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Viewpoint

The latest woolly mammoths (*Mammuthus primigenius* Blumenbach) in Europe and Asia: a review of the current evidence

Anthony J. Stuart[a,*], Leopold D. Sulerzhitsky[b], Lyobov A. Orlova[c], Yaroslav V. Kuzmin[d], Adrian M. Lister[a]

[a] *Department of Biology, University College London, London WC1E 6BT, UK*
[b] *Geological Institute, Russian Academy of Sciences, Pyzhevsky 7, Moscow 109017, Russia*
[c] *Institute of Geology, Russian Academy of Sciences, Koptuyg Ave. 3, Novosibirsk 630090, Russia*
[d] *Pacific Institute of Geography, Russian Academy of Sciences, Radio St. 7, Vladivostok 690041, Russia*

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Abstract

During the Last Cold Stage, woolly mammoths ranged very widely across Northern Eurasia into North America, but then disappeared as part of the global phenomenon of Late Quaternary megafaunal extinction. The timing and causes of this highly significant event have generated conflicting opinions and much debate. However, the overriding need is for more data, and recent years have seen the accumulation of significant new finds and radiocarbon dating evidence. In particular, research is currently focussing on the geographical pattern of extirpation leading to final extinction, rather than seeking a single 'last appearance datum'. This Viewpoint article was commissioned by the Editor-in-Chief and is published following the paper by Lõugas et al. (Dating the extinction of European mammoths: new evidence from Estonia. Quat. Sci. Rev. 21 (2002) 1347) to place their finding in a wider context. We give a brief review of the youngest directly dated mammoth remains from different regions of Eurasia, based both on published sources and on our own current research. This includes a very important new record from Cherepovets, North Russian Plain, which together with the new date from Puurmani, Estonia indicates the persistence of mammoth in this region close to the Pleistocene–Holocene boundary. These and other records suggest that the previous picture of mammoths widespread before 12,000 ka BP (uncalibrated radiocarbon years ago), then restricted to limited areas of northern Siberia, although correct in outline, has important exceptions which modify our understanding of mammoth extinction.

Despite the many available radiocarbon dates for Eurasian mammoth relative to other extinct megafauna, it is apparent that much more work is needed. Only then can we adequately tackle the important question of the cause or causes of extinction, whether by climatic/environmental change or 'overkill' by human hunters.

1. Introduction

The mammoth lineage arose in Africa, and first appeared in Europe almost three million years ago (Maglio, 1973; Lister, 1996; Lister and Sher, 2001). European fossils show a chronocline in dental and cranial morphology, from Late Pliocene to Early Pleistocene *Mammuthus meridionalis*, through Middle Pleistocene *Mammuthus trogontherii*, to fully evolved woolly mammoth *Mammuthus primigenius*, which first appears in Europe soon after 200,000 years ago. Recent work (Sher and Lister, 1999; Lister and Sher, 2001) indicates, however, that *M. primigenius* arose in north-east Siberia considerably earlier, perhaps around 800 ka BP, so that its appearance in Europe represents a migration from the east.

During the Last Cold Stage the woolly mammoth was very widely distributed, ranging throughout most of Europe, across northern Asia and into the northern half of North America. Its extinction should be viewed as part of the global wave of extinction of megafauna that occurred in the Late Quaternary. These extinctions have been variously attributed to 'overkill' by human hunters, climatic/environmental changes, or to a combination of factors (Martin, 1984; Stuart, 1991, 1999; Martin and Stuart, 1995). Other megafaunal species that disappeared from Eurasia include: woolly rhinoceros (*Coelodonta antiquitatis*), giant deer (*Megaloceros giganteus*), and cave bear (*Ursus spelaeus*). However, there has long

*Corresponding author.
E-mail address: tony@tandjstuart.freeserve.co.uk (A.J. Stuart).

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been a particular interest in the woolly mammoth and it features prominently in the ongoing debate on the causes of these extinctions. Of the extinct Northern Eurasian megafauna, *M. primigenius* is the species with the greatest number of direct radiocarbon dates.

As more data accumulate, the process of extinction of woolly mammoth looks increasingly complex. This paper is primarily concerned with conclusions derived from the evidence of radiocarbon dates made directly on mammoth material. The dates are derived from the literature or are previously unpublished dates from our current project funded by the UK Natural Environment Research Council, "Late Quaternary Megafaunal Extinctions in Europe and Northern Asia" ('LQME project'). The rationale behind this project is to explore regional variation in the timing of extirpation of woolly mammoth and other extinct megafauna, rather than to seek a single 'last appearance datum' for the whole geographical range. In this way we will be able to explore in more detail any correlations between the disappearance of the megafauna on the one hand, and possible causal factors such a vegetational change or the spread of modern humans, on the other. This ongoing work will form the basis of future publications. Clearly it is not possible to date an extinction event directly, but the latest survival of mammoth, or any other species, in a given area can be estimated from the chronological distribution of radiocarbon dates. Here we summarise the youngest direct dates on mammoth currently known from each region. The focus is especially on Europe, but with broader context provided by the Siberian data.

