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RADIOCARBON DATE FREQUENCY AS AN INDEX OF INTENSITY OF PALEOLITHIC OCCUPATION OF SIBERIA: DID HUMANS REACT PREDICTABLY TO CLIMATE OSCILLATIONS?

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ABSTRACT. Upper Paleolithic humans occupied southern Siberia by about 43,000–38,000 BP (^{14}C yr), and afterward continued to live there despite the very cold climate. If climatic conditions limited expansion of the colonizing population in northern Siberia, the Paleolithic ecumene should have contracted during the coldest episodes within the last 40,000 yr, and fewer ^{14}C-dated sites should be known from those periods. In fact, the human population seems to have remained stable or even expanded during cold periods. Comparison of calibrated ^{14}C dates for Siberian occupations with Greenland ice cores fails to demonstrate a simple correlation between climatic fluctuations and the dynamics of human colonization and persistence in Siberia between about 36,000 and 12,000 BP. Cold climate does not appear to have posed any significant challenge to humans in Siberia in the Late Pleistocene, and a supposed Last Glacial Maximum "hiatus" in population dynamics seems illusory.

INTRODUCTION

The correlation between intensity of human colonization or occupation of particular regions and climatic fluctuations throughout the last 45,000 ^{14}C yr has been the subject of recent research, carried out mainly in Europe (e.g. Gamble et al. 2004, 2005). Several attempts also have been undertaken recently to discern patterns of a possible connection between the dynamics of human occupation and climate during the Late Pleistocene in Siberia (e.g. Goebel 2002; Dolukhanov et al. 2002; Graf 2005; Kuzmin and Keates 2005; Surovell et al. 2005). In this paper, we ask, does the varying intensity of Upper Paleolithic occupation of northern Eurasia correlate with climatic fluctuations?

As Behrensmeyer (2006:478) recently observed, "…climate was only one of many factors affecting human evolution; biological processes including genetic innovation, interspecies competition, and dispersal ability also could have played defining roles. Rather than a simple story of global climate drumbeat and evolutionary response, more informative and exciting revelations about the 7-million-year development of hominin morphology, behavior, and culture will likely come from detailing the prolonged tension between local ecosystems and global climate change. This is also a strikingly relevant theme for the future of our species." In the case of the Paleolithic human occupation of northern Eurasia, we must consider the possible complexities of adaptive responses of both ecosystems and human sociocultural systems to climatic changes. We should not simply assume that humans responded directly to colder temperatures as a negative stress factor by means of population reduction, contraction of settlement area, or outright abandonment of the entire region. We must test the existing data without presuppositions. In this paper, we address the issue of possible human susceptibility to fluctuating climatic conditions at the end of the Pleistocene, using Siberia and the Russian Far East as the key regions.

Discussions of human evolution are generally written by academics who, unlike Arctic natives such as the Eskimo and Chukchi, find extreme cold uncomfortable and unnatural. It is now well established that hominins evolved in subtropical environments in eastern Africa, and that modern humans

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(*Homo sapiens sapiens*) emigrated from there to more northern regions where cultural innovations including protective clothing and shelter and controlled use of fire were essential for survival. It is generally assumed that Neanderthals, having occupied glacial Europe for several hundred thousand years before the arrival of modern humans around 43,000–41,000 cal BP (Mellars 2006; Weninger and Jöris 2006), had adapted both physically and culturally to cold climate. Yet, they evidently were out-competed in their familiar environment by intrusive "moderns." This replacement scenario involves some complicated permutations. On the one hand, the superior mental and behavioral flexibility, complex social structure, and logistical and planning capabilities of modern humans are thought to have permitted their expansion into far northern zones (such as the East European Plain) that were vacant because Neanderthals lacked the cultural equipment to thrive there (Hoffecker 2002; Mellars 2006). However, the same authors suppose that the moderns could only displace Neanderthals from central and western parts of Europe when the latter were undercut by an abrupt *cold* oscillation (Greenland Stadial 9 or 10). It seems paradoxical that a plunge into colder climate would have advantaged tropical-adapted intruders over local hominins with longstanding adaptations to near-glacial environments. Perhaps we have grossly misjudged the relative challenges and opportunities that cold climates posed to anatomically and behaviorally modern humans.

Humans with Upper Paleolithic technology appear to have occupied the southern part of Siberia at a remarkably early date, about 43,000–38,000 ^{14}C yr ago (hereafter BP) (see reviews: Derevianko 2001, 2005). This colonization occurred about the same time as the appearance of the Upper Paleolithic in the Eastern European Plain, e.g. at Kostenki (Anikovich et al. 2007). Settlements persisted for millennia despite the fact that throughout the Late Pleistocene, Siberia was even colder than it is today (e.g. Velichko 1984). In spite of the obvious early human adaptation to very cold conditions, several archaeologists discern evidence of abandonment of northern regions for a millennium or more at the peak of the Last Glacial Maximum (LGM) (generally assumed to be the period when regional temperatures fell to a minimum). For example, Hoffecker (2002:195) observed a hiatus in the central part of the Eastern European Plain from ~20,000 to ~18,000 BP. Dolukhanov and his coauthors (Dolukhanov and Shukurov 2004; Dolukhanov et al. 2002:598; Dolukhanov et al. 2005: 1128, Figure 2) also infer a sparse human population in Siberia at the LGM, which they define as about 19,000–18,000 BP. Similarly, Goebel (2002) sees abandonment of much of Siberia at about 19,000–18,000 BP. But do the data really support this inference?

METHODS AND MATERIALS

Numerical analysis of ^{14}C date series for the Upper Paleolithic of northern Eurasia has become a common approach (e.g. Housley et al. 1997; Bocquet-Appel and Demars 2000; Davies 2001; Dolukhanov et al. 2001; van Andel and Davies 2003; Gamble et al. 2005). However, a major methodological problem for such studies is how to combine the individual ^{14}C dates produced at each site into frequencies of occupation with consequent calibration or comparison (*sensu* van der Plicht 2000) of occupations, for the purpose of examining the relationship of cumulative frequencies of human occupation to proxy records of climate fluctuations, particularly the Greenland ice cores. Several approaches have been used (see review: Kuzmin and Keates 2005:775–7).

