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RADIOCARBON AGES OF MAMMOTHS IN NORTHERN EURASIA: IMPLICATIONS FOR POPULATION DEVELOPMENT AND LATE QUATERNARY ENVIRONMENT

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ABSTRACT. Many mammoth remains have been radiocarbon-dated. We present here more than 360 ^{14}C dates on bones, tusks, molars and soft tissues of mammoths and discuss some issues connected with the evolution of mammoths and their environment: the problem of the last mammoth; mammoth taphonomy; the plant remains and stable isotope records accompanying mammoth fossils; paleoclimate during the time of the mammoths and dating of host sediments. The temporal distribution of the ^{14}C dates of fossils from the northern Eurasian territory is even for the entire period from 40 to 10 ka BP.

INTRODUCTION

Mammoth remains are very valuable objects for the study of Late Quaternary geochronology and paleoecology. The first finds of mammoth remains on northern islands in the Arctic and valleys of the great Siberian rivers drew the attention of scientists to the northern territories more than two centuries ago. The development of the mammoth population is one of the most interesting problems in reconstructing the dynamics of the environment during the Quaternary. The wide use of radiocarbon and paleoecological methods has provided valuable information on these dynamics. Today it is widely accepted that various fossil species of the genus *Mammmuthus* characterize Late Quaternary periglacial environments.

Since the ^{14}C method was first applied to the age determination of mammoth remains, the main problem has been reliability of the data. Geochemically, the most desirable materials for ^{14}C analysis are well-preserved organic residues, *i.e.,* bones rich in collagen, frozen carcasses, cud, dung or stomach contents from frozen ground or dry caves. In Russia, there are numerous sites from which whole carcasses of fossil mammoths have been dated by ^{14}C (Fig. 1, Appendix): Yuribey River (Gydan Peninsula), Gydan (Gyda River), Pyasina River (Taimyr Peninsula), Mochovaya River (Taimyr Peninsula), Mammoth Shrenk (Taimyr Peninsula), Chekurovka Settlement (Lower Lena River), Bukovskiy (Lena River), Beryosovka River, Shandrin River, Kirgilyakh River (baby mammoth "Dima"), Lyakhovskiy Bol'shoi Island, Tirekhtyakh River, Enmynveem (Chukotka Peninsula).

It has been established that woolly mammoths spread over a vast area in northern Eurasia in the Late Pleistocene and even into the Holocene. The first ^{14}C measurement of the fossil remains of mammoths was carried out by Heintz and Garutt (1965). Sulerzhitskij (1995) published more than 180 dates of Late Quaternary mammoths, most of which he had collected and dated himself. Stuart (1991) summarized the majority of ^{14}C dates of mammoths of various species from northern Eurasia and North America.

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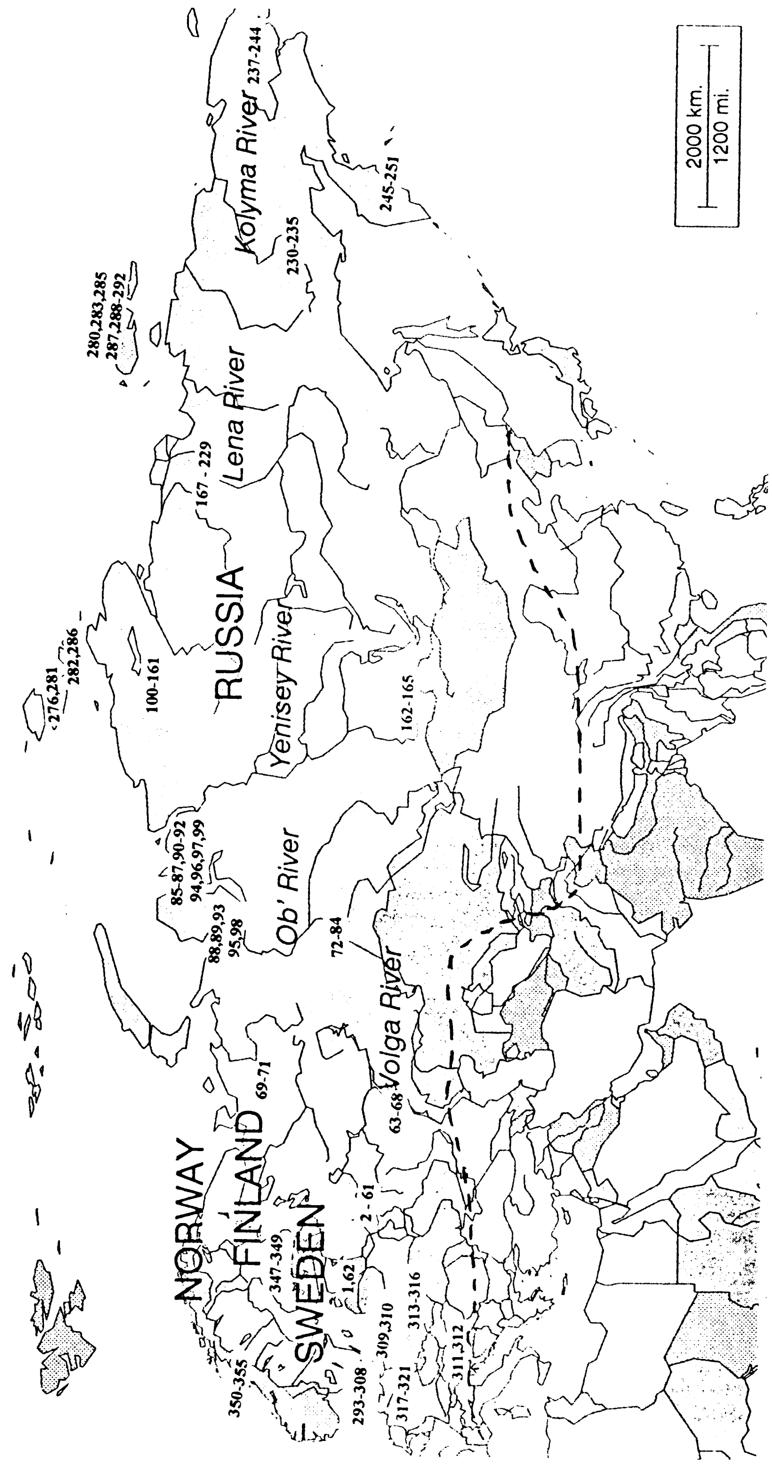

Fig. 1. Location of sites with dated mammoth remains. Site numbers refer to the number in the Appendix. --- = the southern limit of the ice wedge formation in the Late Pleistocene cryochron (40–10 ka BP) (in Asia after Vasil'chuk (1992), in Eastern Europe after Velichko (1984), in Western Europe after Maarleveld (1976).

Methods

We sampled (Vasil'chuk 1992) mammoth bones from many reference sites in northern Yakutia: in the depression near Kular settlement (37.7 ka BP), near Zelyonyj Mys settlement (43.7 and >50 ka BP), Duvannyi Yar natural exposure (28.6, 33.8, 34.7 and >50 and 53 ka BP), and in Chukotka in the Mayn River valley and Ledovyi Obryv natural exposure (15.1 ka BP). We found redeposited bones (drifted fossils) in the Holocene alas sediments, in the Kolyma River valley near the Omolon River mouth (15 ka BP).

Earlier we summarized a number of ^{14}C dates on mammoth remains from northern Asia in order to reconstruct permafrost evolution during the last 40 ka (Vasil'chuk 1992). In addition to that list, we here summarize (Appendix) all the known ^{14}C dates (>360) of mammoth remnants from northern Eurasia, mainly from permafrost areas (Appendix and Fig. 1).

One serious concern in using data obtained by dating of mammoth remains is its reliability. The systematic checking of bone data is underway at the Radiocarbon Laboratory of the Geological Institute in Moscow (L. Sulerzhitskij, personal communication). It is possible to draw some conclusions using the data obtained by multiple analysis of material from the same layer. There are many samples in the Appendix dated by bone material with different degrees of weathering (samples 12, 127, 139, 156, 246). The differences in the data are <1000 yr, in most cases within the statistical uncertainty of the dates. In some cases, different materials from the same layers were dated (Appendix, samples 85, 86, 87; 170, 171; 210, 211; 265, 266; 268,269; 271, 272). The differences in data are modest and also within the limit of statistical uncertainty. This demonstrates that, in principle, fossils of mammoth fauna can be considered reliable as material for ^{14}C dating.

