

## Mammoth calf from Bolshoi Lyakhovskii Island (New Siberian Islands, Arctic Siberia)

Evgeny N. Mashchenko, Alexei N. Tikhonov & Ross D.E. MacPhee

**ABSTRACT.** For the first time, the skull of a mammoth calf of approximately two years is described. This skull comes from Bolshoi Lyakhovskii Island in the New Siberian group, which is the island closest to the mainland. The radiocarbon date of this find,  $24,700 \pm 170$  yrbp (not corrected  $^{13}\text{C}$ ), places the specimen just before the last glacial maximum in Siberia and suggests the absence of oceanic glaciation in this area. The finite date record for mammoths in the New Siberian Islands is compared to that for the immediately adjacent mainland (lower Lena River/Lena Delta region).

**KEY WORDS:** mammoth calf, Bolshoi Lyakhovskii Island, morphology of skull, radiocarbon dates.

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## Детеныш мамонта с острова Большой Ляховский (Новосибирские острова, Арктическая Сибирь)

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**РЕЗЮМЕ.** Описывается череп двухлетнего детеныша мамонта. Это первая находка полного черепа детеныша мамонта такого возраста. Череп происходит с ближайшего к матерiku Большого Ляховского острова из архипелага Новосибирских островов. Радиоуглеродная датировка этой находки,  $24,700 \pm 170$  лет назад, соответствует началу последнего оледенения Сибири, и еще раз подтверждает отсутствие океанических ледников в этом районе. Набор дат с Большого Ляховского обсуждается в сравнении с датами по мамонтам из прилегающих районов (нижнее течение и дельта реки Лены).

**КЛЮЧЕВЫЕ СЛОВА:** детеныш мамонта, Большой Ляховский остров, морфология черепа, радиоуглеродные даты.

### Introduction

In the summer of 2002, a brigade of tusk collectors working for Inter-Mamont (a Moscow-based commercial enterprise) visited the mouth of the Bolshoi Eterikan River on the eastern coast of Bolshoi Lyakhovskii Island, New Siberian Islands, (Bulunsk District, Republic of Yakutia, Russian Federation; Fig. 1). There they collected, along with dozens of tusks, the nearly complete skull and mandible of a mammoth calf. Now this skull is in the collection of the Museum of mammoth in Yakutsk (collection number MMY 7916).

The Bolshoi Eterikan River and its environs are famous for the numerous remains of Pleistocene mammals that have been found there over the years, including mammoth remains with preserved soft tissues. For example, the Lyakhovskii Mammoth found in 1911 (now in the Museum of Natural History in Paris) comes from this area (Volossovich, 1914; Tikhonov, 1996), as do the skin and legs of three different mammoths collected in 1994–1995 (Arai *et al.*, 1996).

It is therefore not much of a surprise that this area has yielded still another rare find. The chief significance of the calf described in this report is its young age (approximately two years old, according to dental comparisons with extant elephants), and the fact that the skull and jaw (which retain a few fragments of soft tissues) represent a single individual. No associated, well-preserved remains of so young an animal have been published heretofore. We thus take this opportunity to revisit questions concerning early stages of tooth ontogeny and suture fusion in *Mammuthus primigenius* Blumenbach, 1799, as well as to examine some population features of high arctic mammoths in the Late Pleistocene.

Nomenclature of bones and other anatomical features follows Eales (1926) and Zаленский (1903).

**Institute abbreviations.** GDM — State Darwin's Museum, Moscow, Russia; MMY — Museum of mammoth, Yakutsk, Russia; PIN — Paleontological Institute, Russian Academy of Sciences, Moscow, Russia; ZIN — Zoological Institute, Russian Academy of Sciences, Saint-Petersburg, Russia.



Figure 1. Map of Eastern Siberia with position of the mammoth calf (MMY 7916) locality on the Bolshoi Eterikan River, Bolshoi Lyakhovskii Island.

## Description

### Skull

The skull of the mammoth calf is incomplete (Figs. 2, 3): the neurocranium is about two-thirds complete, and the bony margins of the nasal aperture are missing (i.e., nasal bones and nasal processes of the frontal bone). Also missing are the occipital condyles and the supraoccipitale and exoccipitale, which do not fuse until the age of 2–2.5 years in *M. primigenius* judging from conditions in other mammoth calves (Kuzmina & Maschenko, 1999). The malar process as such is not preserved, although on the right side the posterior part of the malar process (pars frontalis squamosi) is still present. The internal and external acoustic meatuses and related parts of the petrosal are also not represented (Tab. 1).