Before proceeding to further describe specific aspects of our analysis, we must acknowledge both the limitations of the available data set and the potential flaws in our own assumptions and analytical procedures. We have assumed that varying relative quantities of human habitation episodes over time—for which ^{14}C dates per millennium are a proxy—primarily reflect fluctuations in the size and geographic extent of the human population (i.e. "occupation intensity"). We recognize that other factors might create biases that could distort this record; these include the following:

1. Problems of preservation or visibility of sites. Sites in river valleys may have been destroyed during periods of increased fluvial erosion, or deeply buried by alluvial sediments. Similarly, sites could have been deeply buried by loess during periods of eolian deposition. It is not clear whether these processes would tend to obscure more human occupations during stadial or interstadial episodes.
2. Over the passage of time since deposition, organic materials are less likely to survive, so there are less potential samples for dating from the earliest millennia of human occupation. Furthermore, as one approaches the effective limit of radiocarbon dating at around 40,000 BP, the potential effects of contamination and counting error increase, so dates earlier than ~30,000 BP become both unavoidably less precise and possibly inaccurate. While recognizing these problems, we emphasize that our focus here is primarily on interpretation of dates more recent than 28,000 BP.
3. Research priorities and funding limitations can affect the record. Some sites considered relevant to particular issues—e.g. initial appearance of moderns, demise of Neanderthals, or origin of microblade industries—may have been the focus of more intensive ^{14}C dating programs than other sites. Researchers may have relied on artifact typology or geologic/climatic data for dating of less critical sites.
4. Dates may be artificially concentrated within particular sites or sub-regions. Continuity of occupation in these locations might obscure contemporaneous abandonment of other areas. We have attempted to counteract this bias by combining multiple dates for single stratified components into "occupations."
5. Some dates are clearly inaccurate and unacceptable. This is sometimes apparent because of their incongruity within stratified sequences. When multiple dates over a very wide temporal range occur within a single stratified context, some systematic protocol must be adopted to either include or eliminate the outliers.

We recognize that any or all of these factors could substantially distort the record. In light of these undeniable complications, one has the choice of ignoring the cumulative ^{14}C record from Siberia as too problematic for any meaningful interpretation, or searching for evident patterns in the imperfect data and testing hypotheses that might explain those patterns. We have chosen the latter course.

As an example of how we have treated sites with multiple ^{14}C dates (factor 4, see above), we can use data from the well-known site of Mal'ta in Eastern Siberia (Table 1). The wide variation of ^{14}C values in the site's main component, layer 8, is evident. For some intervals, about 20,000–21,000 BP and 21,000–22,000 BP, many more ^{14}C values were obtained, as compared with the approximately 19,000–20,000 BP interval (Figure 1). If one were to take these records at face value, an obvious distortion of occupation frequency would result due to the numerous ^{14}C dates produced at this particular site for the same cultural component. Following Kuzmin and Keates (2005), we do not use such "raw" ^{14}C records. Instead, we combine dates into 1000-^{14}C yr intervals, so-called "occupation episodes" (Figure 1), in order to make the data set smoother and eliminate the distorting effect of multiple ^{14}C dates for the same cultural layer. This procedure may be contrasted with an alternative approach to the averaging of dates. The mean age of the series is about 21,040 ± 240 BP, and with $\pm 2\ \sigma$ it is 21,520–20,560 BP. In this case, Graf (2005) would exclude several values beyond this time interval, about 21,700–21,600 BP and about 20,340–19,990 BP, and use only the "averaged" ^{14}C value of ~21,040 BP (Figure 1). It is obvious that averaging significantly simplifies the initial information about the ^{14}C age of the site. In this case, only 1 brief "occupation" of the site, at ~21,040 BP, will be detected, while in reality it may have been occupied repeatedly over a longer period, about 19,900–21,700 BP (see discussion in Kuzmin and Keates 2005:779–80). It can be very difficult to distinguish single occupations, true "living floors," from "palimpsests" created by conflation of multiple episodes (Binford 1982). Fine-grained analysis (e.g. studies of refitting lithics) may yield evidence of real contemporaneity of activity areas within a community, but few Siberian sites have ever been subjected to such close scrutiny.

Table 1 ^{14}C records for Mal'ta site, Eastern Siberia (after Lipnina et al. 2001).

Site, cultural layer	^{14}C date, BP	Lab code and nr	Material
Mal'ta, layer 8	21,700 ± 160	OxA-6191	Animal bone
Mal'ta, layer 8	21,600 ± 170	GIN-8475	Animal bone
Mal'ta, layer 8	21,600 ± 200	GIN-7708	Animal bone
Mal'ta, layer 8	21,340 ± 240	OxA-6193	Animal bone
Mal'ta, layer 8	21,300 ± 110	GIN-7702	Animal bone
Mal'ta, layer 8	21,300 ± 300	GIN-7704	Animal bone
Mal'ta, layer 8	21,100 ± 150	GIN-7703	Animal bone
Mal'ta, layer 8	21,000 ± 140	GIN-7706	Animal bone
Mal'ta, layer 8	20,900 ± 200	GIN-4367	Animal bone
Mal'ta, layer 8	20,800 ± 140	GIN-7710	Animal bone
Mal'ta, layer 8	20,700 ± 150	GIN-7709	Animal bone
Mal'ta, layer 8	20,340 ± 320	OxA-6192	Animal bone
Mal'ta, layer 8	19,900 ± 800	GIN-7705	Animal bone
Mean of 13 dates	*21,040 ± 240*		

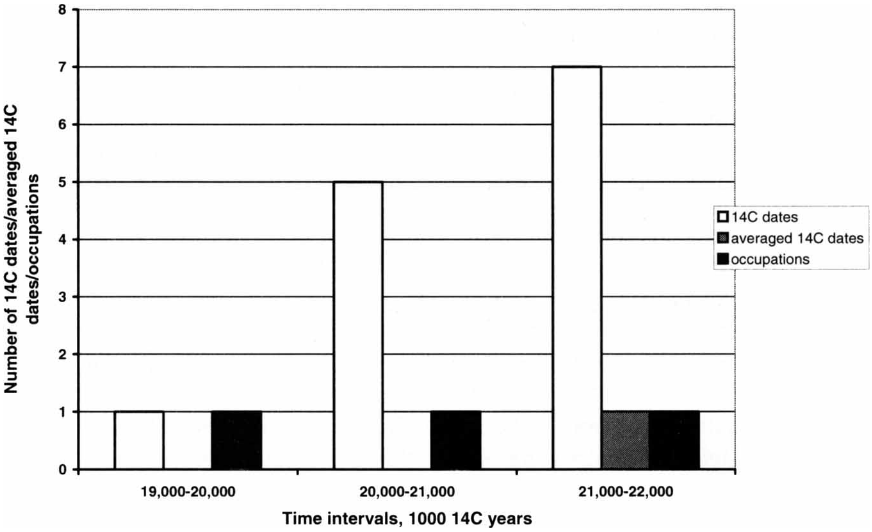

Figure 1 The counting of occupation frequencies at the Mal'ta site

For this paper, we combined ^{14}C dates available for the Siberian Paleolithic as of late 2004 into "occupations" within intervals of 1000 ^{14}C yr (see Vasil'ev et al. 2002; Kuzmin and Keates 2005), and calculated the average ^{14}C age of each occupation (see Appendix). Because there are very few ^{14}C dates for the Siberian Paleolithic earlier than ~36,000 BP (Kuzmin and Keates 2005), only ^{14}C ages of about 12,000–35,800 BP were used. In total, 387 individual ^{14}C dates, mainly from the Upper Paleolithic sites with a few final Middle Paleolithic complexes, were combined into 249 occupations (Figure 2).