The dates in the interval from 10 to 40 ka BP are distributed rather evenly; furthermore, there is no remarkable spatial grouping of mammoth finds in northern Eurasia. If ^{14}C dates are an unbiased sample of mammoth populations, this indicates that mammoths lived constantly and continuously over northern Eurasia during the Middle/Late Würm. Eastern Europe is characterized by a series of dates from 9.7 to >47.7 ka BP. The finds consist predominantly of molars, bones and tusks. In the northwestern part of European Russia, mammoth remains have been dated from 18.3 to >36 ka BP. In southern parts of western Siberia the dates range from 12.8 to 41.9 ka BP.

Whole carcasses have been found in the Yuribey and Gyda River valleys in northwestern Siberia; mammoth remains from this region have been dated from 9.6 to 35 ka BP. On the Taimyr Peninsula, Sulerzhitskij (1995) obtained several dates ranging from 9.6 to >53 ka BP without any significant time gaps. In central Siberia, fewer dates cover the interval from 20.7 to 49.7 ka BP (Appendix); this reduction may be explained by the topography and, consequently, biogeographical conditions of this mountainous region. The abundant ^{14}C dates on mammoth remains in northern Yakutia range from 10.3 to >53 ka BP. From the Magadan region, data are available on the carcass of the Kirgilyakh baby mammoth and a few other finds, with ages from 21.6 to 41 ka BP. The Chukotka Peninsula is characterized by dates from 14.3 to 32 ka BP. In the Kamchatka Peninsula, ^{14}C dates were obtained in the interval 12.6 to 40 ka BP (Sulerzhitskij 1995) (Appendix). Interesting dates are available from Arctic islands, especially Wrangel Island. Dates obtained from a dwarf form of mammoth are the youngest for mammoth finds in the world, falling into the interval 3.9 to 7.7 ka BP. The dates from 12.7 to 20 ka BP from these islands belong to mammoths of normal form (Vartanyan, Garutt and Sher 1993; Vartanyan *et al.* 1995). The oldest date on mammoth remains from the Arctic islands is 32 ka BP.

Mammoth bones also occur rather often in western Europe (Kurten 1968). Berglund *et al.* (1976) and Hakansson (1976) refer to some ^{14}C dates on mammoth remains from South Sweden: 13, 19, 22 and >30 ka BP. In Norway, some ^{14}C dates on mammoth remains in the time interval from 19 to 32 ka BP have been obtained (Follestad and Olsson 1979). In Finland, Jungner and Sonninen (1983) and Donner, Jungner and Kurten (1979) obtained three ^{14}C dates on samples collected by Donner: 15.5, 25.2 and >43 ka BP. Mammoth remains from Denmark have ^{14}C ages from 13 to >39 ka BP (Aaris-Sorensen *et al.* 1990). In Germany, the dates vary from 15.8 to 30.3 ka BP; in Switzerland, from 12.2 to 34.6 ka BP; in Poland, from 20.2 to 23.0 ka BP; and in France, from 12 to 25.8 ka BP. Mammoth remains from Great Britain and Ireland have ages from 11.6 to >39.5 ka BP (Coope and Lister 1987; Stuart 1991).

The temporal distribution of mammoth remains (Fig. 2) displays no essential differences in the number of dated mammoths in the time interval from 15 to 45 ka BP. The spatial distribution of ^{14}C-dated mammoth remains shows that mammoth fauna were connected mainly with Late Quaternary permafrost conditions (Fig. 1).

Discussion

Several issues connected with mammoth evolution are of great scientific interest: the problem of the last mammoth; mammoth taphonomy; paleoclimate during the time of the mammoths and use of mammoth remains for the dating of host sediments.

The Problem of the Last Mammoth

The youngest ^{14}C data for quasi-mammoth remains from the Western Hemisphere are those from North America on the *Mammut americanum*: 4470 ± 160 (M-2436) from Kuhl, Michigan; 8910 ± 150 (GSC-614) from Ferguson Farm, Ontario, and 9568 ± 1000 BP (M-282) from Lenawee, Michi-

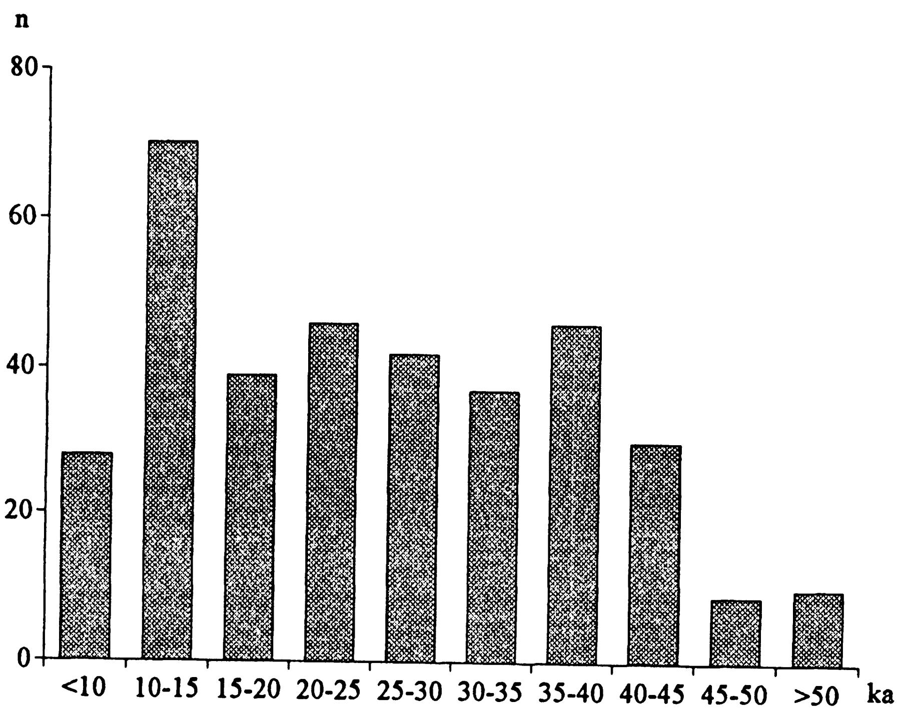

Fig. 2. The temporal distribution of ^{14}C-dated mammoth remains

gan (Meltzer and Mead 1985); and from the Southwest United States, remains of *Mammuthus columbi* from Sandy, Utah dated to 5985 ± 210 (SI-2341b), 7200 ± 190 (RL-464) and 8815 ± 100 BP (SI-2341a) (Semken 1983; Stafford *et al.* 1987; Agenbroad and Mead 1989). However, contamination of samples cannot be excluded, as has been shown by Stafford *et al.* (1987)—for different fractions from the Domebo mammoth sample, dates from 2050 to 11,490 BP were obtained. We also note that no archaeologically associated remains of mammoths younger than Clovis (*ca.* 11,000 BP) (Haynes 1993) have been replicated. It seems that the younger ^{14}C dates on mammoth remains in Northern America need replication.

More than 20 mammoth remnants from Wrangel Island collected by Vartanyan (Vartanyan, Garutt and Sher 1993; Vartanyan *et al.* 1995) were dated in the range 4–7 ka BP; the youngest dates are 3730 ± 40 BP (LU-2741) and 3920 ± 30 (GIN-6980). Two samples were replicated by the AMS dating facility at the University of Arizona (Long, Sher and Vartanyan 1994). Thus, the last mammoths now known lived on Wrangel Island *ca.* 4000 yr ago. The dated remains belong to a dwarf form of a mammoth that lived in isolation on the island under strictly limited food conditions (Grant 1985). One problem connected with these phenomena is that mammoths came to the island as a consummate form (Johnson 1978), but no data exist for the interval 12–8 ka BP. The mammoth refugium must have been disconnected from the continent, otherwise remains of Holocene dwarf mammoths should be found on the continent also. The dwarf form on Arctic islands is a common survival adaptation of large mammalians, such as deer, hippopotamus and elephantids. (Dwarf forms of elephantids lived on some islands of the Mediterranean Sea and on the Channel Islands of California during the Quaternary, with heights of ≤0.9 m.)