The nasal bones were evidently completely ossified, judging by the portions still in contact with the frontal bones. Maximum width of the remaining part of

each nasal bone, ~40 mm; anteroposterior length, 22 mm. The maximum anteroposterior distance along the metopic suture separating the frontals is similarly short, only 41 mm. Both the nasals and the frontal become narrow laterally. The parietal bones (parietales) are quite incomplete inferiorly.

All sutures characteristically seen in newborn mammoth calves (Maschenko, 2002) are distinct and open on this skull: sagittal suture (sutura sagittalis), suture between the nasal and frontal bones (sutura nasofrontalis), and sutures between the lower lateral edges of the parietals and the frontal process of the squamosal (sutura squamo-parietalis). The suture separating the premaxillae (sutura intermaxillaris) remains open in adult stages of both mammoths and extant elephants. Within these sutures, sutural borders tend to be straight or planar (not jagged), and contact zones between bones are two to three times thicker than other parts of the bones. All basicranial synchondroses are distinct, with no cartilaginous remnants preserved. Probably by this growth stage the synchondroses were mostly ossified in any case.

Table 1. Measurements of skull of the mammoth calf from the Bolshoi Eterikan River, Bolshoi Lyakhovskii Island (MMY 7916).

Measurement	Value, mm	Notes
1. Length of skull, condylobasal	446	Condyles broken.
2. Width of skull, maximum	320	Malar arches broken; posterior end of malar process (of the squamosal) preserved on right side only.
3. Width of premaxillary bones, at level of infraorbital foramina	126	
4. Width of midfacial region (premaxillae), at level of nasal aperture	~160	
5. Diameter of infraorbital foramina	26	An average of both sides.
6. Width of skull, at level of orbital processes	~265	Approximate
7. Height of skull	~365	Approximate
8. Width of constriction behind orbits	180	
9. Width of premaxillae, at level of tusk alveolar margins	~122	
10. Width of nasal aperture, at base of frontal processes of maxilla	~167	Approximate.
11. Length of malar arch	210	Reconstructed.
12. Length of premaxillae, from inferior edge of tusk alveolus to base of nasal aperture	219	Reconstructed.
13. Depth of tusk alveolus	156	An average of both sides.

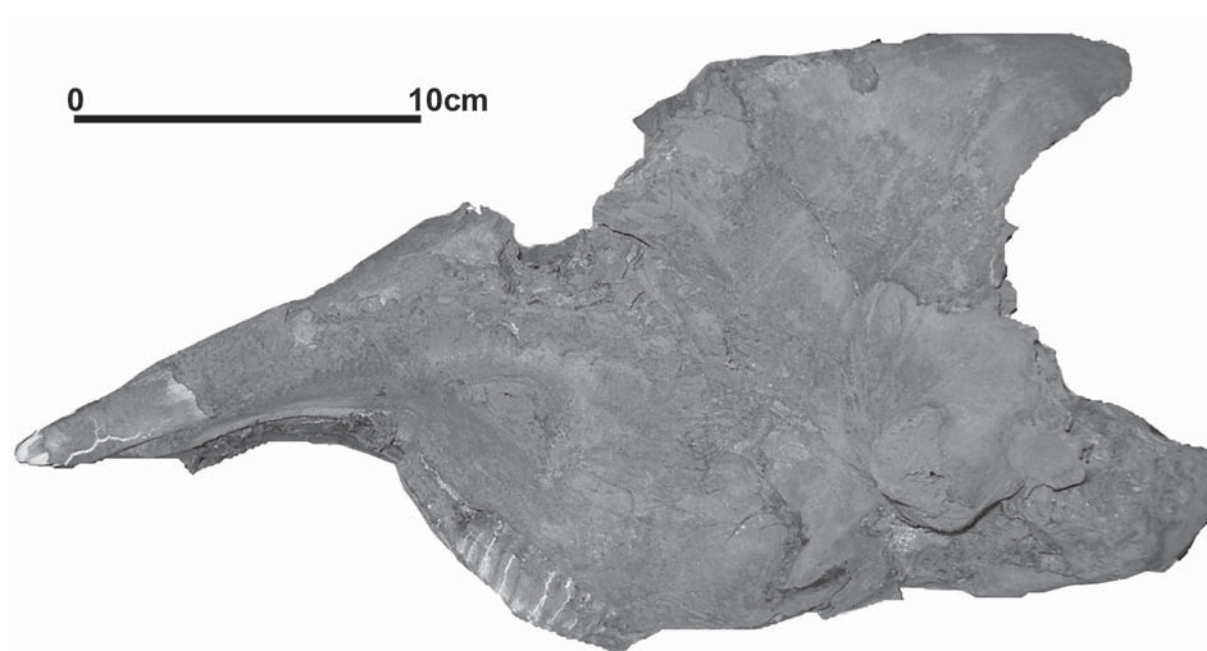


Figure 2. Skull of the mammoth calf from the Bolshoi Eterikan River, Bolshoi Lyakhovskii Island (MMY 7916) in anterior view. Scale bar is 10 cm.