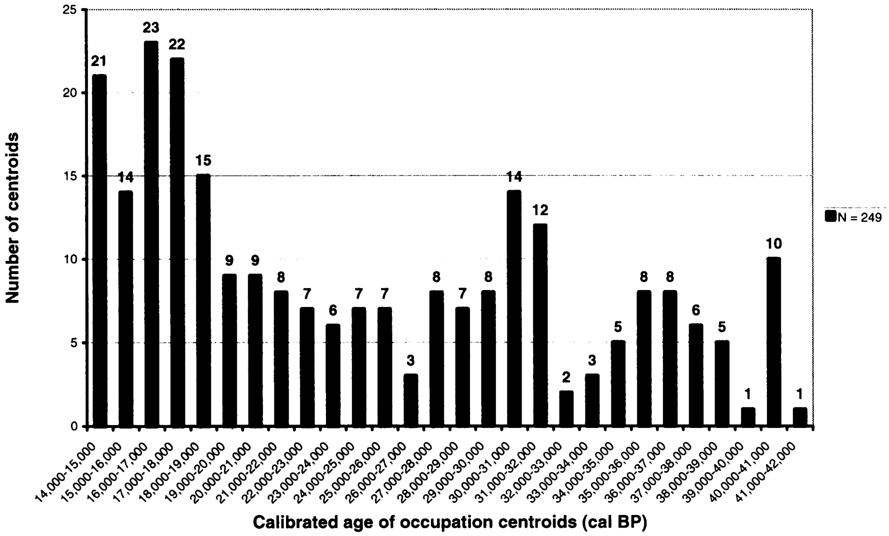

Figure 2 Frequencies of calibrated ages of occupation "centroids" for the Siberian Paleolithic, about 14,000–42,000 cal BP.

After calculating the average ^{14}C values for each occupation episode within the period about 12,000–35,800 BP, the calendar ages (hereafter cal BP) of mean points or "centroids" were determined using 1 of 2 calibration software packages: 1) CALIB 4.4.2 (Stuiver and Reimer 1993) for dates as far back as 19,540 BP (Ust-Kova site, lower component; see Appendix); and 2) CalPal (Weninger and Jöris 2004; Weninger et al. 2005) for older ages. Because the frequency of "centroids" is the main aim of our study, we determined the calendar ages of centroids by calibrating them with a conventional standard deviation (hereafter s.d.) of ±100 yr, and calculated the median calendar age of each centroid with ±2 s.d.

The frequencies of calendar age centroids were counted (Table 2, Figure 2). A similar approach to plotting the calibrated median ages of individual ^{14}C values was recently employed by Gamble et al. (2005:197).

Table 2 Frequencies of "calibrated" occupations of the Siberian Paleolithic, 14,000–42,000 cal BP.

Calendar ages, cal BP	Nr of occupations	Calendar ages, cal BP	Nr of occupations
14,000–15,000	21	28,000–29,000	7
15,000–16,000	14	29,000–30,000	8
16,000–17,000	23	30,000–31,000	14
17,000–18,000	22	31,000–32,000	12
18,000–19,000	15	32,000–33,000	2
19,000–20,000	9	33,000–34,000	3
20,000–21,000	9	34,000–35,000	5
21,000–22,000	8	35,000–36,000	8
22,000–23,000	7	36,000–37,000	8
23,000–24,000	6	37,000–38,000	6
24,000–25,000	7	38,000–39,000	5
25,000–26,000	7	39,000–40,000	1
26,000–27,000	3	40,000–41,000	10
27,000–28,000	8	41,000–42,000	1
		Total occupations	*249*

We recognize that calendar ages beyond about 23,000 cal BP currently must be considered only approximate, with uncertainties up to several thousand years (see van der Plicht et al. 2004). Therefore, all conclusions for the time span older than about 23,000–25,000 cal BP are tentative. Nevertheless, recent studies indicate an emerging consensus of marine core-, ice-core-, and speleothem-derived timescales (e.g. Shackleton et al. 2004; Southon 2004; Weninger et al. 2005; Weninger and Jöris 2006), so it is unlikely that our chronological framework, which is based primarily upon the GISP2 ice core, will prove to be grossly inaccurate.

For comparison of the occupational data to climate fluctuations, we relied primarily upon the GISP2 ice-core record (e.g. Johnsen et al. 2001) of the climatic conditions in the Northern Hemisphere between about 14,000–42,000 cal BP. Both the Hulu Cave speleothems and new data from the NGRIP ice core (North Greenland Ice Core Project Members 2004) indicate that the GISP2 timescale for this period is more accurate than the alternative GRIP chronology. We also referred to some regional high-resolution climatic archives located either in Siberia itself (the Lake Baikal sediments [Prokopenko et al. 2001; Boës et al. 2005]) or relatively nearby (the Hulu Cave stalagmites in southern China [Wang et al. 2001]).

RESULTS AND DISCUSSION

Human-Climate Relationship in the Paleolithic of Siberia

Comparison of climatic fluctuations against the frequency of human occupation (Figure 3) reveals no direct correlation between climate and intensity of occupation. For example, at the so-called "Last Glacial Maximum" (LGM), about 24,000 cal BP, when the climate was very cold and dry, the population in Siberia apparently did not decrease. It remained comparatively stable from roughly 26,000 cal BP until about 19,000 cal BP, and increased sharply afterwards (Figure 3).