Mammoth Taphonomy

Two aspects of the taphonomy of mammoth remains deserve attention. First, bones occurring in an unarticulated condition, almost without exception, indicate the redeposition of remains, typical of deposits of fluvial origin (such as alluvial, lacustrine, fluvioglacial). Therefore, as a rule the ^{14}C dating of mammoth remains from these sediments gives the maximum age of sediment formation. Inclusion of younger bones in an older frozen deposit is not possible. As for syngenetic sediments of fluvial series, we can state with certainty that their ages are younger or equal to the ages of the enclosed bones. Second, the possible delivery of the bones by carnivores must be kept in mind.

The burial of whole mammoth carcasses is obviously an infrequent process, requiring the coincidence of several conditions. To remain intact, a carcass must be covered with sediments or be isolated from carnivores very quickly. Hence, the best conditions for preserving mammoth remains were offered by talus and alluvial sediments, high icy terraces and thermokarst depressions.

Plant remains in the stomach can be used to establish the season of a mammoth's burial. All the mammoth carcasses found belonged to mammoths that perished in the summertime. Remains of mammoths that perished in the winter may have been destroyed by carnivores. This suggests that an important factor for the preservation of mammoth carcasses is the existence of permafrost conditions, during both fossilization and preservation.

Plant Remains and Pollen Accompanying Mammoth Fossils

The majority of the finds of subfossil mammoths and other large animals in northern Eurasia are connected with polygonal ice wedge complexes. Possibly mammoths' pasturage depended directly on polygonal massifs. Palynological and plant macrofossil analyses have revealed an abundance of herbage in polygonal relief areas.

Pollen grains and plant remains in mammoths' guts (Table 1) indicate the feeding habits of the animals (Sukachev 1914; Solonevich, Tikhomriov and Ukraintseva 1977; Ukraintseva 1979; Sokolov 1982; Shilo *et al.* 1983; Guthrie 1990).

TABLE 1. Pollen and Spores in the Stomach Content of the Carcasses of Four Fossil Mammoths and a Selerican Horse (% of total content) (after Tikhomirov and Kupriyanova 1954; Kupriyanova 1957; Belorusova, Lovelius and Ukraintseva 1977; Belaya and Kisterova 1978; Ukraintseva 1979; Gorlova 1982)

Site (see Appendix)	^{14}C age (BP), number of samples	P_{tr}*	P_{sr}	P_{hr}	S
Yuribey River (Gydan Peninsula)	10 ka (4)	5–6	15–17	17–20	56–63
Shandrin River (northern Yakutia)	36 ka (1)	2	1	19	77
Kirgilyakh River (Magadan Region)	39 ka (6)	2–10	6–20	60–77	8–18
Beryosovka River (northern Yakutia)	44 ka (1)	1	1	97	1
Bolshoy Selerican (Indigirka River)	38 ka (1)	4	5	80	11

*P_{tr} = tree pollen, P_{sr} = shrub pollen, P_{hr} = herb pollen, S = spores.

The host sediments that enclosed the Kirgilyakh baby mammoth are characterized by the predominance of pollen of herbs and shrubs (60–77%). Pollen of grass and sedges occur in equal quantities (10–25%), and other grasses are represented by 28 families such as Ranunculaceae (2–4%), Cruciferae (4–10%) and Artemisia (up to 4%). There are also pollen of hydrophilous taxa such as Potamogeton, Myriophyllum and Alismataceae. The content of Ericaceae (<2%), which is usually dominant in subfossil pollen spectra, is very small. The presence of larch pollen is evidence of larch forest at that time (Belaya and Kisterova 1978).

Pollen analyses of mammoths' digestive tracts and host sediments show a predominance of herb pollen or spores, presence of larch pollen (1–5%) and pollen of species that now live in southern areas (*e.g.*, pollen of *Ribes, Betula* sect *Albae*), and the existence of typical tundra elements in the vegetation, *e.g., Dryas punctata.* The pollen and spores spectra showed some regional features, but these were evidence that mammoths lived in environments close to the modern larch forest and forest tundra.

Fossil flora found in the remains of the Yuribeyskiy mammoth (Gorlova 1982) consist of Cyperaceae (9 species), Poaceae (4 species), Salicaceae (3 species), Rosaceae (2 species), Betulaceae, Ericaceae and Pinaceae (1 species each). The present vegetation in the Arctic and the Subarctic is rather similar. However, the presence of macrofossils of *Larix sibirica* L. and *Ribes* spp. testifies to more favorable climatic conditions during the era of mammoths.

Naturally, to some extent, the content of the stomach reflects feeding preferences of mammoths. Plant remains belong to different life forms—shrubs, grasses, moss—and different habitats—dry meadows, steppe slopes, bottomland meadows, floodplain swamps, *etc.* This suggests the diversity of environmental conditions and biocoenoses in the areas where mammoths could live. Willow brushwood occurred in closed valleys, cereals and herbage occupied southern slopes of alluvial terraces, and sedges (particularly *Carex* strains) grew in meadows.

Analyses of both plant microfossils and pollen from dung and gut contents indicate a summer diet of grasses, sedges, mosses, and shoots of willow, draft birch and alder. A frozen forage mass from the stomach and gut of the Shandrin mammoth, found in Lower Indigirka, weighed *ca.* 250 kg. The greater part of it consisted of stems and leaves of sedges, grasses and cotton-grass and the smaller part of sprouts of willow, birch and alder (Solonevich, Tikhomirov and Ukraintseva 1977; Vereshchagin 1979). There were not any ripe seeds that might testify that the animal died in summer.

Well-preserved contents of mammoths' digestive tracts have been studied from the Shandrin mammoth carcass (Ukraintseva 1979). The remains of Cyperaceae, *Eriophorum* spp., Poaceae, *Larix Daurica* Turcz., Ericaceae, *Vaccinium vitis-idaea* L., some species of *Polytrychum, Aulacomnium* and *Sphagnum* have been identified. The main part of the pollen spectra from the enteron consists of spores of *Bryales* and *Sphagnum* (77%). Pollen of grasses makes up 19.4%, the majority of them pollen of grasses and sedges. Pollen of *Dryas punctata, Valeriana capitata, Artemisia* spp., *Ledum* spp. and *Saxifraga* spp. are also represented. All of these species presently grow in the same area. Pollen of larch, birch and alder bush were also found (*ca.* 4%). Nowadays analogous landscapes of larch light forests occur *ca.* 200 km to the south.

Sukachev (1914) identified grasses and sedges with ripe seeds in the stomach of Beryosovka mammoth, which evidently perished in late summer. Kupriyanova analyzed pollen and spores remains from the stomach of this mammoth: 8198 pollen grains and 7 spores were found (Tikhomirov and Kupriyanova 1954; Kupriyanova 1957). These are pollen of cereals (97%), forbs (2%), trees (1%) and spores. The pollen spectra are affected by the time of the mammoth's death (second half of summer), showing a small amount of tree pollen, with predominance of the cereal pollen blooming during that period. The species list of the pollen from the mammoth's stomach evidenced a varied flora corresponding to biocoenoses that exist at present *ca.* 1000 km to the south. Species of bunchgrass steppe with forbs and wormwood (*Artemisia*), upland meadow, inundation meadow, salt meadow and herb meadow have been determined.

Zaklinskaya studied the pollen content in the Taimyr Peninsula mammoth host sediments. All pollen spectra were characterized by the predominant herb pollen. The main part of the pollen consists of herbs of meadow plant communities of polygonal tundra, with cereals and sedges dominating (Zaklinskaya 1954). The paleobotanical and palynological data evidenced no sharp changes in the vegetation features, which therefore cannot be a cause of the mammoths' extinction.

One of the details of paleobotanical characteristics was obtained from Selerican horse remains (Belorusova, Lovelius and Ukraintseva 1977; Ukraintseva 1979). Plant remains are represented by fossils of poplar, birch and mosses. Pollen spectra show a presence of hazel, juniper, spruce and elm in plant societies and *Kobresia capilliformis* as a dominant of dry meadows.

Lister and Sher (1995) pointed out that one problem of the climatic model of extinction is explaining how woolly mammoths survived an earlier interglacial. They proposed that the vegetation of the interglacial differed from that of the Holocene. In Siberia several interglacials have been recorded, but during these intervals, the vegetation differed from the vegetation of the modern larch-dominated taiga. Unfortunately, even now the climate-driven models do not show uniquely the reasons for the extinction of the mammoth population. Undoubtedly, in many cases, human involvement was important (Stuart 1991).

