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## Possible evidence of mammoth hunting during the Epigravettian at Yudinovo, Russian Plain

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## ABSTRACT

Whether or not mammoth hunting was practised during the Late Palaeolithic has been a controversial issue ever since large accumulations of woolly mammoth bones associated with prehistoric artefacts were discovered more than 100 years ago. Detailed taphonomic and palaeobiological analyses of the mammoth bone complexes from the Epigravettian Yudinovo site in the Russian Plain were carried out. The combination of the homogeneous weathering rate of the mammoth bones, the isolated state of most of the skeletal elements, the restricted spatial range of the carnivore gnawing traces, the breakage pattern of the skulls and long bones, the sex ratio, the small body size of the adult mammoths, the age profile (with an important frequency of prime-aged cows), and the large number of individuals, suggest that the bone complexes at Yudinovo were constructed from body parts and bones that were extracted from freshly killed mammoths and that mammoth hunting was practised at this site during the Epigravettian.

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Large mammoth bone accumulations in association with Upper Palaeolithic artifacts were first discovered on the Russian Plain at the end of the 19th century (Polyakov, 1880; Soffer, 1985). Since then, numerous prehistoric mammoth sites have been excavated not only in Russia or the Ukraine but also in Central Europe (Klima, 1969; Kozłowski and Sachse-Kozłowska, 1974; Péan and Patou-Mathis, 2003; Fladerer, 2003; West, 2001; Svoboda et al., 2005). It has long been debated what relationship to attribute to the mammoth fossils and the archaeological implements. The following explanations have been proposed to clarify the human involvement with the mammoth bone accumulations: (i) the gathering of mammoth bones from natural death sites; (ii) the modification of natural accumulations of mammoth bones by humans; (iii) the exploitation of mammoth remains from buried bone beds deposited by running water; and (iv) the use of mammoth bones from actively hunted and killed mammoths (Absolon, 1938; Soffer, 1985, 2003; Pidoplichko, 1998; Haynes, 1999; West, 2001; Kozłowski, 2003; Kuzmin and Orlova, 2004; Svoboda et al., 2005). However, the idea that prehistoric humans actively hunted mammoths remains controversial (Soffer, 1993; West, 2001; Hoppe, 2004). In this paper, we wish to widen and enrich the debate about whether or not humans hunted mammoths during the Late Upper

Palaeolithic by reviewing the mammoth bone material from the Yudinovo site on the Russian Plain.

The remainder of this paper is organized as follows. Section 2 presents the site. Section 3 provides an overview of (i) the material, (ii) the theoretical basis for comparison of the Yudinovo material with other fossil and recent elephant bone assemblages, and (iii) the biology of the Elephantidae, both fossil and extant. Section 4 presents the results of the taphonomic and palaeobiological analyses. In Section 5, we compare the results with the taphonomic and palaeobiological references and assess archaeological and ethnographical evidence. Section 6 concludes.