Early paleoclimatic models for Siberia (e.g. Kind 1974) postulated 2 broad subdivisions, the (relatively) warm Karginsky or Karginian "Interglacial" (properly termed an interstadial) around 50,000–24,000 BP, and the cold Sartan "Glacial" (i.e. stadial), about 24,000–10,000 BP, each with minor fluctuations. However, integration of recent data requires a much more complicated paleoclimate reconstruction. Rather than the simple dichotomy of warm Karginsky and cold Sartan periods, it is likely that the Siberian Late Pleistocene climate from about 50,000–11,000 cal BP displayed the same "sawtooth" pattern of abrupt warm and cold oscillations that has been recognized in the Greenland ice cores, GRIP and GISP2 (e.g. Johnsen et al. 2001). The precise synchronicity of East Asian climate oscillations with the GISP2 sequence is shown by the Hulu Cave stalagmite record of the East Asian monsoon from China (Wang et al. 2001). Periods of maximum dust accumulation in the GISP2 core (notably between 26,180 and 23,340 cal BP) also correlate directly with cold, dry, windy periods in Central Asia; the dust in the ice has been traced to Mongolia and northern China (Biscaye et al. 1997). Although interpretation of specifically Siberian data from Lake Baikal sediments is complicated, magnetic susceptibility data from the Continent Ridge core indicate a rough correlation with GISP2 events; the coldest period occurs about 26,000–23,000 cal BP (Boës et al. 2005). Prokopenko et al. (2001:67) recognize abrupt erosional events in Lake Baikal that are "confidently correlated to the intervals of Heinrich layers in the North Atlantic." These events indicate "a surprisingly strong climatic teleconnection of the remote mid-continent Baikal location with the Dansgaard-Oeschger events and the Bond cycles in the North Atlantic region" (Prokopenko et al. 2001:67).

Basically, Dansgaard-Oeschger (D-O) events are warm episodes and Heinrich (H) events are cold ones. The D-O marine events are coeval with atmospheric events recorded in the Greenland ice as relatively warm interstadials; Heinrich events equate to abrupt cold (stadial) episodes in the ice (Greenland Stadials, GS). The latest correlation of ocean (coral U/Th dates) and ice records for the period 20,000–50,000 BP, with calibrated ^{14}C dates for D-O marine events, has been presented by Shackleton et al. (2004) (Table 3).

Table 3 The sequence of warm (Dansgaard-Oeschger, D-O) and cold (Heinrich, H; Greenland Stadials, GS) climatic events in northern Eurasia for the period about 12,000–37,000 BP (after Shackleton et al. 2004).

D-O event	Calendar age, cal BP	^{14}C age, BP	Cold event (H/GS)	Calendar age, cal BP	^{14}C age, BP
1	14,700	12,500			
			H1	16,000	13,000
2	23,700	19,600			
			H2	24,000	20,000
3	29,000	24,450			
			GS4	29,500	25,000
4	30,100	25,300			
			H3 (GS5)	31,000	27,000
5	33,400	28,500			
			GS6	33,000	28,000
6	34,600	29,500			
			GS7	34,000	29,500
7	36,300	31,900			
			GS8	36,000	32,000
8	39,000	33,800			
			H4	40,000	34,000
9	40,800	35,500			
			GS9 [?]	41,500	36,000
10	42,100	36,100			
			GS10 [?]	43,000	37,000

Since 1976, when the Last Glacial Maximum was defined by the CLIMAP group, a date of 18,000 BP has been conventionally assigned to the LGM, and climate stability between 14,000 and 24,000 BP has been assumed (Mix et al. 2001). LGM refers specifically to the moment when the proportion of the planet's water locked into ice sheets was greatest in relation to liquid water in the ocean. The latter is measured by sea level, so the LGM is the moment of lowest recorded sea level in the Late Pleistocene. Although "LGM" is often used as shorthand for extreme cold, Greenland ice-core proxies for temperature (oxygen isotope ratios in snow layers, which reflect sea surface temperatures in the North Atlantic) show that the coldest temperatures and greatest ice sheet volumes were not precisely synchronous. Ice sheet extent in Europe at any given time was actually influenced by a complex interplay of precipitation and temperature (Rinterknecht et al. 2006). Based upon minimum sea levels of about 130–135 m below present level off the northern coast of Australia, Yokoyama et al. (2000) dated the LGM as the period from 22,000 to 19,000 cal BP (16,000 BP). A sharp rise in sea level marks the end of the LGM in this record. Citing both marine and ice-core data, the EPILOG group defined the LGM chronozone as the interval from 23,000 to 19,000 cal BP (i.e. 19,500–16,100 BP) (Mix et al. 2001). Recently, Peltier and Fairbanks (2006) have interpreted sea-level data from Barbados as indicating an earlier minimum and thus, the LGM beginning at around 26,000 cal BP.

If we set aside the rather arbitrary definition of LGM and instead examine the GISP2 ice-core record of oxygen isotope ratios directly as an index of cold temperatures in the far north (Figure 3), we find that the coldest episodes in the last 40,000 yr occurred at ~36,000 cal BP (corresponding to ~32,000 BP); ~33,000 cal BP (~28,000 BP); 32,000–29,000 cal BP (~28,000–25,000 BP); and ~24,000 cal BP (~20,000 BP) (Table 3). At the time equivalent to 18,000–19,000 BP, or 21,000–22,000 cal BP (Hughen et al. 2004)—the conventionally defined LGM—it was quite cold, but not measurably colder than at ~12,500 cal BP or ~16,000 cal BP, and not nearly as cold as at ~24,000 cal BP or at ~30,000 cal BP. In fact, the longest period of sustained cold with no warming oscillation is the 4000 yr from ~27,500 to 23,500 cal BP (about 24,000–20,000 BP). If cold climate was the limiting factor on expansion of human settlement in Siberia, these are the periods when we should anticipate the greatest contraction of occupied area and the fewest dated sites and components.

However, this expectation is not confirmed by our data set and its analysis. A particularly interesting and rather complicated portion of the sequence is that between 33,000 and 30,000 cal BP. Our data indicate very sparse occupation at 33,000–32,000 cal BP, followed by a surge in dates (and inferred occupation intensity) at 32,000 cal BP continuing to 30,000 cal BP. This is the period of the brief occupation of the Yana RHS site in the high Arctic (about 71°N). A series of published dates seems to put the occupation around 27,000 BP, or 31,000 cal BP (Pitulko et al. 2004), but a date closer to ~28,000 BP (32,500 cal BP) is now preferred (Pitulko 2006). Pollen and other paleoenvironmental data indicate a relatively warm, interstadial climate at the time of occupation. The original date of ~27,000 BP would make Yana RHS coeval with the H3 cold event, which is framed by D-O episode 4 at ~25,300 BP (30,000 cal BP) and D-O episode 5 at ~28,500 BP (33,400 cal BP) (Shackleton et al. 2004). Given the pollen record from the site, however, it seems that the occupation more likely occurred toward the end of the relatively warm D-O episode 5. It is intriguing to observe that the date of Yana RHS corresponds precisely to the maximum frequency of dated horse and mammoth bones from the Laptev Sea area (Hubberten et al. 2004: Figure 6). Perhaps human hunters were responding to a maximum availability of prey animals in far northern Eurasia at that time.