The nasal cavity is filled with cartilage-like material and other soft tissues (Fig. 3). Soft tissues are also represented on surfaces of the premaxillae, hard palate, gums, distal part of DP4, and basicranium. Inside the cerebral cavity fragments of dura mater and pia mater

can be identified, and basicranial apertures are filled with decayed soft tissues.

The permanent tusks (I) are just protruding out from their alveoli and appear to be well preserved (Fig. 4). The lower 2/3 of each alveolus is oval in cross section,



Figure 3. Skull of the mammoth calf from the Bolshoi Eterikan River, Bolshoi Lyakhovskii Island (MMY 7916) in left lateral view. Scale bar is 10 cm.

while the remaining 1/3 is round. As in adults, the alveolus does not perforate the nasal cavity, and is instead separated from it by a space of 4.5 cm. This space is pneumatized, as are the lateral and superior surfaces of the premaxillae and maxillae.

Damage has exposed a series of air chambers pneumatizing the frontal and parietal bones (Fig. 3). The chambers are rather large, 5–20 mm wide in the frontal bones, narrower in the nasal bones. In the preserved superior and lateral parts of the parietals, large air chambers are distributed in rows. Air chambers on the lateral surface of the parietals are somewhat smaller than those on the superior surface. Toward the basicranium the chambers become larger.

### Tusks

The permanent tusks (I) of the Eterikan mammoth calf are in natural position inside their alveoli (Fig. 4), with tips extending ~24 mm beyond alveolar margins. The surface layer of cement coats approximately 2/3 of the tusk's length. It does not reach the tip of the tusk, the last 10 mm or so being uncovered. At this ontogenetic stage each tusk consists of a dentine core comprised of 3 circumferential layers, visible at the tip of the tusk. Except for the area around the alveolus, a thick, multi-



Figure 4. Tusks of the mammoth calf from the Bolshoi Eterikan River, Bolshoi Lyakhovskii Island (MMY 7916). Scale bar is 10 cm.

layered deposit of cement covers all surfaces. The tip is strongly compressed in a vertical plane. The tusks of a mammoth calf in the collection of the Paleontological Institute (No 4531-24) have the same size and structure (Tab. 2) (Maschenko, 2001). Nor does this layer cover that part of the tusk which forms the pulp cavity; instead, the proximal or pulp end of the tusk bears externally a series of parallel ridges and valleys that conform to mirror-image sculpturing on the internal aspect of the bony alveolus, as in adult individuals. The edge of the surface layer on the tip section is weakly sculptured and rough. The complex of cement and mineralized dentine strata provide the structure for anchoring the tusk inside its alveolus. In later stages, the protective covering of cement continues to grow and mineralize in concert with tusk growth (Lucert, 1996).

### Cheek teeth

The approximate length of the chewing surface on the upper row (DP3–DP4) is 95 mm, 80 mm on the lower row. Teeth are completely formed and covered with cement.

On the upper DP3, all plates are worn (five plates remain on the upper DP3); four plates remain on the lower dp3. On the upper DP4, five mesial plates are worn, while on the lower dp4 wear affects six mesial plates (Fig. 5). Individual age as determined from tooth formation and degree of wear is one year four months to one year eight months. In terms of comparative tooth



Table 2. Measurements (mm) of permanent tusks (I) of mammoth, *Mammuthus primigenius* and Indian elephant, *Elephas maximus* calves during first three years of life.

Specimen	Individual age and tooth generation	Length of the tusk	Maximal (vertical/horizontal) diameters	Depth of pulp cavity	Transverse diameters (vertical/horizontal) of dentine spike	Width/length of depression on the internal surface of the tusk
<i>M. primigenius</i>						
PIN 4353-1008	1.5–2 years	–	18/24	20(?)	12/6	5/15
PIN 4353-1000	1.5–2 years	–	17/23	–	14/6	4/23
PIN 4531-25	1.5–2 years (?)	215	25/28	70	13/6	5/46
PIN 4353-933	Around 1 year; seven worn plates left DP3	64	11/17	–	–	7/(?)
PIN 4531-24	Around 2 years	160	24/31	–	14/7	No depression
MMY 7916	1 year and 4 to 8 months; five plates left on DP3	168	19/15	47	12/6	Very shallow
Skull from Bykovskii Peninsula *	1 year and 5 to 9 months; five plates left on DP3	101	29/14	58	11/5.5	–
<i>E. maximus</i>						
GDM 421-1	Around 1 year; Six mesial plates worn on DP3	73	21/25	50	–	–

\* data of A.V. Sher.