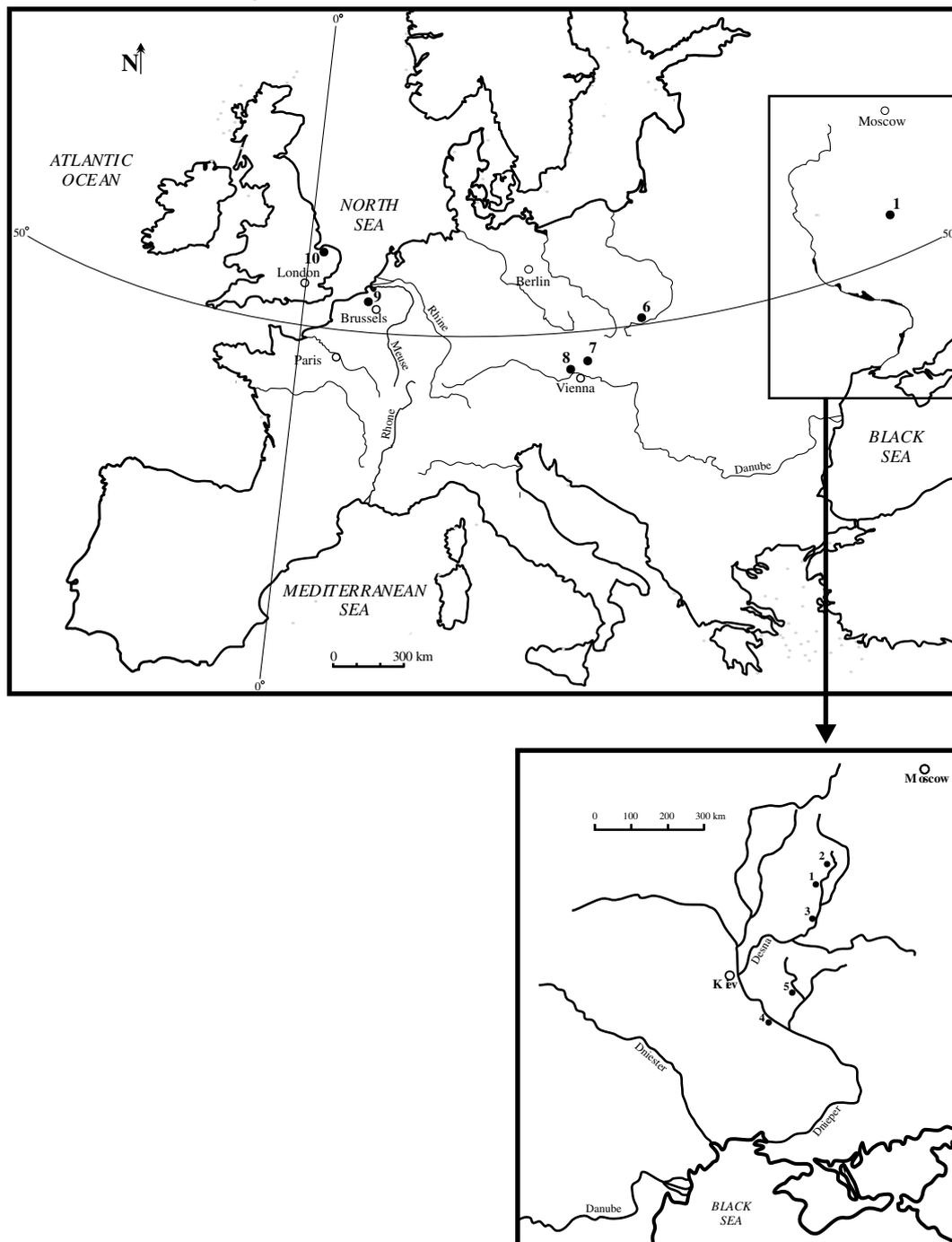
## The Yudinovo site

The Upper Palaeolithic open-air site Yudinovo is situated at the edge of the Yudinovo village (Pogor District, Briansk Region, Russia, 52°40'15" N, 33°15'45" E), on the right bank of the Sudost' River (a tributary of the Desna) some 100 km south-southwest of the city of Briansk (Abramova, 1993) (Fig. 1). The site is located on a 10–12 m high promontory, that is limited by two shallow ravines running into the first river terrace.

The site was discovered by K.M. Polikarpovich in 1934 and excavated by him in 1947 and 1961 (Polikarpovich, 1968). In 1962, 1964, 1966, and 1967, the archaeological exploration of Yudinovo was continued by V.D. Bud'ko. In 1980, after a long break, excavations in Yudinovo were resumed (Abramova, 1995). In

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**Fig. 1.** Map showing the location of the discussed sites (1: Yudinovo, 2: Eliseevich, 3: Mezin, 4: Mezhirich, 5: Gontsy, 6: Cracow, 7: Dolní Věstonice and Milovice, 8: Krems-Wachtberg, 9: Flemish Valley, 10: Lynford).

1980–1985, a pavilion was constructed to protect the bone accumulations from these latter excavations. From 1995, the fieldwork was led by G.V. Grigor'eva and since 2004 it has been led by G.A. Khlopachev. In total, more than 800 m<sup>2</sup> of the single cultural layer were excavated during the Yudinovo explorations. The cultural layer is located 1.8–2 m, sometimes 2–2.5 m, below the modern surface in loess-like loam that was formed on the first terrace of the Sudost' River (Velichko, 1961). The cultural layer is 20–40 cm thick. In some places, the cultural layer was disturbed by frost cracks and water erosion. The presence of rodents and avifauna reflects cold, tundra conditions (Soffer, 1985). According to geomor-

phological data, the Yudinovo site was occupied during the end of Valdai period (Velichko, 1961). Such geological dating is in agreement with the radiocarbon data. Several radiocarbon dates were obtained. All of them range from c. 16,000 to 12,000 BP and the majority date from 15,000 to 13,000 BP (Abramova et al., 2001). During that time, permafrost was present. The environment can be described as a periglacial steppe with open woodlands in the river valleys. The mean annual precipitation was estimated to be around 350 mm/year. In summer, air masses from the Atlantic reached East Europe bringing some rainfall; during winter the snow cover was usually thin (Velichko and Zelikson, 2005).