Our data show a sharp increase in occupation frequency beginning about 19,000 cal BP (16,000 BP). This is well in advance of the abrupt Bølling-Allerød warming at 14,700 cal BP. The period from 22,000 to 18,000 cal BP appears only slightly warmer than 27,000 to 24,000 cal BP in GISP2. However, Greenland climate of that period may not have been representative of wider patterns. Lagerklint and Wright (1999) point to several Northern Hemisphere records of warming beginning around 18,000 cal BP. Antarctic ice cores show a steady warming trend into the Holocene that begins about 20,000 cal BP (Bender et al. 1999). Cosmogenic nuclide dating of moraines indicates that glacial recession in mid-latitudes of both the Northern and Southern hemispheres may have begun in some areas about 19,000 cal BP, but was certainly well underway globally by ~17,400 cal BP. This recession is ascribed to rising summer temperatures (Schaefer et al. 2006). Orbitally calculated summer insolation for 60°N starts to increase at about 20,000 cal BP (Berger and Loutre 1991). This might have had appreciable effects on plant cover, thus increasing forage for the herbivores upon which Siberian hunters were dependent. The record of Laptev Sea fauna dates is not precisely synchronous with the Siberian occupation dates, but it is grossly similar; the former series has an extreme low point at 17,500–15,000 BP, but this is followed by a steep (threefold) increase at 15,000–12,500 BP (Hubberten et al. 2004: Figure 6). Again, this increase precedes the Bølling-Allerød warming (12,500 BP, or 14,700 cal BP). It is reasonable on this basis to hypothesize that increasing availability of prey animals may have been the proximate cause of the growth and expansion of Siberian Upper Paleolithic populations.

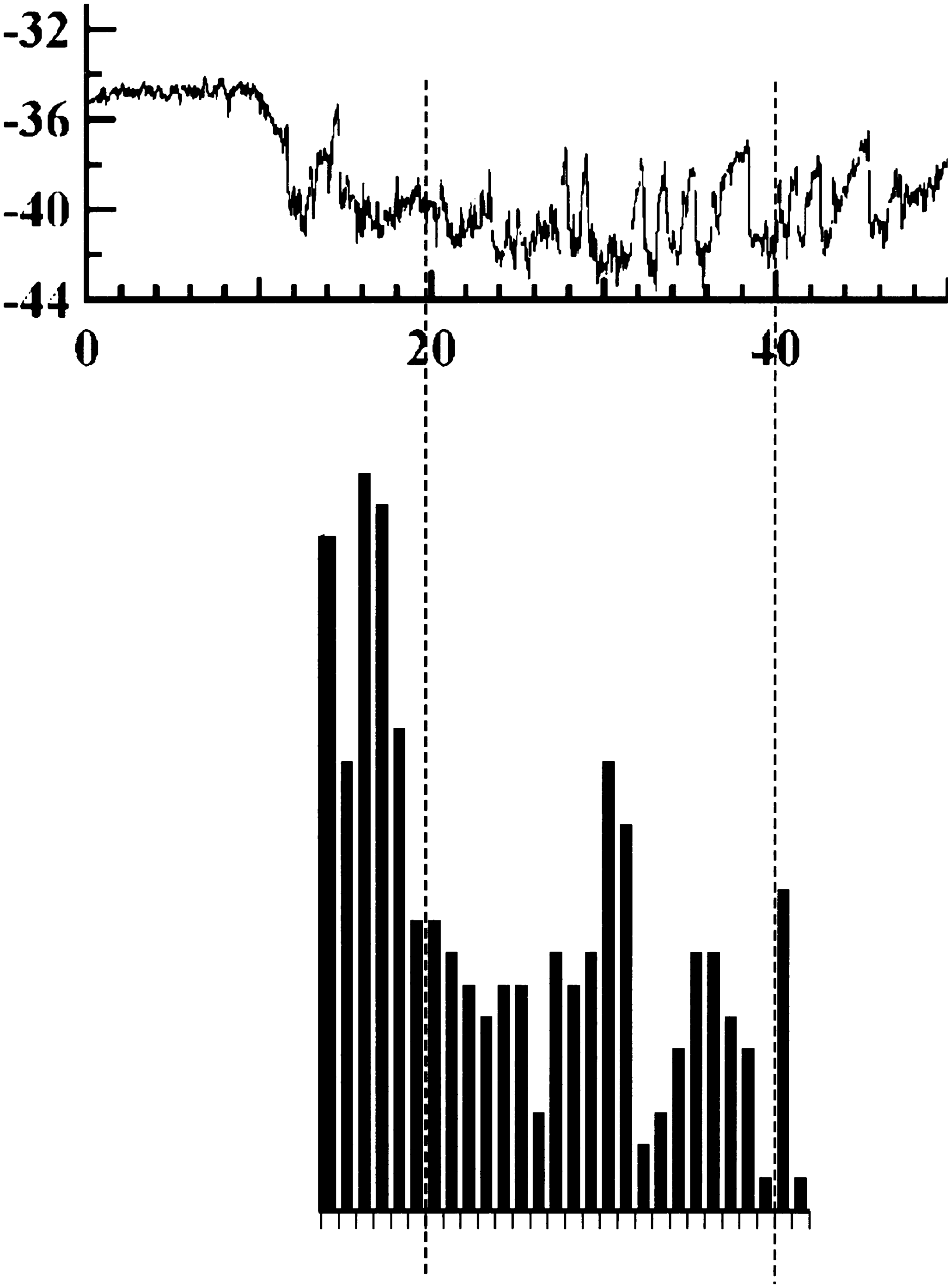

Figure 3 Comparison of the occupation frequencies for the Paleolithic of Siberia (below; see also Figure 2) and the GISP2 ice-core records (above; after Johnsen et al. 2001). Vertical axis above is $\delta^{18}O$ (‰); horizontal axis is ice-core age (kyr BP).