Figure 5. Upper teeth of the mammoth calf from the Bolshoi Eterikan River, Bolshoi Lyakhovskii Island (MMY 7916). Scale bar is 5 cm.

ontogeny, the age of the mammoth calf would correspond to 1–1.5 years in Asian elephants, *Elephas maximus* Linnaeus, 1758 (Roth & Shoshani, 1988). In African elephants, *Loxodonta africana* (Blumenbach, 1797) with a similar degree of wear to DP3–DP4, the corresponding age is 2.5–3 years (Laws, 1966; Sikes, 1966; Jachman, 1988).

The upper and lower third milk premolars are strongly worn: four-seven plates still remain, the two mesial-most lacking closed loops. Their mesial parts are worn down to the base of the crown (Tab. 3). Six mesial plates are worn on the fourth milk premolars. In the damaged crypt of the DP4 it is possible to count eight mineralized plates. Plates are oriented vertically to the chewing surface of the functioning teeth (Fig. 5). In the

Table 3. Measurements of DP3 and dp3 of the mammoth calf from the Bolshoi Eterikan River, Bolshoi Lyakhovskii Island (MMY 7916).

Measurement	DP3	dp3
Length/Width of crown, mm	48.0/35.0	38.0/31.0
Number of plates	7*	4*
Length/Width of plate, mm	5.3/32.5	4.5/28.0(?)
Width of inter-plate intervals, mm	1.5	~4.0**
Enamel thickness, mm	0.7	0.6
Number of worn plates/Length of occlusal surface, mm	7/48.0	4/38.0

\* All worn.

\*\* Plates are worn down to the base of the crown.

Table 4. Measurements of DP3 and dp3 of the mammoth, *Mammuthus primigenius* calves of the Central Russia and Eastern Siberia (data from Urbanas, 1980; Sher & Garutt, 1985a).

Measurement	Central Russia		Eastern Siberia	
	DP3	dp3	DP3	dp3
Length of the crown, mm	54.0–67.0	43.5–66.0	53.0–56.5	28.5–37.0
Width of the crown, mm	32.0–43.0	28.5–37.0	28.0–40.0	26.0–36.0
Number of plates	7–8	7–9	7–9	7–10
Length of plate, mm	4.0–6.0	4.0–5.5	6.6–7.9	7.2–7.6
Enamel thickness, mm	0.5–0.8	0.5–1.0	0.7–1.3	0.7–1.0

Table 5. Measurements (in mm) of DP4 and dp4 of the mammoth calf from the Bolshoi Eterikan River, Bolshoi Lyakhovskii Island (MMY 7916).

Measurement	DP4	dp4
Length/Width of crown, mm	86.0/41.0	82.0/35.0
Number of plates	14(15?)	14(?)
Length/Width of plate, mm	5.0/34.0	4.7/29.0
Width of inter-plate intervals, mm	5.0	5.5
Number of plates in 10 cm	16–17	17–18
Enamel thickness, mm	0.8	0.7
Number of worn plates/Length of occlusal surface, mm	5/47.0	6/42.0

broken crypt of lower m1 it is possible to count 11 mineralized plates, but these do not form a common crown base and lack a cement covering. Intercalated plates are not present. The mandibular teeth show noticeably more wear than do the maxillary teeth, a difference which is particularly visible at the dp3 locus.

**Upper teeth, DP3 and DP4** (Fig. 5). The DP3 is worn practically to the base of the crown. Six plates remain on the left side and seven plates on the right. The linear size of DP3 and key parameters of crown structure agree with data on this locus for teeth collected in eastern Siberia (Vereshchagin, 1977; Sher & Garutt, 1985a; Tab. 4). No anomalies of crown structure or delays in replacement are evident in the mammoth calf.

The distal parts of the crowns of the upper DP4s are covered with soft tissues, making it impossible to determine whether the plate count for these teeth is 14 or 15.

The five mesialmost plates are worn; two among these are also deformed, due to the impaction of the mesial edge of the DP4 crown on the distal end of DP3. The degree of abrasion and other crown parameters do not differ from those found in late representatives of *M. primigenius* from eastern Siberia (Tab. 6).