Four concentrations of woolly mammoth bones were discovered on the site. The first mammoth bone complex, which was excavated in 1947 by Polikarpovich (1968), was about 9 m in diameter. It comprised 30 skulls, scapulae, ilia and limb bones. Many of the ilia and limb bones have artificial holes. The bones were derived from at least 30 mammoths (Abramova, 1993). A second complex, which was discovered in 1947 (Bud'ko, 1966), was about 5 m in diameter and was composed of seven skulls, 11 lower jaws, and 42 limb bones. Here the remains from at least 13 mammoths were preserved (Abramova, 1993). The excavations from the 1980s brought to light two additional mammoth bone complexes. The pavilion was constructed to preserve complexes 3 and 4 *in situ*.

At Yudinovo, several production areas were revealed: 10 for flint processing, two for mammoth ivory processing, and seven for polar-fox skinning and butchering; most were found outside the pavilion. The areas for flint processing each cover 0.3–0.5 m<sup>2</sup>. They have a high concentration of flint debitage (flakes, splinters, tiny chips, and worked-out cores). In one area for the initial processing of mammoth ivory, five ivory cores and more than 300 ivory flakes and splinters were concentrated on 2.5 m<sup>2</sup> (Khlopachev, 2006; Khlopachev et al., 2006). A detailed analysis of the production areas will be reported separately.

The recent excavations brought to light more than 80,000 pieces of flint, including chips, blades and bladelets, edge and burin splinters, core-like splinters, and cores. More than 1500 flint tools were found: burins, scrapers, truncated and retouched bladelets, combined tools, and *pièces escaillées*. The tools were used for processing bone and ivory, judging from their morphology and use-wear analysis. In the pavilion, both projectile points and butchering tools were discovered. Furthermore, during the recent excavations about 40,000 pieces of bone artifacts, including small blades and splinters, were found on the site. About 90% of this assemblage is made of ivory. There are pieces related to initial ivory and bone processing (ivory cores, flakes, blade-like flakes, and pieces of bone with traces of splitting and cutting), hunting tools (tanged points for spears, darts, and arrows), working tools (digging tools made of mammoth ribs, hammers of reindeer antlers, awls, perforators, and needles and needle cases made of arctic fox tubular bones) and ornaments (tab beads, pendants, and arm-ring fragments made of ivory). On many art pieces, such as pieces of mammoth tusks, ivory blades, and mammoth bones, rich rhomb ornamentation were engraved. Numerous pendants made of perforated shells were unearthed. Some of them were made from *Theodoxus sluvialis* shells from the Black Sea coast, near Kherson, some 800 km from Yudinovo (unpublished data).

The fauna of the Yudinovo pavilion, with the exception of the mammoth remains, has been reported by Vereshchagin and Kuzmina (1977), Kuzmina and Sablin (1993), Burova (2002), and Khlopachev et al. (2006). Bones of fish (one specimen after sieving), birds, and mammals were identified (marmot, beaver, hare, arctic fox, wolf, brown bear, cave lion, horse, reindeer, saiga, musk ox, and mammoth). The mammalian fauna is dominated by arctic fox and mammoth (Table 1). Remains of *Alopex lagopus* are represented by all parts of the skeleton, including skulls, vertebrae, and ribs. Arctic fox paw bones were often found in anatomical order, which suggests that complete extremities were left on the site, probably with the skin. It is possible that the hunted arctic foxes were preyed upon not only for their fur, but also for meat and bones, which were used for food and handicrafts, respectively. Pelt quality is best at the beginning of winter; hence, it may be assumed that the foxes were hunted at that time, as was probably also the case for the wolves (cf. Soffer, 1985). The faunal remains excavated outside the pavilion have, at the time of writing, not been studied in detail.

The extremely rich presence of stone and bone artifacts, tools, ornaments, and the occurrence of hearths and large charcoal con-

**Table 1**

List of species present at Yudinovo (pavilion)

Species	MNI	% MNI
<i>Lepus sp.</i>	1	0.4
<i>Marmota bobak</i>	5	1.9
<i>Castor fiber</i>	1	0.4
<i>Mammuthus primigenius</i>	63	24.2
<i>Alopex lagopus</i>	173	66.5
<i>Canis lupus</i>	4	1.5
<i>Ursus arctos</i>	1	0.4
<i>Panthera spelaea</i>	1	0.4
<i>Equus latipes</i>	2	0.8
<i>Rangifer tarandus</i>	3	1.2
<i>Saiga borealis</i>	1	0.4
<i>Ovibos pallantis</i>	5	1.9
Total	260	100.0

MNI: Minimal Number of Individuals.

centrations at the site suggest strongly that Palaeolithic hunters visited and stayed at Yudinovo for significant periods (Abramova, 1993, 1995). According to Soffer (1985), sites in the Russian Plain that have mammoth bone complexes located on the flood plain were cold-weather settlements. She concluded that Yudinovo was occupied during the cold half of the year (October–April) and was a complex base camp.