Combining ^{14}C Dates into Occupations: Progress and Problems

The research protocols used to detect regional-scale patterns of human occupation on the basis of ^{14}C dates must confront and somehow resolve 2 methodological complications: 1) If listed and counted separately, multiple ^{14}C values from the same site or cultural component may distort the "real" signal of human occupation (Figure 1). Weighted disproportionately against single dates obtained for sites/components of other periods, the multiple dates might create a false impression of intensified human activity during the period they represent. 2) On the other hand, pooling of all the multiple ^{14}C dates for a single component into 1 averaged, "weighted," or "combined" value, which is then used for calibration and comparison, may result in a misleading conflation and temporal compression of what are really discrete episodes of occupation spanning a long period (Figure 1; see discussion: Kuzmin and Keates 2005:775–7). Here, we illustrate how these 2 difficulties have affected other researchers' conclusions based on the Siberian data.

Surovell et al. (2005), using Kuzmin and Orlova's (1998) data set of Siberian Paleolithic ^{14}C dates, observed that, "Occupation intensities generally increase geometrically through time, with significant declines occurring during the LGM (23–18 ka)" (Surovell et al. 2005:6234). However, using essentially the same database (Kuzmin and Keates 2005; this paper) our conclusion is quite different: no definite decline in occupation intensity occurs at the LGM (Figure 2).

Graf (2005) used the dates listed in another basic source (Vasil'ev et al. 2002), which are very similar to Kuzmin and Orlova's (1998) dates, and concluded that, "In fact, no sites in Siberia can be unequivocally shown to date to between 23,000 and 22,000 CALYPB" (Graf 2005:4). To create her graph of the "number of ^{14}C-dated cultural occupations across Siberia," the original ^{14}C dates "were averaged by calculating a weighted mean for each occupation layer. Aberrant dates (that did not overlap other more consistent dates at two sigmas) were not used in the calculations" (Graf 2005:3).

In our research (Kuzmin and Keates 2005; this paper), we have not combined ^{14}C dates and counted only the mean values. Instead, we have assumed that *all* ^{14}C dates represent episodes of site occupation, and have combined them into 1000-^{14}C yr intervals. This allows use of primary information with less distortion (see example above from the Mal'ta site; Table 1, Figure 1).

According to our results (Figures 2–3), the ostensible gaps in human occupation at 22,000–23,000, 32,000–34,000, and 39,000–40,000 cal BP (Graf 2005:3, Figure 1) appear to be methodological *artifacts*. It is impossible to detect 1000-yr gaps in occupation using ^{14}C dates that have associated standard deviations of up to several hundred years (see Kuzmin and Keates 2005:785 for the original LGM ^{14}C dates from Siberia).

Dolukhanov et al. (2002) and Dolukhanov and Shukurov (2004) also employed averaging of ^{14}C date series, and they concluded that human occupation intensity in Siberia decreased at the LGM. Nevertheless, Dolukhanov (2004:228) has also stated that during the LGM, "the frequencies of sites increased throughout Siberia, including Yakutia and Russian Far East." Dolukhanov's inconsistent interpretation must be clarified before it can be either criticized or defended (see also Kuzmin and Keates 2006).

We suspect that pooling of ^{14}C dates, even from the same cultural "component," may be a procedural mistake. Each ^{14}C-dated sample may represent a particular episode of human visitation at the site; people typically came and went repeatedly throughout hundreds or even thousands of years, during each visit leaving behind organic remains with different ^{14}C ages (Kuzmin and Keates 2005: 779–80; see also Table 1 and Figure 1). Therefore, averaging of ^{14}C dates from Paleolithic sites may cause a significant loss of information and create a misleading picture of human occupation intensity. This can be illustrated using the issue of LGM human presence in Siberia. Previous models of human occupation based on pooling of original ^{14}C data seem to be invalid. As critical evaluation of primary data has shown, people did not disappear from Siberia during the so-called LGM or other cold periods (Kuzmin and Keates 2005:783–5).

CONCLUSION

Available records do not allow us to establish any straightforward connections between climatic fluctuations and dynamics of human colonization and persistence in the cold region of Siberia in the latter part of the Late Pleistocene, about 36,000–12,000 BP. The frequency of sites and components and inferred density of population in Siberia show no obvious changes in direct response to the rapid temperature fluctuations in the second part of the Late Pleistocene. There is no evidence that very cold climate posed an extraordinary challenge to humans in Siberia, and there is no confirmation for an LGM "hiatus" (whether LGM is defined as about 18,000–19,000 BP [21,000–22,000 cal BP], as about 19,000–20,000 BP [22,000–23,000 cal BP], or as suggested here, about 24,000 cal BP). Population increased rapidly beginning at ~16,000 BP (19,000 cal BP), *prior* to significant D-O 1 (Bølling-Allerød) warming, but perhaps in delayed response to increasing summer insolation and the mid-latitude warming trend that may have begun as early as 19,000 cal BP and was widespread by 17,400 cal BP.

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APPENDIX

Table The occupations' mean ^{14}C ages and "calibrated" ages of their median points (centroids) for Paleolithic sites in Siberia, about 12,000–35,800 BP (original ^{14}C dates are after Vasil'ev et al. 2002; Kuzmin and Keates 2005). l. = layer(s).

Site name and layer nr	Average ^{14}C age, uncalib BP	Nr of ^{14}C dates used	Median point, cal BP	Site name and layer nr	Average ^{14}C age, uncalib BP	Nr of ^{14}C dates used	Median point, cal BP
Strizhovaya Gora, l. 16-14	12,115	3	14,510	Shestakovo, l. 17	19,190	1	22,800
Bolshoi Yakor, l. 3v	12,390	13	14,770	Ui 1, l. 2	19,280	1	22,900
Malye Kuruktachi	12,250	2	14,630	Ogonki 5, l. 2b	19,380	2	23,010
Eleneva Cave	12,050	4	14,470	Ust-Ulma 1, l. 2	19,360	1	22,990
Sosnovy Bor, l. 3b	12,080	2	14,490	Ust-Kova, lower component	19,540	1	23,190