**Lower teeth, dp3 and dp4** (Fig. 6). In the dp3s, the forward root and the three plates lying directly above it have been destroyed by abrasion, leaving 3–3.5 plates in the distal part of the tooth. It is impossible to carry out exact crown measurements because of the amount of wear.

The dp4 most likely consists of 14 plates; 13 plates are visible and there is probably 1 still in the alveolus. Wear has removed six plates mesially. In crown size and enamel thickness, these teeth agree with their counterparts from eastern Siberia.

In comparison with calves of modern elephants, mammoth calves wore their teeth down faster (Sher & Garutt, 1985b). At the same time, linear measurements of the skull and mandible are greater in modern elephant calves than in mammoth calves of roughly the same age (Maschenko, 2002). The reason for these differences probably lies with the ecology of the woolly mammoth, which lived in cold climatic conditions and experienced a long winter season. During the winter the mammoth calves would have had to learn to feed by foraging much earlier than do modern elephant calves. Also, the transition from one kind of feeding to another would have occurred over a shorter interval. Most likely, the calf would have had to experience a complete change-over in food supply (milk/mixed feeding/dry vegetation found under the snow) within 1–2 months of the exhaustion of green forage resources.

Table 6. Measurements of DP4 and dp4 of the mammoth, *Mammuthus primigenius* calves of the Central Russia and Eastern Siberia (data from Urbanas, 1980; Sher & Garutt, 1985a).

Measurement	Central Russia		Eastern Siberia	
	DP4	dp4	DP4	dp4
Length of the crown, mm	104.0–110.0	94.0–128.0	86.0	82.0
Width of the crown, mm	48.0–56.0	45.0–58.0	41.0–62.0	35.0–56.0
Number of plates	11–13	11–12	10–14	11–14
Length of plate, mm	4.5–6.5	5–6	–	–
Enamel thickness, mm	0.95	0.95	0.70	0.70



Figure 6. Lower teeth of the mammoth calf from the Bolshoi Eterikan River, Bolshoi Lyakhovskii Island (MMY 7916). Scale bar is 10 cm.

### Mandible

The lower jaw displays some damage to the ascending rami (ramus mandibulae) (Figs. 7 and 8). The horizontal ramus and symphysis are intact on each side. The ascending rami are broken off in their middle portions. The back edge of both ascending rami is also broken, thus exposing five-six plates of the lower m1, not yet covered with cement. Plates of this tooth are inclined medially (Fig. 7).

The mental (symphyseal) suture between the right and left horizontal rami, which is present in newborn mammoths, is absent in this specimen. On the left side

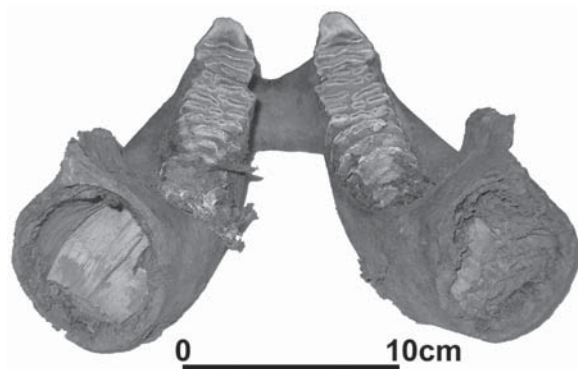


Figure 7. Mandible of the mammoth calf from the Bolshoi Eterikan River, Bolshoi Lyakhovskii Island (MMY 7916) in posterior view. Scale bar is 10 cm.

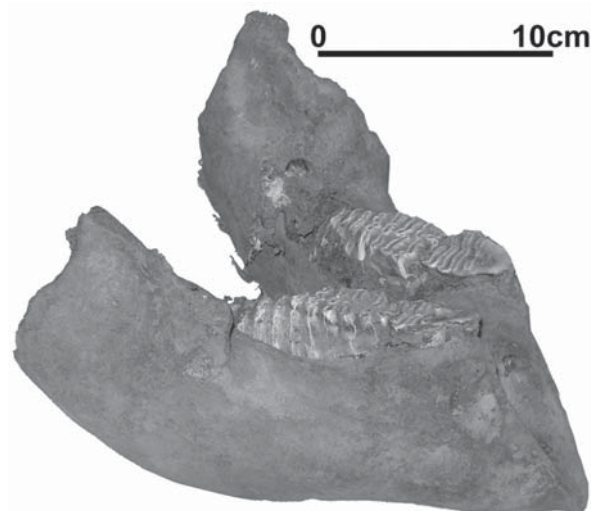


Figure 8. Mandible of the mammoth calf from the Bolshoi Eterikan River, Bolshoi Lyakhovskii Island (MMY 7916) in lateral view. Scale bar is 10 cm.

there are two mental apertures (foramina mentalis). The larger (4.5 x 3.2 mm, oval in section) of the two is located closer to the symphysis; the smaller (1.5 x 1.5 mm, round in section) is not only located further away from the symphysis, but is also higher on the ramal body.