Until very recently it was thought, on the basis of available radiocarbon dates, that mammoths had disappeared from all of Europe and most of Northern Asia by about 12 ka BP. (Stuart, 1991, 1999), surviving beyond this time only in the far north of Siberia, on the Yamal, Gydan and Taymyr Peninsulas and on Wrangel Island (Fig. 1) (Vartanyan et al., 1993, 1995; Sher, 1997). However, new dates on mammoth material from both Europe and southern Siberia are now causing a radical rethink. Lõugas et al. (2002) report radiocarbon dates close to 10 ka BP on mammoth material from Estonia. Here we discuss early Holocene dates on a mammoth skeleton found north of Moscow, and other late mammoth finds from Europe and northern Asia.

It is worth making a few general points about the interpretation of radiocarbon dates as evidence for the survival of mammoth, or other extinct megafauna, to a particular time. First, it is becoming apparent from unpublished LQME Project results that dating of finds by their contexts, including associated dates on other material, is not always reliable, due both to stratigraphic uncertainties and to the tendency of Palaeolithic people to collect old mammoth ivory and bones and other

Fig. 1. Northern Eurasia, showing location of Wrangel Island and latest mammoth remains <11 ka.

faunal material. There is a further problem inherent in inferring the presence of mammoth on the basis of ivory artefacts, as it is possible that pieces of ivory, especially worked ivory, could have been traded from regions where mammoths still survived to regions from which they had disappeared.

Second, even when the target species has been directly dated, caution must attach to single determinations, and significant extensions to the mammoth's chronological or geographical range must be regarded as provisional until confirmatory dates are available. Our confidence in the results is much increased when: (i) more than one sample is dated from a site (preferably from different individual animals); (ii) there are confirmatory dates from another laboratory; and (iii) there are similar results from more than one site in the region.

Throughout this paper, dates are given in uncalibrated radiocarbon years BP. We explain our reasons for accepting, querying or rejecting some of the published results.

2. Europe

Woolly mammoths were present over most of Europe during much of the Last Cold Stage (the interval ca 115–10 ka BP, corresponding to OIS 5d-2). However, they appear to have survived many millennia longer in central and northern Europe than in the south or in Ireland. The latest dates for each region of Europe are listed in Table 1 and plotted in Fig. 2, and European ^{14}C dated mammoth localities mentioned in the text are mapped in Fig. 3.

2.1. Southern Europe

Mammoth remains are rare in southern Europe, but a date of 19,700 ± 500 BP (OxA-10122, LQME Project) on a molar fragment from Cueto de la Mina, northern Spain, is probably close to the latest occurrence of mammoth in Iberia. There is no record of mammoth from younger levels in the many caves in this region (Aguirre, 1989; Altuna, 1992). It may have disappeared from the Italian Peninsula even earlier. The latest available dates, on a pelvic bone from Settepolesini near Ferrara, are 35,800 ± 500 BP (OxA-10521, LQME project) and 33,830 ± 690 BP (Beta-128160, B. Sala, pers. comm. to A.J. Stuart, February 2001).

2.2. British Isles

Before 1986 it was thought that mammoth was absent from Britain in the Lateglacial (Stuart, 1982). However, in that year, the skeleton of an adult mammoth together with material representing three juveniles was discovered at Condover, Shropshire (Coope and Lister, 1987; Lister, 1991, 1993). The remains occurred in sediments infilling one of many hollows produced by melting ice of the Last Glacial Maximum (LGM) in the region. Radiocarbon dates made directly on the mammoth material indicated a Lateglacial age. A molar from the adult skeleton was dated at 12,300 ± 180 BP (OxA-1316) and a juvenile molar at 12,330 ± 120 BP (OxA-1456). However, pieces of a shattered adult tusk gave dates that range from ca 12.4–12.9 ka BP (Birmingham and Oxford laboratories). The rather wide range of dates from Condover might be explicable if the tusk came from an additional adult individual a few hundred years older than the dated adult and juvenile skeletons.

Subsequently the existence of Lateglacial mammoth in southern Britain was confirmed by direct AMS dates on fossils from caves of the Creswell Crags, in northern Midland England. A mammoth calcaneum from Pin Hole in this region was dated at 12,460 ± 160 BP (OxA-1204), and ivory fragments from Robin Hood's Cave at 12,320 ± 120 BP (OxA-1462) (Housley, 1991; Lister, 1991).

