angara River basin; Ust'-Kova in the northern part of Angara River basin; Studenoe 2 in the southern Transbaikal; and Alekseevsk 1 in the northern part of Cis-Baikal), and the Russian Far East (Ust'-Ulma 1, Khodulikha, and Ogonki 5).

With reference to the latest environmental reconstruction for the LGM of northern Eurasia (Velichko et al. 2014; see also Roche et al. 2007; Allen et al. 2010), sites with the most reliable record of LGM occupation in Europe (e.g., Terberger 2013; Terberger and Street 2002) and northern Asia (this study) were located in tundra steppe and light forest landscapes; the overall distribution of sites also incorporates the periglacial tundra steppe biome (Fig. 7). It is noteworthy that the northernmost charcoal-dated sites in Siberia (Ust'-Kova and Alekseevsk 1) are situated at 58° N, quite far north if we take into account the harsh type of the LGM environment.

Besides this, according to the most recent data from the Yana site cluster (70° N), the direct ^{14}C age of a bone ivory artifact (core fragment) from the Lagerny locality (Fig. 1) is ca. 22,040 BP (Pitulko et al. 2015; see Table 1). This is an in situ find; in addition, it is controlled by the ^{14}C ages of the overlying and underlying sediments, and thus can be accepted as evidence (perhaps sporadic) of human occupation in the Siberian High Arctic at least at the beginning of the LGM.

In light of the newly established duration of the LGM (e.g., Clark et al. 2009; Rasmussen et al. 2014), our concept is in agreement with the record of human presence in Siberia based on the frequency of occupation (Fig. 8). It is notable that at the beginning of the LGM, ca. 21,000–23,000 BP (ca. 25,000–27,000 cal BP), Siberia was more extensively occupied than immediately before that, at ca. 23,000–25,000 BP (ca. 27,000–29,000 cal BP). This observation requires further study; at this stage, we do not have clear explanation for it.

In the course of this discussion, it is necessary to evaluate the latest views on humans in Siberia at the LGM. The identification of nuclear-genetic similarities in the genomes of Afontova Gora-2 (ca. 17,000 cal BP) and Mal'ta (ca. 24,000 cal BP) leads Raghavan et al. (2014: 89) to the conclusion that "…the presence of an ancient western Eurasian genomic signature in the Baikal area before and after the LGM suggests that parts of south-central Siberia were occupied by humans throughout the coldest stages of the last ice age." Based on this, Graf (2015: 521) concluded: "Certainly, this is not the smoking gun proving continued occupation through the LGM, but it is quite compelling. We need to find archaeological sites in well-dated geological contexts characterizing climatic-minimum conditions."

However, this is in contrast to the opinion of Graf, one of the lead co-authors of Raghavan et al. (2014: 87), who had previously insisted that the opposite concurs with the evidence: "The southern Siberian Upper Paleolithic radiocarbon record signals very low population levels, perhaps even a pause in habitation, during the LGM climatic minimum." (Graf 2009b: 522). Even so, quite recently, Graf (2015: 521) suggested either no or very limited human occupation in the