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Site name and layer nr	Average ^{14}C age, uncalib BP	Nr of ^{14}C dates used	Median point, cal BP
Kosaya Shivera 1, l. 14	12,070	1	14,480
Kokorevo 2	12,090	1	14,490
Ust-Kyakhta 17, l. 5	12,170	2	14,600
Dyuktai Cave, l. 7a	12,530	3	14,840
Mayiniskaya	12,310	6	14,640
Studenoe 1	12,300	7	14,640
Goly Mys 4	12,645	4	14,970
Mal'ta	12,315	2	14,650
Kaminnaya Cave, l. 11v	12,160	1	14,600
Tashtyk 1, l. 1	12,530	2	14,840
Ust-Mil 2, l. 3	12,200	1	14,620
Nizhniaya Dzhilinda 1, l. 7	12,330	1	14,760
Volchiya Griva	12,520	1	14,830
Verkholenskaya Gora 1, l. 3d	12,570	1	14,890
Ust'-Kyakhta 4, l. 2	12,595	1	14,910
Kokorevo 3	12,690	1	15,000
Ust-Karenga 12, l. 8	12,800	2	15,110
Avdeikha	12,900	1	15,210
Tyitkesken' 3, l. 6	12,850	1	15,150
Golubaya 1, l. 3	12,940	2	15,250
Bolshaya Slizneva, l. 7	12,930	1	15,240
Berelekh	12,930	1	15,240
Kokorevo 1, l. 2-3	12,970	2	15,290
Golubaya 1, l. 3	13,350	2	15,900
Dyuktai Cave, l. 7	13,350	4	15,900
Listvenka, l. 12-6	13,510	3	16,240
Kokorevo 1, l. 2-3	13,200	2	15,660
Kurla 3, l. 1	13,160	1	15,600
Divnyi 1	13,220	1	15,690
Siberdik, l. 3	13,225	1	15,700
Lugovskoe	13,465	1	16,130
Kaminnaya Cave	13,800	4	16,570
Kokorevo 2	13,300	1	15,820
Malye Kuruktachi	13,560	2	16,300
Afontova Gora 2, l. 2-4	13,610	6	16,350
Berelekh	13,420	1	16,030
Studenoe 1, l. 18/1	13,430	1	16,050
Bolshaya Slizneva, l. 8	13,540	1	16,280
Tashtyk 2, l. 2	13,550	1	16,290
Ust-Karenga 12, l. 8	13,560	1	16,300
Ikhine 2	19,695	1	23,490
Mal'ta, l. 8	19,890	2	23,800
Tesa	20,040	1	23,940
Studenoe 2	20,620	1	24,600
Ikhine 2	20,080	1	23,980
Mogochino 1	20,150	1	24,070
Malaya Syia	20,300	1	24,330
Mal'ta, l. 8	20,730	5	24,700
Anyi 2, l. 8	20,350	1	24,380
Shestakovo, l. 19	20,580	5	24,570
Kashtanka 1	20,800	1	24,800
Mal'ta, l. 8	21,420	7	25,600
Kunalei	21,100	1	25,320
Buret'	21,190	1	25,410
Shishkino 8	21,190	1	25,410
Igeteisky Log 1, l. 4	21,260	1	25,470
Anyi 2, l. 3-4	21,390	2	25,580
Shestakovo, l. 17, 21	21,430	2	25,610
Kashtanka 1	21,800	1	26,400
Novoselovo 13, l. 3	22,000	1	26,600
Shestakovo	22,580	6	27,280
Alexeevsk 1	22,415	1	26,940
Khodulikha	22,530	1	27,080
Dvuglazka	22,500	1	27,040
Anyi 2, l. 8	22,610	1	27,370
Podzvonkaya	22,675	1	27,490
Ui 1, l. 2	22,830	1	27,680
Sabanikha	22,915	2	27,760
Arta 2, l. 3	23,200	1	27,800
Shestakovo, l. 19, 22	23,290	3	28,070
Anyi 2, l. 6	23,430	1	28,210
Kurtak 4, l. 11	23,760	3	28,690
Biika 1, l. 5	23,480	1	28,280
Ust-Mil 2, l. 4 (upper part)	23,500	1	28,310
Igeteisky Log 1, l. 4	23,640	2	28,530
Ust-Kova, middle component	23,920	1	28,850
Kurtak 4, l. 11	24,620	3	29,680
Anyi 2, l. 8	24,205	1	29,080
Ikhine 2, l. 2b	24,480	3	29,480
Shestakovo, l. 19, 24	24,480	2	29,480

Table The occupations' mean ^{14}C ages and "calibrated" ages of their median points (centroids) for Paleolithic sites in Siberia, about 12,000–35,800 BP (original ^{14}C dates are after Vasil'ev et al. 2002; Kuzmin and Keates 2005). l. = layer(s). *(Continued)*

Site name and layer nr	Average ^{14}C age, uncalib BP	Nr of ^{14}C dates used	Median point, cal BP	Site name and layer nr	Average ^{14}C age, uncalib BP	Nr of ^{14}C dates used	Median point, cal BP
Novoselovo 6	13,570	1	16,310	Masterov Kliych, l. 4	24,360	1	29,310
Volchiya Griva	13,600	2	16,340	Igeteisky Log 1, l. 6	24,400	1	29,360
Ushki 1, l. 7	13,700	2	16,460	Kamenka 1	24,625	1	29,700
Novoselovo 13, l. 1	13,630	1	16,380	Kashtanka 1	24,805	1	29,840
Eleneva Cave, section 1	13,665	1	16,420	Yana RHS	25,800	1	30,670
Mayiniskaya, l. 3-4	13,800	2	16,570	Balyshevo 3, l. 2	25,100	1	30,050
Biruisa 1, l. 4	13,840	1	16,620	Tolbaga, l. 4	25,200	1	30,160
Ust-Kova, middle component	13,860	1	16,640	Malaya Syia	25,250	1	30,230
Shishkino 2, l. 3	13,900	1	16,690	Sabanikha	25,440	1	30,460
Strizhovaya Gora, l. 18	14,000	1	16,810	Kamenka 1	25,540	1	30,520
Afontova Gora 2	14,195	4	17,030	Kara-Tenesh	25,630	1	30,580
Mayiniskaya, l. 3	14,070	1	16,890	Shestakovo, l. 24	25,660	1	30,590
Studenoe 2	14,485	1	17,370	Mal'ta, contact l. 7 and 3	25,760	1	30,650
Oznachennoye 1	14,100	1	16,920	Priiskovaya	25,825	1	30,680
Kaminnaya Cave, l. 13-14a	14,340	2	17,200	Podzvonkaya	26,000	1	30,780
Kurla 6	14,150	1	16,980	Nepa	26,100	1	30,840
Listvenka, l. 7-9	14,460	2	17,340	Sokhatino 4	26,110	1	30,850
Volchiya Griva	14,240	2	17,080	Khotyk 3, l. 2	26,220	1	30,920
Biruisa 1, l. 4	14,520	4	17,410	Ust-Karakol 1, l. 4-5	26,715	3	31,180
Malye Kuruktachi	14,200	1	17,040	Dvuglazka, l. 4	26,580	1	31,120
Novoselovo 7	14,610	2	17,510	Kamenka 1	26,760	1	31,200
Ust-Kova, upper component	14,220	1	17,060	Anyi 2, l. 12	26,810	1	31,220
Kurtak 3	14,430	3	17,300	Kara-Tenesh	26,875	1	31,250
Ushki 1, l. 7	14,300	1	17,150	Tolbaga, l. 4	26,900	1	31,260
Ui 2, l. 6	14,310	1	17,160	Yana RHS	27,535	4	31,860
Kokorevo 4A, l. 5-3	14,320	1	17,180	Ust-Karakol 1, l. 5	27,020	1	31,310
Kokorevo 1, l. 3	14,450	1	17,330	Anyi 2, l. 9, 12	27,530	2	31,860
Chernoozierye 2, l. 3-2	14,500	1	17,380	Dvuglazka Cave	27,200	1	31,420
Tashtyk 4	14,700	1	17,620	Tolbaga, l. 4	27,210	1	31,430
Mal'ta	14,740	2	17,660	Kurtak 4, l. 12-11	27,470	1	31,750
Dmitrievka, l. 4-3	14,750	1	17,670	Yana RHS	28,250	1	32,780
Ust-Menza 2, l. 11	14,830	1	17,770	Ust-Kova, lower component	28,050	1	32,520
Studenoe 1, l. 15	14,900	1	17,850	Kamenka 1	28,440	2	33,090
Oznachennoye 1	15,020	1	17,990	Okladnikov Cave, l. 1	28,470	1	33,150
Novoselovo 13, l. 1	15,030	1	18,000	Ust-Karakol 1	28,700	1	33,720
Tolbaga, l. 3	15,100	1	18,080	Denisova Cave	29,200	1	34,460
Suvorovo 4	15,410	4	18,440	Masterov Kliych	29,860	1	35,190
Afontova Gora 2, l. 5	15,130	1	18,110	Tolbaga, l. 4	29,200	1	34,460
Kokorevo 1, l. 2-3	15,550	2	18,600	Derbina 5	29,230	1	34,490
Mayiniskaya	15,350	2	18,370	Malaya Syia	29,450	1	34,720