In addition, an ivory rod (artefact) from Gough's Cave, Somerset, excavated in 1987 (Currant et al., 1989), gave a date of 12,170 ± 130 BP (OxA-1890), which does not differ significantly (at 1σ) from the two youngest dates from Condover. The sample had not been treated with glue or preservatives and the result is considered reliable. However, there is rather less certainty about the date on another ivory rod, from Kent's Cavern, Devon, found during nineteenth century excavations by Pengelly. The rod, recovered from the "Black Band"—a palimpsest of Late Upper Palaeolithic hearths—was dated at 11,650 ± 130 BP (OxA-2155), significantly younger than any other dates on mammoth from Britain. The reliability of the result has been questioned due to the possibilities both of incomplete removal of fish glue, and of contamination when the CO_2 sample had to be recovered from the ion-source and redated (R.A. Housley, pers. comm. to A.M. Lister 1990). Because of these doubts we have to reject this date. Even if reliable, there would remain the possibility that the artefact might have been traded from elsewhere (see above).

Mammoths do not appear to have returned to Ireland after the LGM. The youngest date is 20,630 ± 220 BP (OxA-4233) from Castlepook Cave (Woodman et al., 1997).

2.3. Western Europe (France)

So far only a few direct dates have been published on mammoth material from French localities. A mammoth scapula from the open-air Late Magdalenian site of Etiolles, northern France, gave a date of 12,000 ± 220 BP (Ly-1351) (Taborin et al., 1979). However, all of the accepted dates on other material from the same locality

Table 1
Latest mammoth dates for each region of Europe

Locality	Country	Material dated	^{14}C age, BP ($\pm 1\sigma$)	Lab i.d.
Iberia				
Cueto de la Mina	Spain	Molar fragment	19,700 ± 500	OxA-10122
Italy				
Settepolesini	Italy	Pelvic bone	33,830 ± 690[1]	Beta-128160
Settepolesini	Italy	Pelvic bone	35,800 ± 500[1]	OxA-10521
Britain				
Gough's Cave	England	Ivory rod (artefact)	12,170 ± 130	OxA-1890
Robin Hood's Cave, Creswell Crags	England	Tusk fragment	12,320 ± 120	OxA-1462
Pin Hole Cave, Creswell Crags	England	Calcaneum	12,460 ± 160	OxA-1204
Condover	England	Adult molar	12,300 ± 180	OxA-1316
Condover	England	Juvenile molar	12,330 ± 120	OxA-1456
Ireland				
Castlepook Cave	Ireland	Bone	20,630 ± 220	OxA-4233
Fennoscandia				
Lockarp	Sweden	Tusk	13,090 ± 120[2]	LU-796.2
Lockarp	Sweden	Tusk	13,260 ± 110[2]	LU-865
Lockarp	Sweden	Tusk	13,360 ± 95[2]	LU-796
Herttoniemi, Helsinki	Finland	Humerus	15,500 ± 200	Hel-1074
W Europe				
Etiolles	France	Scapula	12,000 ± 220	Ly 1351
La Colombière Rockshelter	France	Bone	13,390 ± 300	Ly 433
C Europe				
Praz Rodet	Switzerland	Tusk	12,270 ± 210	Ly 877
Kesslerloch Cave	Switzerland	Rib	13,980 ± 110	OxA-10237
Oelknitz	Germany	Tusk fragment	14,100 ± 100	OxA-10240
Gönnersdorf	Germany	Femur	14380 ± 100	OxA-10239
Gönnersdorf	Germany	Tusk fragment	14570 ± 90	OxA-10199
N Russian Plain				
Zhidikhovo Peatbog, Cherepovets	Russia	Rib	9,760 ± 40[3]	GIN-8885c
Zhidikhovo Peatbog, Cherepovets	Russia	Rib	9,810 ± 100[3]	GIN-8676a
Zhidikhovo Peatbog, Cherepovets	Russia	Rib	9,840 ± 50[3]	GIN-8885b
Puurmani	Estonia	Molar	10,100 ± 100[4]	Hela-423
Puurmani	Estonia	Molar	10,200 ± 100[4]	Hela-425
C Russian Plain				
Timonovka	Russia	Molar	12,200 ± 300	IGAN-282
Eliseevichi	Russia	Molar	12,630 ± 360	GIN-4137
Dobranichevka	Ukraine	Molar	12,700 ± 200	OxA-0700
Mezhirich	Ukraine	Molar	12,900 ± 200	OxA-0709
Eliseevichi	Russia	Molar	12,970 ± 140	LU-102

Numbers in superscript indicate multiple dates on remains of the same individual. (NB. it is uncertain if the Puurmani molars are from the same individual).

are 800–1000 years older (Gowlett et al., 1986a, b). It seems desirable to obtain dates on additional mammoth material from this site. The next youngest date is 13,390 ± 300 BP (Ly 433) on a mammoth bone from La Colombière Rockshelter, Ain (Evin et al., 1973).

2.4. Central Europe

A piece of tusk from the Praz Rodet mammoth skeleton, Switzerland, gave a date of 12,270 ± 210 (Ly 877) (Weidmann, 1969; Evin et al., 1976). In view of the importance of this late record, we are pursuing further samples for dating. The next youngest date so far obtained for the region is 13,980 ± 110 BP (OxA-10237, LQME Project) on a rib from a Magdalenian level in Kesslerloch Cave, Switzerland.