## Materials and methods

Only the mammoth bones from the Yudinovo pavilion are considered here in detail. The mammoth bones in the pavilion remain *in situ*. They were only partly freed from the sediment. A number of them is not completely visible. Furthermore, several bones are partly buried under other bones. A total of 517 mammoth bones were counted over a surface of about 85 m<sup>2</sup> (Fig. 2a and b). Table 2 shows the frequency distribution of the skeletal elements in NISP (number of identified specimens) and MNIE (minimum number of individuals for each skeletal element).

For the taphonomic analysis of the available material, we counted the isolated skeletal elements and articulated skeletal parts and considered the breakage, carnivore damage, weathering, abrasion, and plant root traces of the bone material. The palaeobiological analysis considered the sex ratio of the remains using the tusks and postcranial material as a basis; we reconstructed the body size and body weight of the mammoths present and determined the age distribution on the basis of the dentition and limb bones.

We used published studies on the following as reference material concerning the taphonomic aspects: (i) postmortem developments and the burial of mammal remains in general, (ii) mammoth assemblages from fluvial and lacustrine deposits and from Palaeolithic sites, and (iii) recent elephant mass deaths.

The disarticulation of carcasses can occur as a result of several processes, such as weathering, scavenging, trampling, gravity, water action, or human manipulation. The relative time span between the death of an animal and the burial of its bones can be deduced from the weathering stages. Six weathering stages were described by Behrensmeyer (1978), from fresh bones (stage 0) to bones falling apart (stage 5). Furthermore, carnivores can attack carcasses and bones lying on the surface (Haynes, 1983). Bone abrasion can occur because of the impact of wind- or waterborne particles on bone. In general, such abrasion consists in the rounding of the edges of the articular surfaces of bones (Shipman, 1981). Abrasion is a relatively sensitive indicator of the degree of interaction with moving sediment. Experiments in the East Fork River, Wyoming, showed that bones can acquire definite abrasion after only 1.5–3 km of transport (Behrensmeyer, 1982). Bone bed