The pollen and plant fossils in the sediments accompanying the mammoth remains and the content of their stomachs show that the favorable season for mammoths' fossilization in permafrost areas was late summer. More detailed paleoclimatic information about the time of mammoths' existence can be provided by stable isotope data both from syngenetic sediments with ice wedges and directly from mammoth remains.

Isotope Records

Variations of the oxygen isotope composition are not substantial in the Late Pleistocene permafrost syngenetic deposits where mammoth remains have been found. The interval of $\delta^{18}O$ in the syngenetic ice wedge that formed 40–10 ka ago (Table 2) varies in the north of western Siberia from –24 to –21‰, in northern Yakutia from –34 to –29‰ and in northern Chukotka from –32 to –29‰ (Vasil'chuk 1992). As snow meltwater was the main source of the moisture for ice wedges, the oxygen isotope records reflect mainly winter precipitation temperatures.

TABLE 2. Oxygen Isotope Composition in Syngenetic Ice Wedges ($\delta^{18}O$, ‰), Mean Winter (t_{mw}) and Mean January Temperatures (t_{mJ}) 40–10 ka BP in Different Regions of Siberian Mammoths' Habitats (after Vasil'chuk 1992, 1993)

Region of Siberia	$\delta^{18}O$ (‰)	$t_{mw_{D,J,F}}$ (°C)	t_{mJ} (°C)*
Yamal and Gydan Peninsulas, north of western Siberia	–21 to –24	–21 to –24	–32 to –36 (–22 to –28)
Bykovsky Peninsula, mouth of Lena River, western Yakutia	–30 to –34	–30 to –34	–45 to –49 (–32 to –34)
Upper Kolyma River, northeastern Yakutia	–29 to –33	–29 to –33	–43 to –49 (–30 to –34)
Vilyui and Aldan Rivers, central Yakutia	–29 to –31	–29 to –31	–43 to –46 (–37 to –45)
Ayon Island, northern Chukotka	–29 to –32	–29 to –32	–44 to –46 (–27 to –29)
Anadyr' and Mayn Rivers, southern Chukotka	–21 to –29	–21 to –29	–31 to –43 (–21 to –27)

*Present mean January temperatures in parentheses for comparison

Using the relationship between the mean winter temperatures and oxygen isotope records obtained by Vasil'chuk (1992), it is possible to say that the winter climate was cold, stable and unchangeable in northern Eurasia from 40 to 10 ka ago.

Seasonal Climatic Conditions During the Time of the Mammoths

Mammoth remains are usually treated as indicators of very cold climatic conditions. The extinction of mammoths is one of the most often discussed problems in the paleogeography of the Late Quaternary. One of the most important causes of their extinction is connected with the change of climatic conditions and, therefore, the composition and production of biomass. The paleotemperature record obtained immediately from mammoth habitats, *i.e.*, detailed records of syngenetic ice wedges, which have been dated as Late Pleistocene and Early Holocene, give valuable information about the mammoths' environment. The oxygen isotope and pollen data from the same sections make it possible to reconstruct separately winter and summer temperatures. This approach is of great significance. Comparing the trends of winter and summer temperatures, we can see that winter temperatures changed especially abruptly at the Pleistocene/Holocene boundary.

An analysis of all information obtained indicates that mammoths were excellently adapted to Late Pleistocene long and cold winters without any thaws. They had long, shaggy coats and underwool, a thick layer of subcutaneous fat, tiny ears and short tails. Underwool is characterized by thick hair, which was four times thicker than that of present-day cold-adapted animals. Mammoths did not have adipose glands in their skin, so their wool would get wet when it was raining or foggy. Large tusks came in handy for scraping snow and ice both for drinking purposes (like present-day elephants) and to expose buried forage. Their large size and spreading cushioned feet on which they distributed their weight may have enabled them to cope with snow better than most large herbivores in arctic and subarctic environments. The survival of such large animals in regions with a marked seasonal temperature range requires not only abundant summer herbage but also large quantities of winter feed, probably including dead grasses and bark from shrubs and trees.

At the Pleistocene/Holocene transition, winter temperatures changed sharply. Increasing Atlantic influences caused an increase in winter temperatures and the appearance of winter thaws. If thaws occurred in February or March, they could be fatal for mammoth herds, because the resulting multilayered ice crust made it impossible to find food and to move. The animals could not move because their legs were adapted to friable and relatively shallow snow cover but not to multilayered ice crust. Moreover, mammoth hair would have quickly become covered with ice, making the animals look like terrestrial icebergs.

We have reconstructed the environment in the mammoths' time applying different methods. The oxygen isotope data in ice wedges enabled us to determine that during the interval from 40 to 10 ka BP, mean January temperatures in northern Siberia were *ca.* 8–12°C lower (in Chukotka up to 17–18°) than the modern ones (Table 2). We have established that the interval from 40 to 10 ka BP was a single cryochron (Vasil'chuk 1992, 1993) with severe winters when the oscillations of temperatures were rather small, thawing was rare and the snow cover, as a rule, quite friable. Such winters permitted mammoths to dig out the grass easily from under the snow. Interpretation of pollen data enabled us to reconstruct the mean July temperatures for the period 40–10 ka BP. They were *ca.* 1–4°C lower than the contemporary ones (almost 7°C lower in the Chukotka Peninsula). During short periods of warming, the July temperatures could have been by 1–3°C higher than modern ones (Vasil'chuk and Vasil'chuk 1995).

Use of Mammoth Fossils for Dating the Host Sediments

Mammoth remains have been used widely in the dating of host sediments. The high degree of validity of ^{14}C dates of mammoth bones (Sulerzhitskij 1995), enables us to determine the lower limit of the host sediment age. In several sequences (Duvannyj Yar, Zelyonyj Mys and Kular in northern Yakutia) we have produced a series of ^{14}C dates on different kinds of organic matter—plant remains, peat, roots and wood, and bones. In many cases, the ^{14}C ages of plant remains were younger than the ages of bones from the same layers. For example, the ages of plant remains from Zelyonyj Mys sequences were in the interval from 27 to 37 ka BP and those of bones from the same depth from 43.7 to >50 ka BP (Vasil'chuk 1992). The same situation occurred in the Duvannyj Yar natural exposure, where the series of ^{14}C dates of plant remains lies in the interval from 40 to 20 ka BP, with three dates of mammoth bones in a normal sequence (28.6, 33.8, 34.7) and two inversion dates of >50 and 53 ka BP (Vasil'chuk 1992). We received non-inversion dates on tusk (15.1 ka BP) in the Ledovyj Obryv natural exposure in Chukotka, which were between the dates on plant remains of 34 and 14 ka BP (Vasil'chuk 1992). These data show that the dating of the host sediments by the use of mammoth bones is, in principle, possible; however, redeposition of separate bones is typical and must be taken into account in determining the host sediments' age.

Because whole carcasses are, as a rule, not redeposited, their ^{14}C dates conform better with the age of the host formation. However, there are some exceptions. For example, the Kirgilyakh baby mammoth (which is ^{14}C-dated to 38–41 ka BP) had been redeposited together with frozen host sediments into the younger (^{14}C-dated as Late Holocene) permafrost complex.

Mammoth Fossils and Reconstruction of Environmental Conditions

Some important regularities in the distribution of mammoth fossils appear within the Eurasian territory. First, the temporal distribution of the mammoth remains found in Eurasia is rather even for the whole period from 10 ka BP to the older limit of the ^{14}C method (Fig. 2). Second, the spatial distribution of dated fossils shows that the southern boundary of the mammoths' distribution is very close to the southern boundary of the ice wedge cast distribution, which is located *ca.* 45°N (Fig. 1). It may be assumed that the Late Pleistocene mammoth habitat corresponds to the severe permafrost area characterized by vast polygonal ice wedge landscapes. Third, as no breaks occur in the series of data from northern Asia, the European part of Russia and western Europe including Great Britain, it seems that the mammoths lived everywhere over this vast area. Therefore, the series of ^{14}C dates from 40 to 10 ka BP on mammoth fossils from Scandinavia gives reason for critical evaluation of the scale and dynamics of the Late Pleistocene Glaciation in this region. Mammoth remains in South Sweden (from 13 to >30 ka BP), Norway (from 19 to 32 ka BP), Finland (from 15 to >43 ka BP) and Denmark (from 13 to 32 ka BP) suggest that large parts of Scandinavia were ice-free in Middle and Late Weichselian time (Donner, Jungner and Kurten (1979) reached similar conclusions).