The well-known Magdalenian open sites of Andernach and Gönnersdorf on the River Rhine, Germany, have produced depictions of mammoth, woolly rhinoceros and other animals engraved on pieces of slate

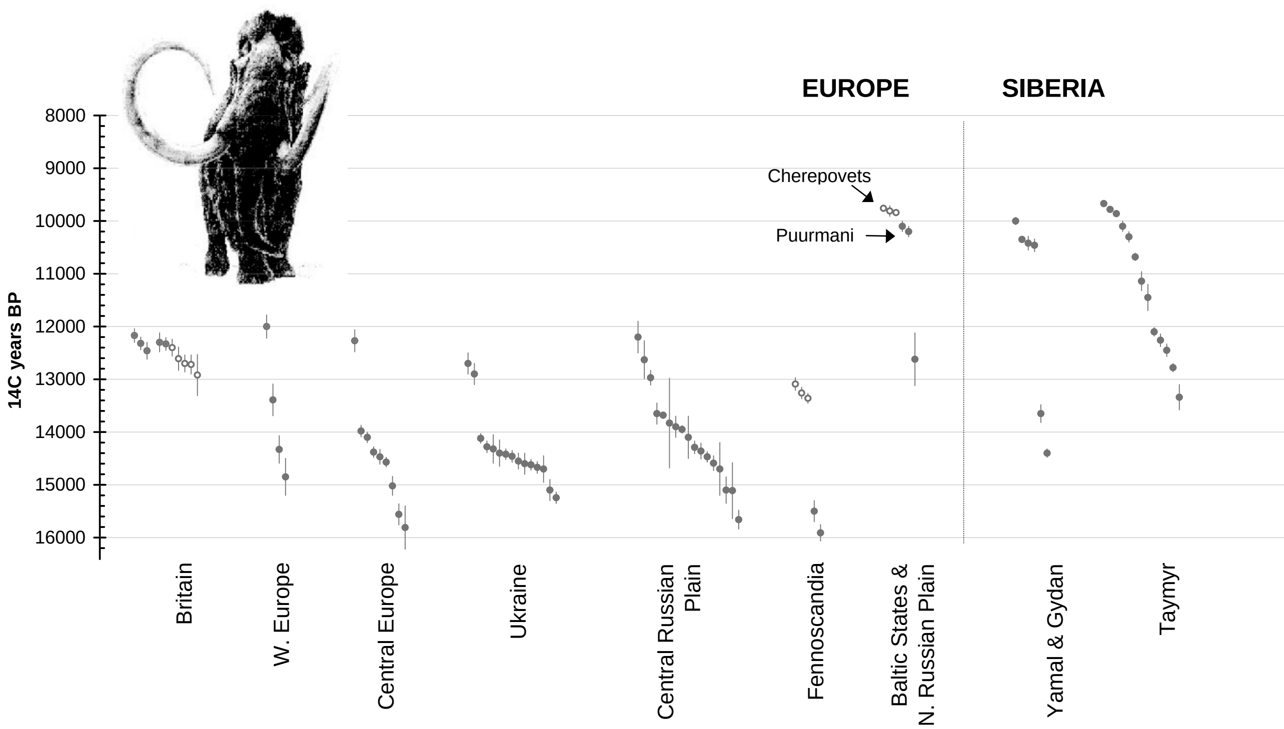

Fig. 2. Chart of radiocarbon dates <16 ka on woolly mammoth (*Mammuthus primigenius*) for Europe, Northwest and North-Central Siberia. Open symbols indicate multiple dates on remains of the same individual.