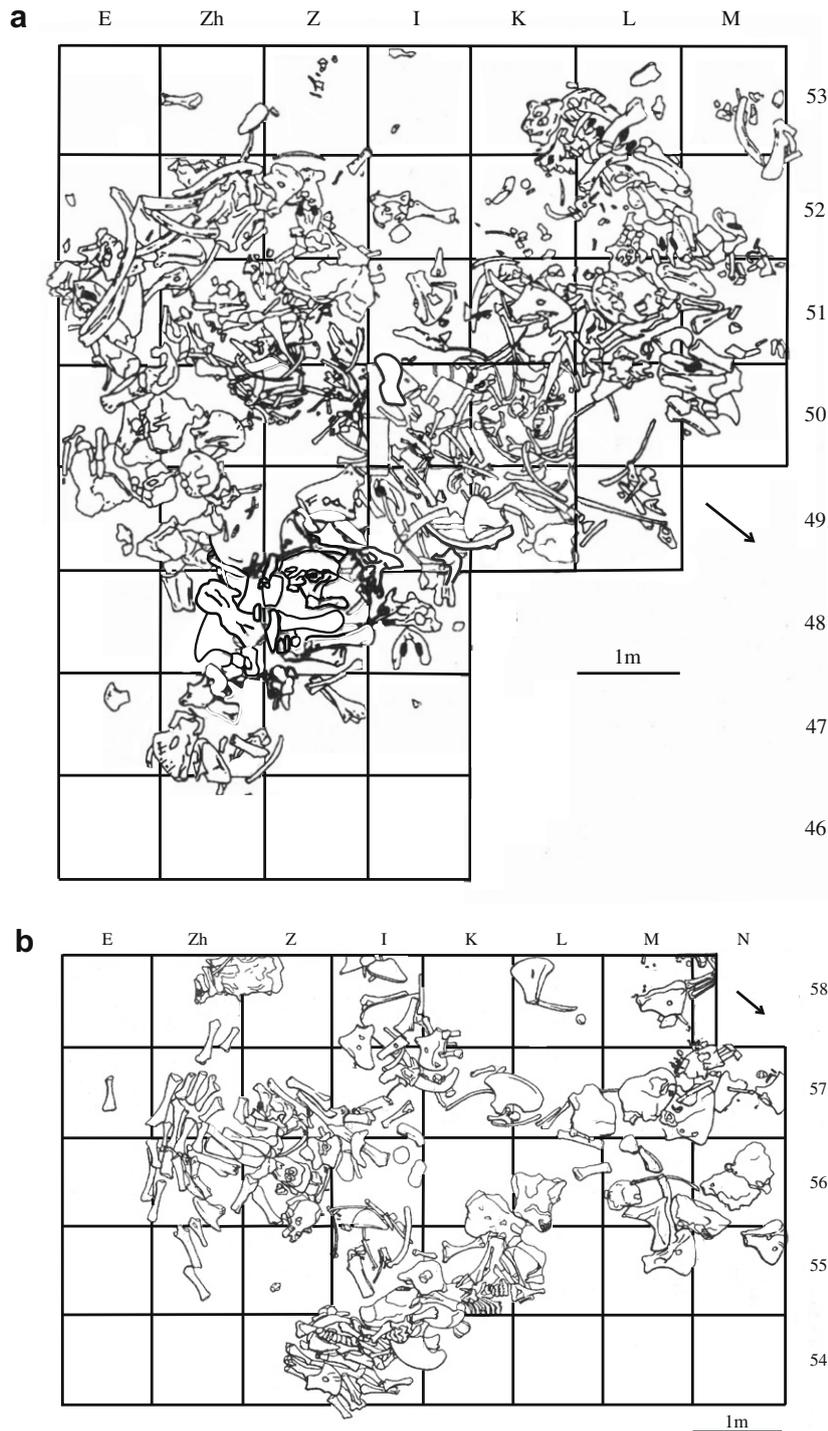


Fig. 2. (a) Yudinovo, pavilion: bone complex 3, modified after Abramova (1995). (b) Yudinovo, pavilion: bone complex 4, modified after Abramova (1995).

concentrations often imply the reworking of fossils from fluvial deposits (Koster, 1987) and can contain a high number of abraded bones. In addition, on the flood plain, abrasion can occur via trampling (Lyman, 1994). Another feature of a prolonged stay on the soil surface or subsurface is marking by plant roots. In particular, bones buried in the grass root zone on vegetated bars, near minor channels, or in a flood plain will display root etching (Badgely, 1986).

Results of taphonomic analyses of mammoth assemblages from fluvial deposits were used as reference material. The fossils in the

Early Glacial and Pleniglacial fluvial sands from the Flemish Valley, Belgium (Germonpré, 1989, 1993a, 2003) accumulated mainly through gradual long-term processes and occur in a dispersed and isolated fashion in the sediments. Sevsik, which is a natural open-air site, located as is Yudinovo on the Russian Plain, dates from about 14,000 BP. Here, a catastrophic death assemblage of one mammoth group, composed of at least 33 mammoths that died simultaneously during spring or early summer, was discovered in oxbow lake deposits in an area of about 800 m<sup>2</sup>. The cause of death

**Table 2**  
NISP and MNIE of the mammoth remains from Yudinovo (pavilion)

Mammoth bones	Total		Articulated bones		Traces						Broken			
	NISP	MNIE	NISP	MNIE	Impact/hole		Cut marks		Worked		Carniv. gnaw.		NISP	%*
					NISP	%*	NISP	%*	NISP	%*	NISP	%*		
Yudinovo														
Cranium	53	53											35	66.0
Maxilla	3	3											3	100.0
Mandibula	24	22											4	16.7
I	27	17							5	19.2			17	63.0
Molar	6	1											4	66.7
Os costa	95	3											3	3.2
Vertebrae														
Atlas	4	4												
Cervical	6	1	4	1										
Thoracic	37	2	17	1									11	32.4
Lumbar	2	1	2	1										
Sacrum	3	3	1	1									1	33.3
Scapula	71	38			31	43.7					1	1.4	9	12.7
Humerus	35	19	2	1	1	2.9					3	8.6	2	5.7
Ulna	24	14	1								2	2.8	2	8.3
Radius	8	5	1	1									1	12.5
Ilium	35	19			3	8.6							22	62.9
Femur	25	13	2	1							8	32.0	3	12.0
Patella	1	1												
Tibia	39	21	5	2			1	2.7			1	2.7	1	2.7
Fibula	3	2	1	1										
Carpalia/tarsalia														
Astragalus	2	1	1	1										
MC/MT	1	1												
Phalanges	0	0												
Long bone indet.	13												13	100.0
Total NISP	517		37	4	35		1		5		15		131	
Total NISP %	100.0		7.2		6.8		0.2		1.0		2.9		25.3	

NISP: Number of Identified Specimens, MNIE: Minimal Number of Individuals for each skeletal element, \* percentage of NISP of each skeletal element. I: tusk, MC/MT: metacarpalia/metatarsalia, indet: indeterminate.

could be related to a catastrophic flood (Maschenko, 2002; Maschenko et al., 2006). However, according to Velichko and Zelikson (2005), the mammoths died in a thermokarst depression. At the Pleniglacial site of Lynford, UK, a large quantity of extremely fragmented mammoth remains were found in a former meander cut-off. There is some indirect evidence for human involvement in the origin of part this mammoth assemblage; however, the specimens have very different depositional histories and were incorporated in several stages in the sediment (Schreve, 2006). The Late Glacial Berelekh site is situated in north-eastern Siberia, above the Arctic Circle. Here, a natural accumulation of more than 100 mammoths represented by at least 8500 bones was found in fluvial deposits. The bone assemblage was the result of recurring deaths of mammoths over several thousand years (Vereshchagin and Tichonov, 1986; Haynes, 1991).