Table The occupations' mean ^{14}C ages and "calibrated" ages of their median points (centroids) for Paleolithic sites in Siberia, about 12,000–35,800 BP (original ^{14}C dates are after Vasil'ev et al. 2002; Kuzmin and Keates 2005). l. = layer(s). *(Continued)*

Site name and layer nr	Average ^{14}C age, uncalib BP	Nr of ^{14}C dates used	Median point, cal BP
Kurla 3, l. 1	15,200	1	18,200
Avdeikha	15,200	1	18,200
Berezovyi Ruchei 1	15,310	1	18,320
Anyi 2	15,350	1	18,370
Ust-Menza 2, l. 17	15,400	1	18,430
Kokorevo 4B	15,480	1	18,520
Pritubinsk, l. 3	15,600	1	18,660
Ikhine 2	15,780	1	18,660
Sokhatino 4, l. 6	15,820	1	18,910
Bolshoi Yakor, l. 6	15,900	1	19,000
Novoselovo 7	15,950	1	19,050
Khaergas Cave, l. 6	16,000	1	19,110
Mayiniskaya, l. 5	16,360	2	19,520
Listvenka, l. 19	16,470	2	19,650
Studenoe 2	16,580	2	19,770
Khodulikha	16,480	1	19,660
Ust-Karenga 12, l. 8	16,430	1	19,600
Ikhine 1, l. 2	16,660	1	19,860
Ui 1, l. 2	16,760	1	19,980
Sokhatino 4, l. 7-8	16,900	2	20,140
Kurtak 3	16,900	1	20,140
Ust-Menza 2, l. 17, 20	16,940	2	20,180
Varvarina Gora, l. 1	17,035	1	20,290
Ezhantsy, l. 3	17,150	1	20,430
Studenoe 2	17,630	4	20,980
Ust-Menza 2	17,400	2	20,710
Nizhny Idzhir 1	17,200	1	20,480
Ui 1, l. 2	17,520	1	20,850
Bolshoi Yakor, l. 5	17,840	1	21,220
Ogonki 5, l. 2b	17,860	1	21,240
Mamakan	18,670	1	22,190
Ust-Kova	18,035	1	21,450
Shestakovo, l. 17	18,040	1	21,450
Shikaevka	18,050	1	21,470
Novoselovo 6	18,090	1	21,510
Tomsk	18,300	1	21,760
Verkhne-Troitskaya, l. 6	18,300	1	21,760
Studenoe 1, l. 19/4	18,550	1	22,050
Ogonki 5, l. 2b	18,920	1	22,480
Krasny Yar 1, l. 6	19,100	1	22,690
Voenny Gospital	29,700	1	35,000
Ust-Karakol 1	29,830	3	35,160
Varvarina Gora, l. 2	29,895	1	35,230
Ust-Kova, lower component	30,100	1	35,420
Kamenka 1	30,340	2	35,590
Mokhovo 2	30,330	1	35,580
Ust-Karakol 1, l. 5	30,460	1	35,660
Varvarina Gora	30,600	1	35,770
Kara-Bom, l. 2d	30,990	1	36,130
Kamenka 1	31,060	1	36,190
Makarovo 3	31,200	1	36,290
Ust-Karakol 1	31,400	3	36,420
Kara-Tenesh	31,400	1	36,420
Mamony 2, l. 4	31,400	1	36,420
Strashnaya Cave	31,510	1	36,510
Kurtak 4, l. 17	31,850	1	36,800
Masterov Kliych	32,510	1	37,930
Kara-Bom, l. 4-3	32,200	1	37,600
Kurtak 4, l. 17	32,280	1	37,750
Okladnikov Cave, l. 2-3	32,580	2	37,970
Derbina 5	32,430	1	37,870
Geographical Society Cave	32,570	1	37,960
Nepa	33,100	1	38,210
Malyi Yaloman Cave, l. 3	33,350	1	38,330
Ust-Karakol 1, l. 9v	33,400	1	38,360
Okladnikov Cave, l. 1	33,500	1	38,440
Aryshevskoe 1, l. 6	33,630	1	38,810
Kara-Bom, l. 2c, 4	33,790	2	40,000
Kara-Bom, l. 4	34,180	1	40,280
Ust-Kova, lower component	34,300	1	40,330
Geographical Society Cave	34,400	3	40,370
Malaya Syia	34,460	2	40,390
Kara-Tenesh	34,760	1	40,540
Tolbaga, l. 4	34,860	1	40,600
Varvarina Gora	34,900	1	40,620
Ust-Karakol 1, l. 10	35,100	1	40,740
Geographical Society Cave	35,100	1	40,740
Denisova Cave, l. 21	35,140	1	40,770
Kamenka 1	35,845	1	41,750