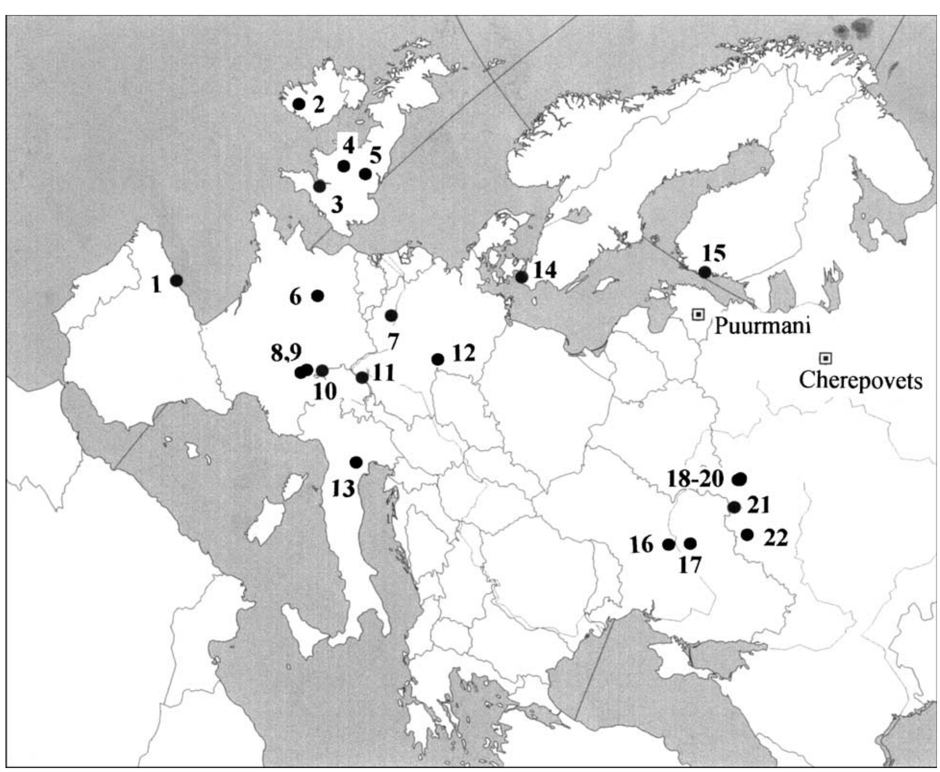

Fig. 3. European localities with ^{14}C dated mammoths mentioned in the text. The youngest records: Puurmani (ca 10 ka) and Cherepovets (ca 9.8 ka) are indicated. Other localities: 1, Cueto de la Mina; 2, Castlepook Cave; 3, Gough's Cave; 4, Condover; 5, Pin Hole and Robin Hood's Cave; 6, Etiolles; 7, Gönnersdorf; 10, Praz Rodet; 11, Kesslerloch; 12, Oelknitz; 13, Settepolesini; 14, Lockarp; 15, Herttoniemi; 16, Mezhirich; 17, Dobranichevka; 18–20, Eliseevichi, Timonovka, Yudinovo; 21, Sevsk; 22, Avdeevo.

(Bosinski, 1984). A series of radiocarbon dates on animal bone places the Magdalenian occupation of Andernach at approximately 13.2–12.9 ka BP, and of Gönnersdorf, slightly later at 12.9–12.7 ka BP (Street, in Hedges et al., 1998). However, dates obtained recently (LQME Project) on mammoth material from Gönnersdorf are more than 1.5 ka BP older than other dates from the site: 14,380 ± 100 BP (OxA-10239 on a femur); and 14,570 ± 90 BP (OxA-10199 on ivory). The discrepancy probably results from the collection of older mammoth material by Palaeolithic people at the site (M. Street, pers. comm. to A.J. Stuart, 2001). Similarly, ivory from the Magdalenian site of Oelknitz, Thüringia, Germany, gave a date of 14,100 ± 100 BP (OxA-10240, LQME project), while a series of dates on other faunal remains from the same site falls within the range ca 11.8–12.8 ka BP (Hedges et al., 1998). So the engravings suggest the presence of mammoths in Germany as late as ca 12.8 ka BP, but at present we have no direct dates to confirm this.

2.5. Fennoscandia

As discussed by Lõugas et al. (2002), mammoth finds are very rare in northern Fennoscandia, due largely to extensive ice cover in much of the Last Cold Stage. However, there are many more finds from the south of the region, especially from Denmark and south Sweden (Berglund et al., 1976; Aaris-Sørensen et al., 1990; Liljegren and Ekström, 1996).

There are very few mammoth dates from the Lateglacial. A tusk from Lockarp, Sweden, gave dates of 13,090 ± 120 BP (LU-796.2), 13,260 ± 110 BP (LU-865), and 13,360 ± 95 BP (LU-796) (Berglund et al., 1976; Liljegren and Ekström, 1996). This is the latest record of mammoth for the region. A tusk from Rosmos, Denmark, which yielded a date of 13,240 ± 70 BP (K-3697B), has been re-dated at 33,270 ± 350 BP (OxA-10189) (LQME Project). The date of 15,500 ± 200 BP (Hela-321) on a mammoth humerus from Herttoniemi, Helsinki (Ukkonen et al., 1999), is the youngest known from Finland. The bone was found in Holocene littoral sediments and may have been transported by an iceberg from its original locality (Ukkonen et al., 1999).

2.6. Central Russian Plain

There are five dates in the range 13–12 ka BP available for the central Russian Plain (Table 1). The three youngest are: Timonovka, Russia, 12,200 ± 300 BP (IGAN-282); Eliseevichi, Russia, 12,630 ± 360 BP (GIN-4137); and Dobranichevka, Ukraine, 12,700 ± 200 BP (OxA-700) (Sulerzhitsky, 1997).

A mammoth scapula from a human burial at the Kostienki 2 site was dated to 11,000 ± 200 BP (GIN-93) (Cherdyntsev et al., 1968). This result should be rejected as the date was run on bulk carbon, not extracted collagen (Sulerzhitsky, 1997).