So, for the period of the last glaciation, ^{14}C dates on mammoth remains have been obtained from the entire territory of the supposed last glaciation area. ^{14}C dates for the period of the last glaciation have been obtained in North America as well. Weber *et al.* (1981) received six ^{14}C dates from bone fragments from Canyon Creek in interior Alaska—*ca.* 28, 32, 38, 39, 39 and 40 ka BP. In Canyon Creek, a portion of a tooth plate and bone fragments of *Mammuthus primigenius* and many bones of *Equus, Alces, Lepus, Canis, Ovis, Bison, etc.,* were sampled (Weber *et al.* 1981). Assuming that the ^{14}C dates are trustworthy, the finds of mammoth remains show that our knowledge about the glaciation environment needs essential supplements.

Conclusion

Comprehensive analyses of ^{14}C, pollen, oxygen isotope and geological data enable us to draw some conclusions about the development of the mammoth fauna and their environment. In particular our data show that:

1. Mammoth remains from frozen ground are a very suitable material for ^{14}C dating.
2. The temporal distribution of the ^{14}C dates of fossils from the vast Eurasian territory is even for the whole period from 40 to 10 ka BP.
3. No time breaks appear in the series of dates in northern Asia, nor in eastern and western Europe.
4. The southern boundary of mammoths' distribution is close to the southern boundary of the ice wedge cast distribution (and therefore close to the southern limit of severe permafrost). This demonstrates that the mammoth fauna is a typical component of Late Quaternary permafrost environments.

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APPENDIX: RADIOCARBON DATES OF MAMMOTH REMAINS IN EURASIA

No.	^{14}C date (yr BP), Lab code	Material dated	Site
Eastern Europe			
1	9780 ± 260 (TA-12)	Bone	Kunda Settlement
2	11,000 ± 200 (GIN-93)	Bone	Kostenki Settlement
3	12,200 ± 300 (IGAN-282)	Molar	TimonovkaI Settlement
4	12,630 ± 360 (GIN-4137)	Molar	Eliseevichi Settlement
5	12,900 ± 200 (OxA-709)	Molar	Mezhirichi Settlement
6	12,970 ± 140 (LU-102)	Molar	Eliseevichi Settlement
7	13,650 ± 180 (LU-153)	Molar	Yudinovo Settlement
8	13,680 ± 60 (GIN-6209)	Tusk	Sevsk Town
9	13,900 ± 200 (IGAN-78)	Bone	Avdeevo Settlement
10	13,950 ± 70 (GIN-5778)	Bone	Sevsk Town
11	14,100 ± 400 (GIN-4139)	Molar	Eliseevichi Settlement
12	14,290 ± 120 (GIN-2356)	Tusk	Or'ya Settlement
13	14,320 ± 270 (QC-897)	Molar	Mezhirichi Settlement
14	14,360 ± 150 (GIN-2913)	Bone	Shatrishche Settlment
15	14,400 ± 250 (OxA-712)	Molar	Mezhirichi Settlement
16	14,470 ± 100 (LU-126)	Molar	Eliseevichi Settlement
17	14,590 ± 140 (GIN-4136)	Molar	Eliseevichi Settlement
18	14,600 ± 200 (OxA-717)	Molar	Gontsy Settlement
19	14,700 ± 250 (OxA-715)	Molar	Chulatovo Settlement
20	14,700 ± 500 (GIN-2593)	Molar	Kintu Lake
21	15,100 ± 200 (OxA-719)	Molar	Mezin Settlement
22	15,100 ± 250 (OxA-716)	Molar	Berdyzh Settlement
23	15,110 ± 530 (LU-358)	Bone	Timonovka I Settlement
24	15,660 ± 180 (LU-127)	Molar	Yudinovo Settlement
25	15,245 ± 1080 (QC-900)	Molar	Mezhirichi Settlement
26	16,300 ± 700 (GIN-2002)	Molar	Timonovka I Settlement
27	16,850 ± 120 (GIN-4138)	Molar	Eliseevichi Settlement
28	17,340 ± 170 (LU-360)	Molar	Eliseevichi Settlement
29	17,930 ± 100 (LE-1432A)	Molar	Gagarino Settlement
30	18,300 ± 200 (GIN-3727)	Molar	Zaraisk Town
31	18,320 ± 280 (TA-121)	Bone	Byzovaya Settlement

32	18,690 ± 770 (LU-361)	Molar	Pogon Settlement
33	19,000 ± 300 (OxA-697)	Molar	Radomyshl' Settlement
34	19,200 ± 350 (OxA-718)	Molar	Kirillovka Settlement
35	19,200 ± 200 (LE-2946B)	Molar	Leski Settlement
36	19,280 ± 600 (KI-1058)	Bone	Mezhirichi Settlement
37	19,800 ± 350 (OxA-698)	Molar	Novgorod-Severski Town
38	20,150 ± 100 (LE-1432B)	Molar	Gagarino Settlement
39	20,300 ± 200 (LE-1602)	Molar	Sagaidak I Settlement
40	20,620 ± 100 (LE-1432C)	Molar	Gagarino Settlement
41	21,240 ± 200 (LE-1602a)	Molar	Sagaidak I Settlement
42	21,600 ± 2200 (GIN-4)	Molar	Mezin Settlement
43	22,000 ± 300 (GIN-3698)	Molar	Zaraisk Town
44	22,200 ± 300 (GIN-3634)	Bone	Kostenki Settlement
45	22,600 ± 300 (GIN-3633)	Bone	Kostenki Settlement
46	22,800 ± 300 (GIN-3632)	Bone	Kostenki Settlement
47	23,430 ± 180 (LU-104)	Molar	Berdyzh Settlement
48	23,660 ± 270 (LU-359)	Molar	Khotylevo Settlement
49	23,770 ± 1540 (LE-2946A)	Molar	Leski Settlement
50	24,600 ± 150 (LE-2624)	Molar	Anetovka II Settlement
51	24,950 ± 400 (IGAN-73)	Molar	Khotylevo Settlement
52	25,000 ± 300 (GIN-2463)	Bone	Nizhniy Novgorod Region
53	25,300 ± 400 (GIN-6143)	Molar	Lower Kama River
54	26,470 ± 420 (LU-125)	Molar	Yurovichi Settlement
55	27,500 ± 800 (KI-1051)	Molar	Mezin Settlement
56	27,700 ± 500 (GIN-5880)	Bone	Sungir', Vladimir Region
57	30,500 ± 900 (LU-60)	Bone	Tver' Region
58	32,100 ± 500 (GIN-6146)	Molar	Lower Kama River
59	35,100 ± 1000 (GIN-6633)	Soft tissue	Starun Town
60	37,000 ± 500 (GIN-6141)	Molar	Lower Kama River
61	37,300 ± 1000 (GIN-6142)	Molar	Lower Kama River
62	37,600 ± 400 (GIN-3231)	Molar	Viliya River (Neman)
63	38,400 ± 1000 (GIN-6148)	Molar	Lower Kama River
64	42,200 ± 300 (GIN-6410)	Tusk	Novopetrovskoe Settlement, Moscow Region
65	43,600 ± 1000 (GIN-6145)	Molar	Lower Kama River
66	44,000 ± 1000 (GIN-6144)	Molar	Lower Kama River
67	44,200 ± 1000 (GIN-6147)	Molar	Lower Kama River
68	>47,700 (GIN-7075)	Bone	Pavlovsk, Voronezh Region
North of European Russia			
69	18,320 ± 280 (TA-121)	Bone	Pechora River
70	29,300 ± 300 (GIN-7575)	Molar	Bol'shezemel'skaya tundra
71	>36,000 (IEMAE)	Tusk	Kanin Peninsula
Western Siberia			
72	12,860 ± 90 (SOAN-1283)	Bone	Irtysh River, W.S.
73	13,350 ± 60 (GIN-7539)	Bone	Krasnoyarsk Town
74	13,930 ± 80 (GIN-7541)	Bone	Krasnoyarsk Town
75	14,240 ± 160 (SOAN-78)	Bone	Volch'ya Griva Settlement
76	18,600 ± 2000 (GIN-2862)	Bone	Middle Enisey River
77	19,500 ± 200 (GIN-2859)	Bone	Middle Enisey River
78	19,700 ± 200 (GIN-2861)	Tusk	Middle Enisey River
79	19,960 ± 80 (GIN-3016)	Bone	Chulym River
80	20,100 ± 100 (GIN-2863)	Tusk	Middle Enisey River
81	20,100 ± 300 (GIN-3017)	Bone	Middle Enisey River
82	20,400 ± 240 (SOAN-1513)	Tusk	Mogochino Settlement
83	20,200 ± 100 (GIN-2860)	Bone	Chulym River
84	41,900 ± 800 (GIN-5337)	Molar	Tavda River
North of Western Siberia			
85	9600 ± 300 (VSEGINGEO)	Soft tissue	Yuribey River
86	9730 ± 100 (MGU-763)	Stomach contents	Yuribey River
87	10,000 ± 70 (LU-1153)	Stomach contents	Yuribey River
88	10,350 ± 50 (GIN-6386)	Molar	Seyakha Mutnaya River
89	14,400 ± 80 (GIN-7292)	Bone	Seyakha Zelyonaya River
90	17,500 ± 300 (GIN-7576)	Molar	Parisento River
91	25,400 ± 300 (GIN-2210)	Bone	Upper Yuribey River