In addition, works dealing with mammoth assemblages found at prehistoric sites were consulted, especially those from the Russian Plain and Central Europe. From the Russian Plain, the following sites date from the Epigravettian: Mezin, which is well known for its round mammoth bone dwelling; Mezherich where four mammoth bone dwellings are present (Pidoplichko, 1998; Shovkopljias, 1965; Soffer, 1985; Sinityn et al., 1997; Soffer et al., 1997) and Eliseevich, where there are remains of at least eight mammoth bone structures. Eliseevich delivered the oldest dogs known with an age of c. 13,900 BP (Sablín and Khlopachev, 2002, 2003). The Central European mammoth sites date from the Gravettian period. Milovice G in Czechia and Krakow-Spadzista Street (B) in Poland have been interpreted as killing and butchering sites (Svoboda et al., 2005; Wojtal and Sobczyk, 2005). Dolní Věstonice, Czechia, is considered to be a mammoth butchering site (Svoboda et al., 2005; West, 2001). The Austrian Krems-Wachtberg mammoth assemblage resulted from mammoth hunting (Fladerer, 2003).

Actualistic studies on recent elephants were used also as a reference base. These studies include the work of Haynes (1991) on natural death sites of African elephants in Zimbabwe, particularly at Shabi Shabi, which is a recent natural water source where the remains of 216 African elephants that died during drought years accumulated.

For the palaeobiological aspects, we used data on size dimorphism and ageing in extant elephants and consulted works on elephant ethology. Recent African and Asian elephants are similar in several aspects of their biology and behaviour. They have similar gestation periods and birth rates and the maximum life span of both species is about 60 years (Olivier, 1982; Haynes, 1991). The African elephant lives in family units of four to 12 individuals, composed of two to four related mother-offspring units. These families may split into nuclear mother-calf units under drought conditions (Owen-Smith, 1992). During the wet season, elephants show the tendency to aggregate in fewer, larger groups (Wittemyer et al., 2005). In recent African elephant family units from Kenya, matriarchs younger than 35 years lead small families composed of four or five individuals. Matriarchs that are older than 35 years are, given their age, grandmothers and lead three-generation families composed of around 10 individuals (Wittemyer et al., 2005). The mean group size of Asian elephants ranges from more or less six to nine individuals (Sukumar, 1992). Recent African elephants reach sexual maturity at an age varying from 8 to 14 years (Laws, 1966). The male animals leave the herd 2 or 3 years later (Olivier, 1982). The mean age at first parturition for the African elephant cows fluctuates from 13 to 18 year (Owen-Smith, 1992), but the majority of the cows have their first calf when they are between 14 and 15 years (Moss, 2001). The mean birth interval for the African elephant is 4.5 years and elephants nurse until the birth of the next calf, 4 or 5 year later (Owen-Smith, 1992). In general, Asian elephant cows have their first calf at 18–20 years old and the calving interval is 4.8 years.

Bulls become independent of their families by the age of 15 years (Sukumar, 1992). Sexual size dimorphism in recent elephants is well expressed. The cows are smaller and lighter than the bulls, because bulls grow faster and for longer than cows (Lee and Moss, 1995). Furthermore, the cows have more slender tusks than bulls (Hanks, 1972). Recent African elephants have heights that range from 2.3 m to 3 m for the cows and from 2.9 m to 3.7 m for bulls (Lee and Moss, 1995). Hanks (1972) gives a weight of 2.5 ton for recent African elephant cows and a weight between 4.7 ton and 6 ton for recent bulls.