Clumps of what appears to be dried-up vasculature project from these chin foramina. The more proximal aperture passes through the interalveolar crest (crista interalveolaris), and on an internal surface forms a pit into which the mandibular canal (canalis mandibularis) also opens. Decayed leashes of tissue (vessels or nerves?) run from the mandibular canal into this pit.

A dehiscence in the left horizontal ramus—actually a continuation of the distal end of the dp4 alveolus—is closed by a knot of soft tissues (?pterygoid musculature, ?ligaments).

The chin spout is not completely formed yet and projects insignificantly beyond the line of the interalveolar crest and symphysis (Figs. 7, 8). Proportions of the symphysis differ a little from those of adult mammoths (Tab. 7).

### Significance of Radiocarbon Record for New Siberian Islands

The New Siberian Islands are one of the richest places in northern Eurasia for recovering mammoths with soft tissues. In effect, these islands act as a “natural freezer” for mammoth carcasses and remains of other Pleistocene mammals. A small piece of bone from the jaw of the baby mammoth was submitted for radiocarbon dating. Results are present in Tab. 8.

Although numerous fossil finds from these islands have been radiocarbon dated in the past, there is no published summary of results (Lozhkin, 1977). To help

Table 7. Measurements of mandible in mammoth, *Mammuthus primigenius* calves.

Measurement, mm	Specimen/Age in months			
	MMY 7916/ 18–22	ZIN 31771/ 11–12	PIN 778-1/ 14–18	PIN 4531-12/ 14–18
Width, maximal	240.0	215.0	250.0	280.0
Length/Height of corpus mandibulae	~280.0/–	310.0/–	290.0(?)–	275.0/152.0
Height of corpus mandibulae near the distal edge of the functioning tooth alveolus	72.0	64.0	68.0	64.0
Length of symphysis	53.0	60.0	62.0	48.0
Length of crista interalveolaris	105.0	108.0	115.0	92.0
Width of ramus mandibulae, maximal	106.0(?)	128.0 (?)	–	125.0
Length of corpus mandibulae between the mesial edge of alveolus and the base of ramus mandibulae	110.0	–	–	–
Distance between right and left functional teeth, mesially/distally	29.0/40.0	38.0/45.0	47.0/52.0	32.0/39.0

Table 8. Radiocarbon dating of the mammoth calf from the Bolshoi Eterikan River, Bolshoi Lyakhovskii Island (Museum of mammoth in Yakutsk, N 7916).

Lab Code	Sample	Provenance Age ( $^{14}\text{C}$ yrbp, not $\delta^{13}\text{C}$ corrected)	Corrected age	$^{13}\text{C}/^{12}\text{C}$ ratio
B-191228	jaw fragment	24,700±170	24,740±170	–22.7

place this new find and the history of *M. primigenius* on the New Siberian Islands in a wider perspective, in Fig. 9 we compare the finite date record of these islands to that of the lower Lena River/Lena Delta region, which has recently been considerably augmented by Sher *et al.* (2005). Because some records in the database are of uncertain or inexact provenience, we restricted the New Siberian Islands sample to specimens from named localities in the archipelago ( $X=9,773.8$  yrbp,  $sd=9130.1$ ,  $n=45$ ). The Lena sample is limited to specimens from localities on the Bykovskii Peninsula, Lena delta, and lower course of the Lena River ( $X=26,582$  yrbp,  $sd=8922.0$ ,  $n=49$ ). The position of the date on the Eterikan mammoth calf is indicated by the star on the New Siberian Islands plot.

The cumulative frequency plots in Fig. 9 are quite similar, and differences in the two data sets are not significant at the 0.05 level (unpaired *t* test,  $p=0.09$ ; Mann-Whitney  $U=873.5$ ,  $p=0.08$ ). However, the dates themselves are not evenly distributed across the entire timeline: in each plot there are periods of several thousand years for which there are no recorded dates, and periods in which many dates fall within narrow time spans. Precision and accuracy of  $^{14}\text{C}$  dates older than 35,000 yrbp are problematic (Geyh & Schleicher, 1990): in the present case, the major gaps in distribution earlier than 40,000 yrbp may or may not be real (cf. MacPhee *et al.*, 2002).