92	27,200 ± 500 (GIN-2021b)	Molar	Yambuto Lake, Gydan
93	29,300 ± 300 (GIN-6386A)	Bone	Seyakha Mutnaya River,
94	30,250 ± 1800 (T-298)	Skin	Gyda River
95	34,500 ± 300 (GIN-6475A)	Tusk	Shchushch'ya River, Yamal
96	31,500 ± 600 (GIN-2201)	Bone	Yekaryauyakha River, Gydan
97	33,500 ± 1100 (T-298)	Blubber	Gyda River
98	34,500 ± 300 (GIN-6475A)	Tusk	Shchushch'ya River, Yamal
99	35,500 ± 1100 (T-298)	Blubber	Gyda River
Taimyr Peninsula			
100	9670 ± 60 (GIN-1828)	Tusk	Nizhnaya Taimyra River
101	9860 ± 50 (GIN-1495)	Molar	Nizhnaya Taimyra River
102	10,100 ± 100 (GIN-1489)	Molar	Engel'gard Lake
103	10,300 ± 100 (GIN-1828k)	Bone.	Nizhnaya Taimyra River
104	10,680 ± 70 (GIN-3768)	Bone	Nganasanskaya River
105	11,140 ± 180 (GIN-3067)	Molar	Taimyr Lake
106	11,450 ± 250 (T-297)	Soft tissue	Mamont River, Shrenk
107	12,100 ± 80 (GIN-1783)	Bone	Taimyr Lake, Baskura
108	12,260 ± 120 (GIN-2943r)	Bone	Severnaya River
109	12,450 ± 60 (GIN-3242)	Bone	Severnaya River
110	12,780 ± 80 (GIN-2677)	Bone	Bikada River
111	13,340 ± 240 (GIN-2758a)	Bone	Bolshaya Balachnya River
112	16,330 ± 100 (GIN-3130)	Mandible	Bolshaya Balachnya River
113	18,680 ± 120 (GIN-5046)	Tusk	Boderbo-Tarida River
114	20,400 ± 100 (GIN-3952)	Tusk	Dudypta River
115	22,750 ± 150 (GIN-3089)	Bone	Taimyr Lake, Baskura
116	23,500 ± 300 (GIN-2763a)	Tusk	Bolshaya Balachnya River
117	23,800 ± 400 (GIN-1296B)	Bone	Taimyr Lake, Sabler
118	24,900 ± 500 (GIN-2160)	Pelvis	Taimyr Lake, Baskura
119	25,100 ± 550 (LE-612)	Soft tissue	Pyasina River
120	26,700 ± 700 (GIN-1216)	Tusk	Gulya River
121	27,300 ± 200 (GIN-3836)	Tusk	Logata River
122	27,500 ± 300 (GIN-3929)	Tusk	Kubalakh River
123	27,500 ± 200 (GIN-3505)	Scalpula	Lygiy-Yurege River
124	28,800 ± 600 (GIN-952)	Tusk	Shrenk River
125	29,400 ± 400 (GIN-3310)	Tusk	Chaidachtar Lake
126	29,500 ± 300 (GIN-2155)	Tusk	Taimyr Lake, Matuda
127	31,800 ± 500 (GIN-3240a)	Bone	Severnaya River
128	31,900 ± 300 (GIN-5726)	Bone	Sualema River
129	32,000 ± 200 (GIN-3117)	Femur	Balakhnya River
130	32,000 ± 500 (GIN-2151)	Limb bone	Taimyr Lake, Matuda
131	35,000 ± 500 (GIN-3821)	Bone	Logata River
132	35,800 ± 2700 (T-169)	Skin	Mokhovaya River
133	36,200 ± 500 (GIN-3822)	Tusk	Logata River
134	36,800 ± 500 (GIN-3122)	Tusk	Bolshaya Balachnya River
135	36,950 ± 4300 (T-169)	Skin	Mokhovaya River
136	38,000 ± 1500 (GIN-942)	Tusk	Khatanga River
137	38,300 ± 600 (GIN-3817)	Tusk	Logata River
138	38,400 ± 700 (GIN-3118)	Tusk	Bolshaya Balachnya River
139	38,500 ± 500 (GIN-3136)	Bone	Boderbo-Tarida River
140	38,500 ± 500 (GIN-2763B)	Molar	Boderbo-Tarida River
141	38,800 ± 400 (GIN-3476)	Tusk	Nemudikatarida River
142	38,800 ± 1300 (GIN-1491)	Tusk	Trautfetter River
143	38,900 ± 600 (GIN-3831)	Tusk	Logata River
144	39,100 ± 700 (GIN-3120P)	Bone	Bolshaya Balachnya River
145	39,300 ± 500 (GIN-3121P)	Bone	Bolshaya Balachnya River
146	39,300 ± 500 (GIN-3071)	Bone	Taimyr Lake, Baykura
147	39,800 ± 600 (GIN-3135)	Bone	Boderbo-Tarida River
148	40,200 ± 600 (GIN-3804)	Tusk	Logata River
149	40,500 ± 800 (GIN-1818P)	Bone	Engel'gard Lake
150	40,800 ± 2000 (GIN-1835)	Bone	Taimyr Lake, Gofman
151	41,200 ± 1000 (GIN-2744B)	Bone	Boderbo-Tarida River
152	41,400 ± 2000 (GIN-3941)	Tusk	Shaitan Lake
153	42,800 ± 800 (GIN-3946)	Tusk	Massonov, Khatanga Riverbasin