It has been argued that it is likely that the habits and life cycle of the recent elephants are similar, to a certain extent, to those of the extinct mammoth (Saunders, 1980; Olivier, 1982; Coneybeare and Haynes, 1984; Haynes, 1991). Suggesting such a likelihood of similarity does not, of course, entail that some behavioural differences did not exist, especially in relation to the cold and open environment in which the mammoths lived. Guthrie (2001) discusses in detail the possible ways in which the woolly mammoths might have differed from the more tropical elephants, such as the timing of the birth season restricted to early spring, a constrained rut that would result in the bulls being more aggressive, and longer nursing periods. Furthermore, according to Guthrie (2001) the timing of life-junctures could have come later than amongst recent elephants, postponing the age of the sexual maturity of the cows until about 20 years. In addition, Vereshchagin and Tichonov (1986) concluded on the spacing of the growth rings found in mammoth tusks from Berelekh that mammoths reached sexual maturity at from 18 to 20 years. Stable isotope analysis of the tusk of a mammoth calf (5.5–6 years of age) from Wrangel Island revealed that the animal at death was probably not completely weaned (Rountrey et al., 2007). Using the foregoing as a basis, it may be surmised that the mean calving interval in mammoths was at least 5 years. A later sexual maturity for the mammoth cows and larger birth spacing could imply that mammoth family units were smaller than those of recent elephants. In that case, the mean size of the family units led by cows aged from between 23 and 34 a.e.y. could have been around three, while the mean size of family units led by older matriarchs (35–48 a.e.y.) could have been about six individuals.

The shoulder height of the mammoths was calculated on the basis of the formulae for the skeletal shoulder height (Germonpré, 2003). The mean body mass of the mammoths was determined on the basis of five equations used to calculate the weight of recent

African elephants. Christiansen (2004) uses the length of the long bones, while the other equations (Johnson and Buss, 1965; Hanks, 1972; Laws et al., 1975) are based on the shoulder height of the individuals.

According to Haynes (1991), in the mammoth just as in the recent elephants, the tusks of cows and bulls can be differentiated.

Several authors reconstructed the age distribution of mammoths by comparing the eruption sequence and wear of their jugal teeth with those of the two modern species (Saunders, 1980; Haynes, 1991; Germonpré, 1993a). Laws (1966) established 30 age classes for the African elephant, using as a basis the progress of eruption and wear of the jugal teeth and allocated real ages to these groups. To obtain an age distribution for the Yudinovo mammoths, Laws' (1966) technique is used here in an adapted form. The mammoth jaws are attributed an "African Elephant Years" (a.e.y.) age, using the data of G. Craig in Haynes (1991, Table A8). These attributions of age facilitate comparisons without implying real absolute ages for the mammoths.

## Results

### *Taphonomic analysis of the mammoth bone accumulations*

#### *Frequency of skeletal elements, isolated bones and articulated skeletal parts*

In general, at Yudinovo (pavilion) large, bulky bones are well represented, while small/slender bones are almost absent (Table 2). No mammoth foetal bones are present, although remains from mammoth calves were recovered (see below) and also small bones of small animals, such as the polar fox (see Table 1). Fragments of small/slender mammoth bones can be found elsewhere on the site. During the recent excavations numerous small crushed fragments (<5 cm) of skulls, teeth, tusks, ribs, vertebrae, and also of phalanges, metacarpals/metatarsals, and carpals/tarsals were found outside the pavilion, especially in ash deposits. There are almost 2000 such specimens.

The frequency distribution of the skeletal elements present at Yudinovo (pavilion) is similar to that at Mezhirich (Pidoplichko, 1998), but differs greatly from that at Dolní Věstonice (Svoboda et al., 2005) (Fig. 3). At the latter site, ribs are the best represented element, while carpals/tarsals and phalanges also occur in higher frequencies than at Yudinovo and Mezhirich. At Sevs, vertebrae,

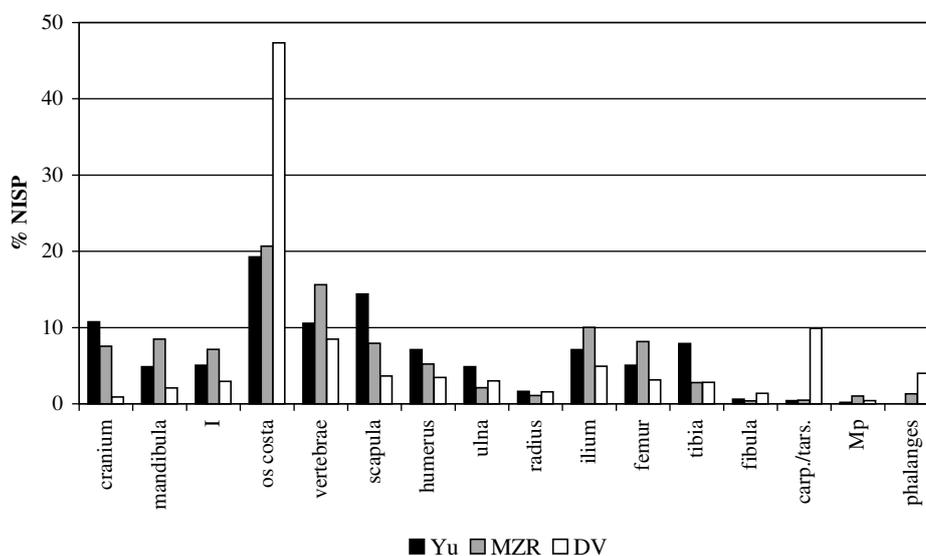


Fig. 3. Frequency distribution of the mammoth skeletal elements from Yudinovo (pavilion) (Yu), Mezhirich (Pidoplichko, 1998) (MZR) and Dolní Věstonice (Svoboda et al., 2005) (DV). (NISP: number of identified specimens, I: tusk, MP: metapodalia).