We shall concentrate instead on the gaps marked A and B in Fig. 9. With regard to gap A, a pronounced break occurs in both of the local records for *M. primigenius* during the interval ~15,000–18,000 yrbp. Empirically, the gap for the New Siberian Islands runs from 18,500±120 yrbp (GIN-8229, Faddeevsky Island)

to 15,420±110 yrbp (LU-1671, Kotelny Island). For the Lena delta region, the gap is 17,780±80 yrbp (GIN-5402, lower Lena River) to 14,730±60 yrbp (GIN-9907, Bykovskii Peninsula). The gap remains noticeable when the samples are combined, as in the histogram of all dates on the right-hand side of Fig. 9. Gap A is similar but not identical to the 18,000–16,500 yrbp (21,000–19,500 CAL yrbp) gap identified in the Taimyr mammoth record by MacPhee *et al.* (2002). The interval is shorter because all finite dates are considered to be of equal validity, and in the Taimyr record there is a single date of 16,330±100 yrbp (GIN-3130) which obviously oversteps the ~15,000–18,000 range. However, since the mainland Taimyr finite  $^{14}\text{C}$  record is much larger ( $X=28,995.4$  yrbp,  $sd=11,368.2$ ,  $n=91$ ) than the other two considered here, and since gaps can only be detected and delimited empirically in any case, slight differences in gap size are expected. Otherwise, the three areas (New Siberian Islands, lower Lena River, and Taimyr) are highly comparable, with few or no dates for mammoths or any other megafauna during gap A as defined here. MacPhee *et al.* (2002: 1036) concluded that although it “is intriguing that Taimyr might have been less frequented by megafauna during the coldest part of the Sartan (=late Weichselian), the radiocarbon evidence for this is far from conclusive.” Given the trend of the New Siberian Islands and the new Lena records, it seems increasingly likely that megafauna really were rare at high latitude during the interval represented by gap A. Rarity may have been a direct effect of environmental conditions prevailing along the Arctic periphery of Asia in the wake of the Last Glacial Maximum. At the height of the Last Glacial Maximum this entire zone must have been a very