154	43,500 ± 1000 (GIN-3072)	Bone	Taimyr Lake, Baykura
155	45,000 ± 1000 (GIN-766)	Bone	Kheta River
156	46,100 ± 1200 (GIN-3073)	Bone	Taimyr Lake, Baykura
157	47,900 ± 1600 (GIN-3118a)	Tusk	Bolshaya Balachnya River
158	>49,500 (GIN-3080)	Tusk	Taimyr Lake, Baykura
159	>49,500 (GIN-3092a)	Tusk	Bolshaya Balachnya River
160	>52,700 (GIN-2764B)	Bone	Boderbo-Tarida River
161	>53,170 (LU-1057)	Bone	Khatanga River
Central Siberia			
162	20,700 ± 150 (GIN-7709)	Bone	Belaya River (Angara)
163	21,600 ± 200 (GIN-7708)	Bone	Belaya River (Angara)
164	23,600 ± 200 (GIN-5886)	Bone	MiddleAngara River
165	41,100 ± 1500 (GIN-7707)	Bone	Belaya River (Angara)
166	49,700 ± 1100 (GIN-689)	Tusk	Maimechya River, Putoran
Northern Yakutia			
167	10,370 ± 70 (SOAN-327)	Bone	Berelyokh River
168	12,000 ± 130 (LU-149)	Tusk	Berelyokh River
169	12,240 ± 160 (LU-139)	Tusk	Berelyokh River
170	12,530 ± 60 (SOAN-2203)	Humerus	Achchaika-Allaikha River
171	12,570 ± 80 (MAG-826)	Humerus	Achchaika-Allaikha River
172	12,850 ± 110 (LU-1055)	Tusk	Berelyokh River
173	13,700 ± 800 (MAG-114)	Soft tissue	Berelyokh River
174	14,340 ± 50 (GIN-4115)	Tusk	Lena River
175	14,800 ± 50 (GIN-3518)	Tusk	Ulakhan-Yuryakh
176	17,780 ± 80 (GIN-5042)	Molar	Lower Lena River
177	18,680 ± 120 (GIN-5046)	Tusk	Bur, Olenyok River Basin
178	18,700 ± 100 (GIN-6099)	Tusk	Amydai, Olenyok Basin
179	21,260 ± 310 (LU-786)	Mandible	Lower Lena River
180	21,630 ± 240 (LU-1328)	Carpal	Bykovski Peninsula
181	22,000 ± 200 (GIN-5574)	Molar	Anabar River, Popigay
182	23,100 ± 200 (GIN-3232)	Pelvis	Tyung, Lena River
183	24,000 ± 1100 (GIN-7176)	Tusk	Kular Settlment
184	25,300 ± 600 (GIN-3502)	Bone	Yarasalakh River
185	26,000 ± 1600 (Mo-215)	Hair	Lena River, Chekurovka
186	28,600 ± 300 (GIN-3867)	Limb Bone	Duvanniy Yar, Kolyma River
187	28,900 ± 300 (GIN-5573)	Tusk	Anabar River, Popigay
188	29,400 ± 400 (GIN-3310)	Tusk	Anabar River
189	29,500 ± 3000 (T-170)	Soft tissue	Lena River, Sanga-Yuryakh
190	29,600 ± 500 (GIN-3234)	Vertebrae	Tyung River, Lena basin
191	30,400 ± 300 (GIN-6023a)	Bone	Khamus-Yuryakh River, Kolyma
192	31,500 ± 2000 (T-170)	Soft tissue	Lena River, Sanga-Yuryakh
193	31,750 ± 2500 (T-299)	Soft tissue	Beryosovka River
194	31,900 ± 300 (GIN-5726)	Ribs	Anabar Gulf, Sualema River
195	32,200 (500 (SOAN-1006B)	Stomach contents	Shandrin River
196	32,300 ± 400 (GIN-5074)	Tusk	Popigay River
197	32,650 ± 2500 (T-170)	Soft tissue	Lena River, Sanga-Yuryakh
198	33,800 ± 500 (GIN-3861)	Bone	Duvanny Yar, Kolyma River
199	34,450 ± 2500 (T-171)	Soft tissue	Lena River (Bykovskaya)
200	34,700 ± 400 (GIN-4434)	Bone	Duvanny Yar, Kolyma River
201	35,000 ± 300 (GIN-3503)	Bone	Laptev Sea coast
202	35,800 ± 1200 (T-171)	Soft tissue	Lena River (Bykovskaya)
203	35,830 ± 630 (LU-504)	Skin	Tirekhtyakh River
204	36,450 ± 420 (SOAN-1005)	Soft tissue	Shandrin River
205	36,600 ± 500 (GIN-5751)	Molar	Anabar River, Popigay
206	37,000 ± 500 (GIN-5750)	Molar	Semiriskai River, Popigay
207	39,400 ± 1000 (GIN-3517)	Bone	Laptev Sea coast
208	40,100 ± 500 (GIN-5726A)	Molar	Anabar Gulf
209	40,300 ± 400 (GIN-5025)	Molar	Anabarka River, Popigay
210	40,350 ± 880 (LU-595)	Stomach contents	Shandrin River
211	41,750 ± 1290 (LU-505)	Soft tissue	Shandrin River
212	41,900 ± 800 (GIN-5224)	Tusk	Anabarka River, Popigay
213	42,400 ± 800 (GIN-6310)	Molar	Khamus-Yuryakh Riv, Kolyma
214	43,200 ± 400 (GIN-6100)	Bone	Amydai, Olenyok Basin

215	43,700 ± 800 (GIN-3849)	Bone	Zelyoniy Mys Settlement
216	44,000 ± 3500 (T-170)	Soft tissue	Lena River, Sanga-Yuryakh
217	44,000 ± 3500 (T-299)	Soft tissue	Beryosovka River
218	44,540 ± 1900 (LU-1050)	Bone	Tirekhtyakh River
219	45,500 ± 1200 (GIN-6105)	Tusk	Amydai, Olenyok Basin
220	46,100 ± 1000 (GIN-3206)	Bone	Lower Kolyma River
221	49,500 (GIN-6101)	Tusk	Nekyu, Olenyok Basin
222	>50,000 (GIN-359)	Bone	Lower Lena River
223	>50,000 (GIN-5731)	Molar	Anabarka River, Popigay
224	>50,000 (SOAN-813)	Soft tissue	Tirekhtyakh River
225	>50,000 (GIN-3848)	Bone	Zelyoniy Mys Settlement
226	>50,000 (GIN-3866)	Bone	Duvanniy Yar, Kolyma River
227	50,400 ± 1300 (GIN-4114)	Tusk	Lower Lena River
228	>53,000 (GIN-3857)	Tusk	Duvanniy Yar, Kolyma River
229	>53,170 (LU-1057)	Skin	Tirekhtyakh River
Magadan Region			
230	21,600 ± 200 (GIN-6309)	Tusk	Tanon River
231	28,400 ± 300 (GIN-5696)	Tusk	Srednekan River
232	39,570 ± 870 (LU-718A)	Soft tissue	Kirgilyakh River
233	39,590 ± 770 (LU-718B)	Soft tissue	Kirgilyakh River
234	40,600 ± 700 (MAG-366A)	Soft tissue	Kirgilyakh River
235	41,000 ± 1100 (MAG-366B)	Soft tissue	Kirgilyakh River
236	41,000 ± 900 (MAG-576)	Soft tissue	Kirgilyakh River
Chukotka Peninsula			
237	14,380 ± 70 (GIN-7289)	Tusk	
238	15,100 ± 70 (GIN-5370)	Tusk	Mayn River
239	31,370 ± 900 (MAG-1000A)	Soft tissue	Enmynveem River
240	31,100 ± 900 (MAG-1000B)	Soft tissue	Enmynveem River
241	32,800 ± 720 (MAG-1001A)	Soft tissue	Enmynveem River
242	32,850 ± 900 (MAG-1000)	Soft tissue	Enmynveem River
243	32,890 ± 1200 (MAG-1001B)	Soft tissue	Enmynveen River
244	32,000 ± 3000 (MAG-1124)	Soft tissue	Enmynveem River
Kamchatka Peninsula			
245	12,630 ± 50 (GIN-3420)	Tusk	Kamchatka River, Urz
246	21,300 ± 400 (GIN-2224)	Skull	Pakhtcha River
247	21,750 ± 150 (GIN-5299b)	Tusk	Kamchatka River
248	30 000 ± 300 (GIN-3415)	Tusk	Kamchatka River
249	36,000 ± 500 (GIN-3425)	Tusk	Kamchatka River
250	39,600 ± 1600 (GIN-3411)	Molar	Kamchatka River
251	40,600 ± 600 (GIN-3407)	Tusk	Kamchatka River
Arctic Islands			
252	3730 ± 40 (LU-2741)	Tusk	Wrangel Island
253	3920 ± 30 (GIN-6980)	Tusk	Wrangel Island
254	4010 ± 50 (LU-2798)	Molar	Wrangel Island
255	4040 ± 30 (LU-2808)	Tooth	Wrangel Island
256	4400 ± 40 (LU-2756)	Tusk	Wrangel Island
257	4410 ± 50 (LU-2768)	Tusk	Wrangel Island
258	4740 ± 40 (LU-2556)	Tibia	Wrangel Island
259	4900 ± 40 (LU-2740)	Tusk	Wrangel Island
260	5110 ± 40 (LU-2794)	Molar	Wrangel Island
261	5200 ± 30 (LU-2745)	Tusk	Wrangel Island
262	5250 ± 40 (LU-2744)	Tusk	Wrangel Island
263	5310 ± 90 (LU-2742)	Tusk	Wrangel Island
264	5480 ± 50 (LU-2535)	Tusk	Wrangel Island
265	6260 ± 50 (LU-2799)	Molar	Wrangel Island
266	6360 ± 60 (AA-11529)	Molar	Wrangel Island
267	6610 ± 50 (LU-2558)	Tusk	Wrangel Island
268	6760 ± 50 (LU-2736)	Tusk	Wrangel Island
269	6890 ± 50 (LU-2810)	Tooth	Wrangel Island
270	7040 ± 60 (LU-2746)	Tusk	Wrangel Island
271	7250 ± 60 (LU-2809)	Molar	Wrangel Island
272	7295 (95 (AA-11530)	Molar	Wrangel Island
273	7360 ± 50 (LU-2559)	Tusk	Wrangel Island