2.7. Baltic states and north Russian Plain

As described by Lõugas et al. (2002), the two molars found at Puurmani, Estonia, have been dated to around the Pleistocene/Holocene boundary at 10,100 ± 100 (Hela-423) and 10,200 ± 200 (Hela-425). The two dated specimens, a left upper molar and a right upper molar, were found with other bones that have since been lost. It is possible that they are from a single individual, but this is not certain (Lõugas, pers. comm. to A.J. Stuart, January 2002). The evidence that the molars came from silt and clay deposited during the transition from the Pleistocene to the Holocene is very important in corroborating the radiocarbon dates.

A previous Holocene date on a mammoth tusk from a Mesolithic site at Kunda Lammasmägi, Estonia (9780 ± 260 BP, TA-12) (Liiva et al., 1966) has generally not been accepted as the date was run on bulk carbon, not extracted collagen (Sulerzhitsky, 1997). The same specimen has now been redated at > 38,000 BP (Hela-424) (Lõugas et al., 2002). Of particular interest are the early Holocene dates recently obtained by the Radiocarbon Laboratory of the Geological Institute, Moscow, on the mammoth skeleton from Zhidikhovo Peatbog, Cherepovets, north of Moscow. In 1943, a pit dug in the peat revealed mammoth bones at a depth of 2.0 m below the surface (Table 2).

The associated bones of one individual, including the mandible with molars, vertebrae, limb bones and ribs (Fig. 4), are preserved in the City of Cherepovets Museum. The dates (all on ribs) are: 9760 ± 40 BP (GIN-8885c); 9810 ± 100 BP (GIN-8676a); and 9840 ± 50 BP (GIN-8885b).

In addition there is a mammoth date of 12,620 ± 500 BP (GIN-8676) from the nearby Sheksna River mouth, Cherepovets.

Table 2
Stratigraphy of the Zhidikhovo Peatbog including occurrence of mammoth remains

0–0.2 m	Grasses and heather, peat
0.2–0.44 m	Peat with *Sphagnum*, tree stumps and bark (birch, alder)
0.44–0.7 m	Peat
0.7–1.15 m	Sapropel
1.15–2.00 m	Grey peat with many shells. Horizon of mammoth bones, radiocarbon dated to ca 9,760–9,840 BP (see text)

Information derived from Cherepovets Museum archives (O.V. Yashina, pers. comm. to A.J. Stuart, Dec. 2001).

Fig. 4. Mammoth remains (ca 9.8 ka) from Cherepovets, North Russian Plain. (A) Mandible with left molar; (B) tibia; (C) ribs; (D) thoracic vertebra; (E) sacrum.

3. Northern Asia

Woolly mammoths were present in northern Asia throughout most of the Last Cold Stage, as they were in Europe. They were still widespread ca 13–12 ka BP, but subsequently underwent a marked reduction in range.

3.1. Southwest Siberia

A single date significantly later than 12 ka BP has been obtained from a stratified sequence at Volchya Griva, southwest Siberia (Fig. 5) (Orlova et al., 2000, 2001). A composite sample of mammoth rib and limb bone from layer 3 at the top of this sequence gave a date of 11,090 ± 120 (SOAN-4921). However, a sample of mammoth tusk collected from apparently the same horizon 40 m away gave a different result of 17,800 ± 100 BP (GIN-11463), the oldest date from the site so far. These results suggest that the stratigraphy may be more complex than previously realised and that further radiocarbon determinations are needed.