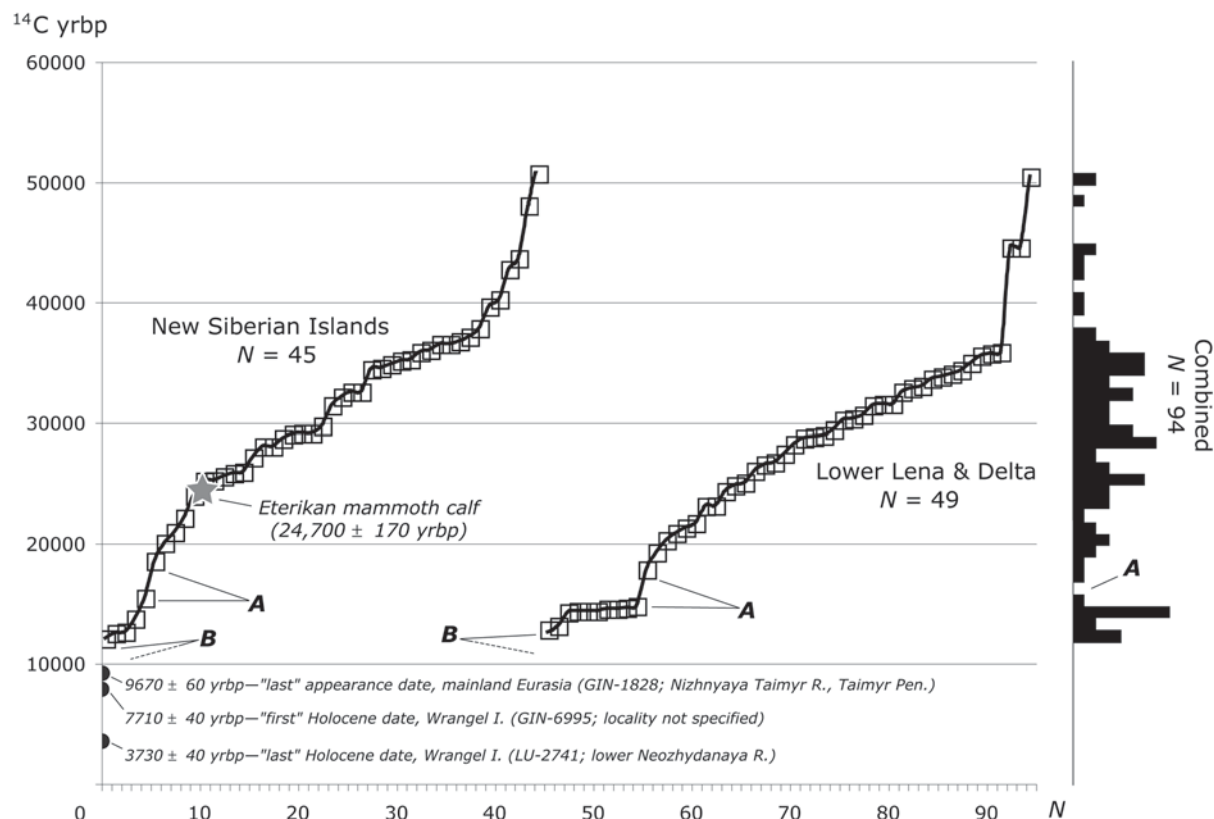


Figure 9. Comparison of selected finite  $^{14}\text{C}$  records for *Mammuthus primigenius* in northeastern Asia.

cold Arctic desert. Although megafauna were evidently present, their numbers must have been extremely small. How quickly this zone might have returned to steppe-tundra conditions is uncertain.

Gap B is quite different: because of extinction, by definition the gap extends to the present. For the New Siberian Islands, the “last” appearance date for mammoths is  $12,030 \pm 60$  yrBP (GIN-10713, Bolshoi Lyakhovskii Island); for the Lena delta region, the equivalent date is  $12,770 \pm 170$  yrBP (GIN-10267, Bykovskii Peninsula). These dates do not overlap even at three sigmas, but in light of the essentially parallel dating trends in the two graphs over a >30,000 year period, it seems reasonable to conclude that the lack of overlap in terminal dates is artifactual (sampling error). These terminal dates, however, are much older than the “last” appearance date for *M. primigenius* on the mainland. The youngest generally-accepted date for mainland mammoth is  $9670 \pm 60$  yrBP, for a specimen from Taimyr (Fig. 9). If all these terminal dates actually mark the disappearance of mammoths from these regions, why did mammoth tenure end some 3000 years earlier in the Lena / New Siberian Islands sector than on the Taimyr Peninsula? Direct consequences of climate change are unlikely to be the answer, whether this is viewed in terms of productivity response (Sher *et al.*, 2005) or according to a more general measure like reduction in potential range. In this latter regard it is worth noting that the amount of subaerial land at high latitude in the

northern hemisphere diminished as Sea level rebounded during early postglacial time, but the reduction was not particularly rapid. According to approximate contour reconstructions in the Paleoenvironmental Atlas of Beringia (<http://www.ncdc.noaa.gov/paleo/parcs/atlas/beringia/images/movies/lbridge.mov>), the cumulative effect of marine transgression on the total land area of the northernmost parts of the Eurasian Arctic plain was not marked until after 10,000 CAL bp ( $\sim 11,500$  yrBP). The land area incorporating the New Siberian Islands was still connected with the mainland as late as 8000 CAL yr ( $\sim 8900$  yrBP), and the modern islands did not reach their current size until 4,000–5,000 CAL bp ( $\sim 4500$ – $5700$  yrBP). Evidently, mammoth disappearance preceded true insularity in the New Siberian Islands by several thousand years. By contrast, even though Wrangel was already a true island by 10,000 CAL bp ( $\sim 11,500$  yrBP), as a landform it followed much the same trajectory of diminution as the New Siberian Islands. However, according to the available  $^{14}\text{C}$  record, mammoths survived on Wrangel for at least another 8,000 years. In sum, if the knock-on effects of subdivision and contraction of the Arctic plain by marine transgression were the primary control on postglacial survival of mammoths, the  $^{14}\text{C}$  records for the New Siberian Islands and Wrangel should be much more similar. This conclusion is reinforced by the recent discovery that mammoths survived well into the Holocene on islands in the Bering Sea (Guthrie, 2004).

We are aware that the human record on the Arctic periphery of northeastern Eurasia now goes back at least 27,000 yrbp (Pitul'ko *et al.*, 2004). As significant as that discovery is, however, in the absence of numerous mammoth kill sites we are not convinced that small numbers of humans could have been primarily responsible for the loss of *M. primigenius* either on the mainland or the Arctic islands north of the Asian mainland. Indeed, to turn the argument around, if humans were present in the high Arctic of Asia as early as 27,000 yrbp, why did it take an additional 18,000 years before the last of the Taimyr stragglers succumbed? Truly, the cause of the late Quaternary megafaunal extinctions remains an intriguing mystery, one that cannot be solved by reference to simplistic explanations.

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