274	7390 ± 30 (LU-2444)	Tusk	Wrangel Island
275	7710 ± 40 (GIN-6995)	Tusk	Wrangel Island
276	11,500 ± 60 (LU-610)	Tusk	Severnaya Zemlya
277	12,010 ± 110 (LU-2823)	Molar	Wrangel Island
278	12,750 ± 50 (GIN-6987)	Tusk	Wrangel Island
279	12,980 ± 80 (LU-2792)	Molar	Wrangel Island
280	15,420 ± 100 (LU-1671)	Tusk	Kotel'niy Island
281	19,270 ± 300 (LU-654B)	Tusk	Severnaya Zemlya
282	19,970 ± 110 (LU-688)	Molar	Severnaya Zemlya
283	19,990 ± 110 (LU-1790)	Tusk	Kotel'niy Island
284	20 000 ± 110 (LU-2807)	Molar	Wrangel Island
285	20,900 ± 100 (GIN-5760)	Tusk	Faddeevskiy Island
286	25,030 ± 210 (LU-749B)	Tibia	Severnaya Zemlya
287	25,800 ± 200 (GIN-4710B)	Tusk	Faddeevskiy Island
288	28,000 ± 200 (GIN-4710)	Tusk	Faddeevskiy Island
289	29,020 ± 190 (LU-1791)	Tusk	Kotel'niy Island
290	29,100 ± 400 (GIN-4330)	Bone	Faddeevskiy Island
291	29,100 ± 1000 (GIN-4711)	Tusk	Faddeevskiy Island
292	32,100 ± 900 (MAG-316)	Skin	Lyakhovskiy Bolshoiy Island
Denmark			
293	13,240 +760/−690 (K-3697)	Tusk	Rosmos 1
294	21,530 ± 430 (K-3703)	Bone	Myrup Banke
295	24,190 ± 420 (K-3806)	Tusk	Munke Bjergby
296	25,110 ± 440 (K-3699)	Tusk	Hadsund
297	25,480 +560/−520 (K-3809)	Tusk	Ostrupgard
298	25,520 +920/−830 (K-3805)	Tusk	Ny Stengaard
299	25,760 +840/−770 (K-3805)	Tusk	Ny Stengaard
300	26,270 +1400/−1210 (K-3805)	Tusk	Ny Stengaard
301	27,810 ± 610 (K-4192)	Tusk	Stengardens Grusgrav 2
302	28,120 +760/−680 (K-3808)	Tusk	Ronninge 1
303	29,570 ± 950 (K-3807)	Tusk	Saxkobing
304	31,840 +1010/−870 (K-3696)	Tusk	Kiskelund
305	32,460 +970/−870 (K-4190)	Tusk	Lundebjerg 1
306	>37,900 (K-4191)	Tusk	Sonder Kollemorten
307	>39,500 (K-4188)	Tusk	Sonder Omme
308	>39,600 (K-4587)	Tusk	Rosmos 2
Germany			
309	15,810 ± 410 (HV-1961)	Molar	Kelsterbach
310	30,300 +2500/−1900 (Fra-5a)	Femur	Kelsterbach
Switzerland			
311	12,270 ± 210 (Ly-877)	Tusk	Praz Rodet
312	34,600 +2700/−1800 (Ly-751)	Tusk	Bioley-Orjulaz
Poland			
313	20,200 ± 350 (OxA-635)	Bone	Spadzista Street, Krakow
314	20,600 ± 1050 (Ly-631)	Bone	Spadzista Street, Krakow
315	21,000 ± 900 (Ly-2542)	Bone	Spadzista Street, Krakow
316	23,040 ± 170 (GrN-6636)	Bone	Spadzista Street, Krakow
France			
317	12,000 ± 220 (Ly-1351)	Scapula	Etiolles
318	14,330 ± 260 (Ly-357)	Bone	La Croze-sur-Suran 1
319	14,390 ± 300 (Ly-433)	Bone	La Columbière rockshelter
320	14,850 ± 350 (Ly-434)	Bone	La Croze-sur-Suran 2
321	25,800 ± 700 (Ly-1863)	Tusk	La Mère Clochette Grotto
Ireland			
322	33,500 ± 1200 (D-122)	Molar	Castlepook Cave, Cork
Great Britain			
323	11,650 ± 130 (OxA-2155)	Ivory rod	Kent's Cavern
324	12,080 ± 130 (OxA-1457)	Skull	Condover, Shropshire
325	12,170 ± 130 (OxA-1890)	Ivory rod	Cough's Cave
326	12,300 ± 180 (OxA-1316)	Molar	Condover, Shropshire
327	12,320 ± 120 (OxA-1462)	Tusk	Robin Hood's cave
328	12,330 ± 120 (OxA-1456)	Molar	Condover, Shropshire

329	12,400 ± 160 (OxA-1455)	Tusk	Condover, Shropshire
330	12,460 ± 160 (OxA-1204)	Calcaneum	Condover, Shropshire
331	12,480 ± 96 (Birm-1273com.)	Tusk	Condover, Shropshire
332	12,700 ± 160 (OxA-1021)	Tusk	Condover, Shropshire
333	12,920 ± 390 (Birm-1273)	Tusk	Condover, Shropshire
334	18,000 +1400/−1200 (Birm-146)	Bone	Cae Gwyn Cave, Wales
335	19,300 ± 700 (Gif-1110)	Bone	Condover, Shropshire
336	26,700 ± 550 (OxA-1205)	Bone	Pin Hole Cave, Creswell
337	33,200 ± 1300 (OxA-1069)	Bone	Conningbrook, Kent
338	34,500 ± 500 (Birm-466)	Bone	Little Rissington
339	34,850 ± 1500 (OxA-1654)	Molar	King Arthur's Cave
340	35,200 ± 1600 (OxA-1610)	Bone	Conningbrook, Kent
341	37,020 +1900/−1350 (Q-2500)	Tusk	Farnham, Surrey
342	37,300 ± 1900 (OxA-1644)	Bone	Conningbrook, Kent
343	38,500 ± 2300 (OxA-1565)	Molar	King Arthur's Cave
344	38,600 ± 2400 (OxA-1611)	Bone	Conningbrook, Kent
345	38,600 +1720/−1420 (NPL-1628)	Tusk	Oxbow, Leeds
346	>39,500 (OxA-1566)	Molar	King Arthur's Cave
Finland			
347	15,500 ± 200 (Hel-1074)	Humerus	Herttoniemi
348	25,200 ± 500 (Hel-1075)	Femur	Lohtaja
349	>43,000 (Hel-1076)	Molar	Espoo
Norway			
350	19,000 ± 1200 (U-4214)	Tusk	Toten, Opland
351	20 000 ± 250 (K-3703)	Tusk	Favang
352	22,370 ± 980 (K-3703)	Tusk	Favang
353	24,400 ± 900 (K-3806)	Tusk	Kvam
354	28,100 +2300/−1800 (U-2766)	Tusk	Toten, Opland
355	32,100 +3100/−2300 (U-4214)	Tusk	Toten, Opland
Sweden			
356	13,090 ± 120 (Lu-796, 2)	Tusk	Lockarp
357	13,260 ± 110 (Lu-865)	Tusk	Lockarp
358	13,360 ± 95 (Lu-796)	Tusk	Lockarp
359	19,150 ± 390 (Lu-887E)	Tusk	Arrie
360	22,000 +900/−800 (Lu-887)	Tusk	Arrie
361	31,200 +3050/−2650 (Lu-746)	Tusk	Orsjo
362	36,000 +1550/−1300 (Lu-879)	Tusk	Dosebacka
363	36,100 +2000/−1600 (Lu-880)	Tusk	Orsjo

References: Berglund, Hakansson and Lagerlund 1976; Follestad and Olsson 1979; Orlova 1979; Jungner and Sonninen, 1983; Aaris-Sorensen *et al.* 1990; Stuart 1991; Vasil'chuk 1992; Svezhentsev and Popov 1993; Vartanyan, Garutt and Sher 1993; Vartanyan *et al.* 1995; Sulerzhitskij 1995.