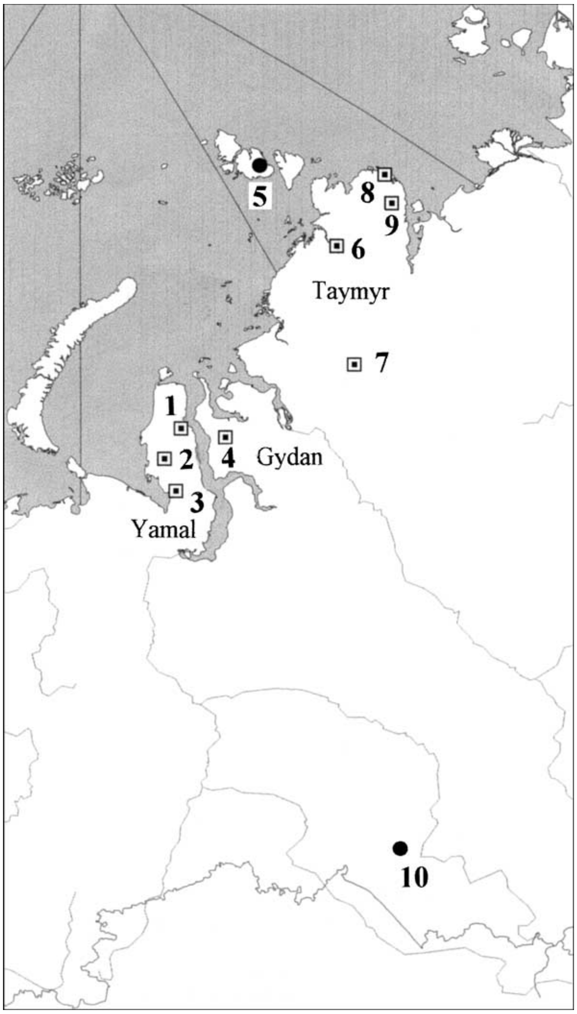

Fig. 5. Localities of latest mammoth dates <11 ka (shown by square symbols) in central Siberia. Yamal, Gydan and Taymyr Peninsulas indicated. 1, Sabbetayaha River; 2, Seyakha Mutnaya River; 3, Yuribei River (Yamal); 4, Yuribei (Gydan) carcass; 6, Nizhnaya Taymyra River; 7, Nganasanskaya River; 8, Andrei Polar Station; 9, Engelgard Lake. Also shown: 5, Servenaya Zemlya Islands (ca 11.5 ka); and 10, Volchya Griva (ca 11 ka).

3.2. Northern Siberia

A few regions of northern Siberia have produced dates later than 11 ka BP, including some dates from the Taymyr Peninsula that extend into the early Holocene (Sulerzhitsky, 1997; Kuzmin et al., 2000, 2001).

The youngest available date for the Yamal Peninsula (Fig. 5, Table 3) is 10,350 ± 50 (GIN-6386) from the Mutnaya Seyakha River (Sulerzhitsky, 1997; Sulerzhitsky and Romanenko, 1997; Kuzmin et al., 2001). Recently two further AMS dates have been published for the Yamal Peninsula: 10,460 ± 120 BP (AA-27377) on a tusk from the Lower Yuribei River, and 10,420 ± 130 BP (AA-27378) on a very large tusk from the Sabbettayaha River (Vasil'chuk et al., 1997).

The latest Gydan Peninsula dates (Fig. 5, Table 3) are from the famous Yuribei mammoth carcasses (Dubrovo, 1982). Two of them, however, 9,730 ± 100 BP (MGU-763) and 9,600 ± 300 BP (VSEGINGEO laboratory) are unreliable because of unsatisfactory pretreatment (Sulerzhitsky, 1997) and are rejected here. A third date of 10,000 ± 70 BP (LU-1153) was based on plant matter from the mammoth's stomach. We are pursuing direct dates on mammoth tissue as part of the LQME project.

The Taymyr Peninsula (north central Siberia) has produced the youngest dates for woolly mammoth in the whole of mainland northern Eurasia, with a series of dates from ca 13 ka BP into the early Holocene (Fig. 5, Table 2). At present, three Holocene dates are available: 9670 ± 60 BP (GIN-1828); 9780 ± 40 BP (GIN-8256); and 9860 ± 50 BP (GIN-1495) (Sulerzhitsky, 1997; Sulerzhitsky and Romanenko, 1997).

There is one date post-12 ka BP from the Servenaya Zemlya Islands (Arctic Ocean north of Taymyr) of 11,500 ± 60 BP (LU-610).

The available mammoth dates for other regions of northern Siberia (Laptev Sea region, Berelekh, Chukotka, Kamchatka, and several islands in the Arctic Ocean) are almost all older than 12 ka BP. The latest of 49 mammoth dates from the Laptev Sea area is 12,700 ± 170 BP (Schirrmeister et al., 2002). The majority of published dates from the well-known 'mammoth cemetery' at Berelekh range from ca 14–12 ka BP, and a new series of (unpublished) dates are all in the region of 12 ka BP or a little older (R.D. Guthrie, pers. comm. to A.M. Lister, December 2001). A single date, 10,370 ± 70 BP (SOAN-372) (Orlova, 1979), stands out as significantly younger.

3.3. Wrangel Island

In the early 1990s our perceptions of the chronology of mammoth survival and extinction were radically altered. A series of conventional and AMS radiocarbon dates on mammoth molars from Wrangel Island (Arctic Ocean, NE Siberia—Fig. 1) unequivocally demonstrated the survival of woolly mammoth many millennia into the Holocene. The youngest dates of 3,730 ± 40 BP (LU-2741), 3,920 ± 30 BP (GIN-6980), 4,010 ± 50 BP (LU-2798) and 4,040 ± 30 BP (LU-2808) (Vartanyan et al., 1993, 1995; Long et al., 1994; Kuzmin et al., 2001) show contemporaneity with ancient Egyptian civilisation. One recently obtained date of 3,685 ± 60 BP (Ua-13366) is even a little younger than these (Karhu et al., 1998). There is an almost unbroken series of available dates from ca 8 to after 4 ka BP, with a gap of about 4 ka to the next dates at ca 12 ka BP and older. Although Lozhkin et al. (2001) indicate a date of ca 12.5 ka BP for the isolation of Wrangel, comparison of local bathymetry with current information on sea-level change suggests a date closer to