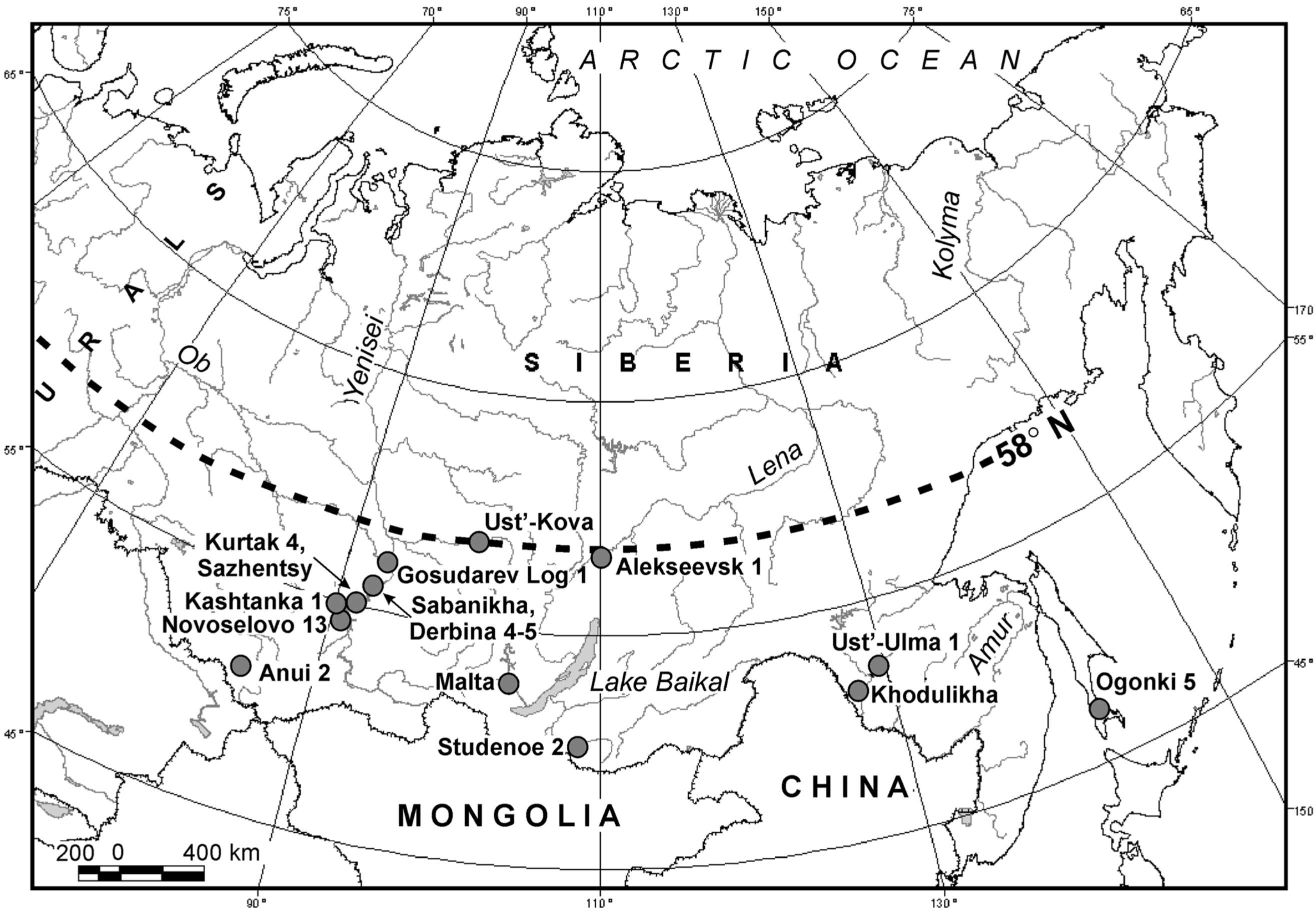

Fig. 6 The most secure LGM-associated sites in Siberia

LGM of Siberia. It is evident that Graf is still not sure—did people live in Siberia at the LGM or not?

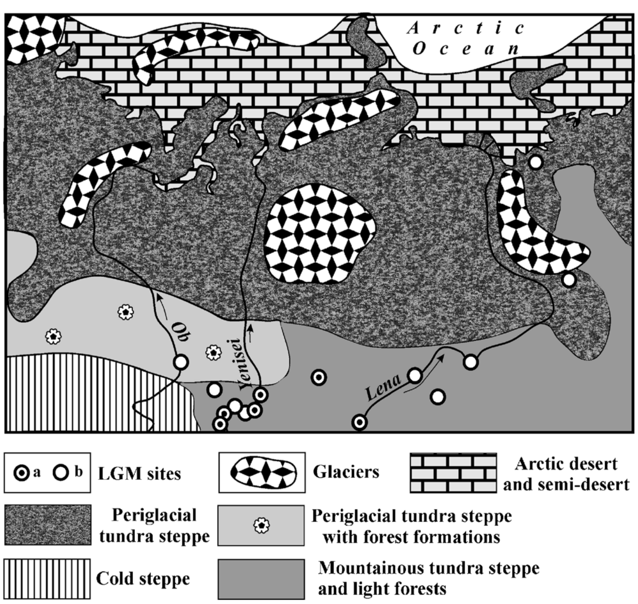

Fig. 7 The LGM landscapes and sites in Siberia and the Urals north of 55° N (after Velichko et al. 2014, modified). In "LGM sites": *a*—sites with charcoal ^{14}C dates; *b*—sites with bone ^{14}C dates

As a matter of fact, with regard to the issue of human presence in Siberia around LGM times, Graf (2015) and Raghavan et al. (2014) repeated the conclusions concerning human presence during the LGM in the given region published before (e.g., Kuzmin and Keates 2005, 2013; Kuzmin 2008). Nevertheless, Raghavan et al. (2014) ignored these sources.

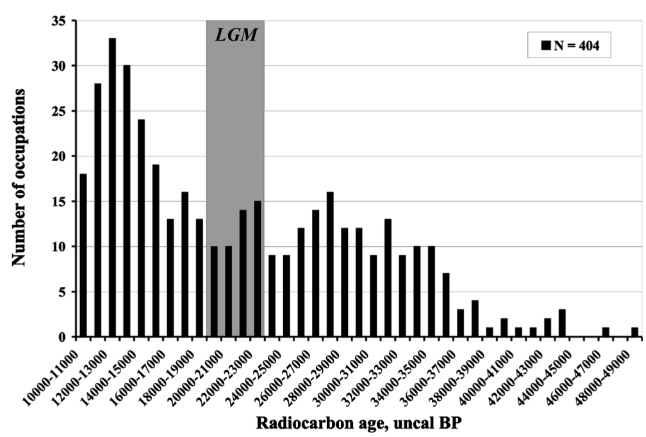

Fig. 8 The frequency of Paleolithic occupations of Siberia (after Kuzmin and Keates 2013, modified). The LGM timespan is in *gray*

Conclusions

The results of our updated analysis of human presence in northern Eurasia at and before the LGM show that previous conclusions about the occupation of the central and southern parts of Siberia at the LGM sensu stricto, now dated to ca. 27,000–23,000 cal BP, are still valid. The highest density of human populations is observed for the basins of the Yenisei and Angara rivers, followed by Western Siberia and the Russian Far East. This is based on a rigorous analysis of ^{14}C records from these regions, selecting the most reliable materials (wood charcoal and human bone). The degree of human adaptation to the harsh Arctic-type climate and environment of Siberia and the Urals was already high in pre-LGM times, at ca. 34,000–26,000 BP (ca. 38,500–30,000 cal BP) if not earlier. Therefore, people were well equipped to cope successfully with the cold and dry conditions of the LGM in Siberia. The latest attempt to establish continuity of human occupation in southern Siberia by Raghavan et al. (2014) resulted in conclusions which only confirm the results of previous studies (e.g., Kuzmin and Keates 2005; Kuzmin 2008).

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