Table 3
Latest mammoth dates (<13 ka) for northwest and north-central Siberia

Locality	Country	Material dated	^{14}C age, BP ($\pm 1\sigma$)	Lab i.d.
Yamal Penninsula				
Mutnaya Seyakha River	Russia	Molar	10,350±50	GIN-6386
Lower Yuribei River	Russia	Tusk	10,460±120	AA-27377
Sabbettayaha River	Russia	Tusk	10,420±130	AA-27378
Gydan Penninsula				
Yuribei (Yuribei carcase)	Russia	Plants from stomach	10,000±70	LU-1153
Taymyr Penninsula				
Nizhnaya Taymyra River, lower stream	Russia	Small tusk	9670±60	GIN-1828
Andrei Polar Station, SW Taymyr	Russia	Tusk	9780±40	GIN-8256
Nizhnaya Taymyra River, lower stream	Russia	Molar	9860±50	GIN-1495
Engelgard Lake	Russia	Molar	10,100±100	GIN-1489
Nizhnaya Taymyra River, lower stream	Russia	Radius	10,300±100	GIN-1828k
Nganasanskaya River	Russia	Limb bone	10,680±70	GIN-3768
Baikura-Neru Bay, Taymyr Lake	Russia	Mandible	11,140±180	GIN-3067
Mamont River	Russia		11,450±250	T-297
Taymyr Lake	Russia	Limb bone	12,100±80	GIN-1783
Severnaya River	Russia	Scapula	12,260±120	GIN-2943r
Severnaya River	Russia	Limb bone	12,450±120	GIN-3242
Bikada River	Russia	Limb bone	12,780±80	GIN-2677
Severnaya Zemlya Islands				
Islands of the October Revolution	Russia		11,500±610	LU-610
Southwest Siberia				
Volchya Griva	Russia	Ribs and limb bone	11,090±120	SOAN-4921

10 ka BP (J.A. Karhu, pers. comm. to A.M. Lister, December 2001).

4. Discussion

In an important contribution to understanding the process of mammoth extinction, Sher (1997) postulated a 'retreat to the north' in which the distribution of mammoths in Eurasia progressively contracted, so that after ca 12 ka BP they were restricted to the far north of Siberia (Yamal, Gydan and Taymyr Peninsulas) before finally going extinct. In the light of new data, this model still provides a valid framework, but the process of mammoth extinction was evidently more complex than previously thought.

The single late date for Volchya Griva, if confirmed, would suggest the possibility that a population of mammoths survived in southwest Siberia a thousand years after they had otherwise apparently become confined to the far north. The exciting new dates from Cherepovets (Russia) and Puurmani (Estonia) indicate the presence of mammoth in the north Russian Plain, close to the margin of the Fennoscandian ice sheet, at ca 10–9.8 ka BP. At first sight, these dates suggest persistence of mammoth in the region two millennia later than its disappearance from all of the rest of Europe, presumably in isolation from the contemporary populations of north central Siberia. However, the lack of records both from the north Russian Plain and from the rest of Europe for the period ca 12–10 ka BP (Fig. 2) suggests an alternative possibility: mammoths may have been genuinely absent from all of Europe during this time, then re-colonised parts of the Russian Plain from the northeast. In the Taymyr Peninsula, unlike Europe, there is continuity of dates through the entire period, and mammoths were still present there and in the Yamal and Gydan peninsulas ca 10.5–10 ka BP—perhaps mammoths re-entered Europe from northern Siberia ca 10 ka BP by migrating around the southern margin of the shrinking Fennoscandian ice sheet?

As new data accumulate, a picture may emerge of complex fragmentation of mammoth range prior to extinction. The late date from Volchya Griva could represent one example of an isolated terminal population. However, much more work is needed, not only in attempting to confirm the Volchya Griva date, but also to identify other possible late-surviving populations elsewhere in Asia and Europe. Based on modern studies, fragmentation of range, with sequential extirpation of local populations, is a very likely prelude to global extinction.

The tentative nature of these suggestions, based on the limited available data, underlines some of the general points made earlier about the interpretation of direct radiocarbon dates as evidence for the survival of mammoth, or other extinct megafauna, to a particular time. The potential unreliability of 'lone' dates, together with the inevitable 'negative evidence' that a species was not present after a given time or in a given area, mean that only when we have many dates from a given region can we with any confidence estimate the time of latest survival of a species there. Of course, in a situation where there are few dated records, further work is likely to extend the range of dates to include younger records.

It is clear that the process of mammoth extinction was complex in time and space. Despite the rather large number of radiocarbon dates now available for Eurasian woolly mammoth, we still require much more data to be able to trace in detail its pattern of range contraction, and the extirpation of local populations which cumulatively resulted in total extinction. Persuasive theoretical models for mammoth extinction continue to be produced, invoking either climatic change, human hunting, or a combination of the two (Haynes and Eiselt, 1999; Alroy, 2001; Guthrie, 2001). However, only with further hard data can we hope to resolve satisfactorily the controversial issue of the cause(s) of the disappearance of not only woolly mammoth, but also the other extinct megafauna.

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