ribs, carpals, metacarpals, tarsals, metatarsals and phalanges number 3256 specimens (88%) out of a total of 3700 bones (Maschenko et al., 2006). This is significantly different from the number of 151 (29%) of these elements out of a total of 517 at Yudinovo (pavilion) (Fisher's exact test  $< 0.0001$ ). Note that several bone tools made of mammoth ribs were collected from the pavilion. These are not counted here.

At Yudinovo (pavilion), skeletal elements are commonly not articulated. However, some sorting of the isolated bones can be distinguished. All femora occur, with the exception of one bone, only in complex 4. Seven tibiae were found in one grid (Zh58). The highest concentration of skulls is in grid Z56, where four skulls are present; this same unit also contains four scapulae (Fig. 4).

Nevertheless, at Yudinovo (pavilion) 37 bones (7.2% NISP) were found in an articulated state or were associated, corresponding to 11 cases of body parts of at least four individuals: five series of articulated vertebrae from at least one adult, a subadult humerus with its unfused proximal epiphysis, a radius and cubitus from another subadult, a left and right femur from one juvenile, two subadult tibiae from two different individuals that occur with their unfused distal epiphysis (Fig. 5), and a distal lower leg that consists of an articulated tibia, fibula, and astragalus (Fig. 6), all fully grown (Table 2).

At Yudinovo (pavilion), the number of mammoth bones per square metre ranges from one to 26. The remains originate from at least 63 individual mammoths, judging from the combined individual ages of the skulls, lower jaws, and postcranial material (see below), which yields a mean density of one mammoth individual per  $1.4 \text{ m}^2$ . Furthermore, the MNI of the complexes 1 and 2 is 43 individuals. This brings the total MNI of the entire Yudinovo site to 106 mammoths.



Fig. 4. View of grids Z56 and Z57 (complex 4) where four scapulae are piled in a tile-like fashion. The skull to the left has an open braincase and broken alveoli of the tusks.



Fig. 5. Subadult tibia: its proximal epiphysis is partially fused with the diaphysis, its unfused distal epiphysis fits with the diaphysis *in situ* (in grid L56, complex 4).



Fig. 6. Articulated adult tibia, fibula and astragalus. To the right is a scapula with a highly weathered spine (grid M51, complex 3).

#### Breakage and human modification

At the Yudinovo (pavilion), 66% of the mammoth skulls are damaged. In general, two types of damage can be recognized: (i) breakage of the alveoli of the tusks and (ii) breakage of the brain case. All skulls ( $n = 23$ ) in which the alveoli of the tusks are visible have broken tusk alveoli and are deprived of their tusks. The remaining 57% of the skulls were partly hidden in the sediment or covered by other bone elements and could not be examined for this characteristic. In 32 skulls (60% of all skulls), the brain case was opened in a systematic way (Fig. 7). In 10 other skulls (19%), the brain case was preserved (Fig. 8). In 11 skulls (21%), it was not possible to judge the state of the brain case.

There are 404 specimens of postcranial elements. Of these, only 68 (17%) are broken (Table 2). Fig. 9 shows that the frequencies of the fragmented long bones and scapulae from Yudinovo and from the recent waterhole at Shabi Shabi, Zimbabwe are very different. Furthermore, several postcranial mammoth bones, but especially the scapulae, display square to circular man-made holes (Polikarpovich, 1968; Abramova, 1993) (Fig. 10). The diameter of the holes ranges from 4 cm to 13 cm. The spines of the scapulae have not been broken off. Clear cut marks were observed on one bone, a tibia found in grid Z56. Furthermore, five tusks were worked (Table 2). In addition, numerous ivory tools were produced from tusks and several ivory nuclei were collected at the pavilion. These are not included here.

#### Incidence of carnivore gnawing

At the pavilion, carnivores gnawed the ends of some long bones and of a scapula. In total, only 15 bones (2.9% NISP) are damaged (Table 2, Fig. 11). Furthermore, the carnivore traces occur mainly on bones from complex 4, especially near the western wall of the pavilion. Here, five femora are standing nearly vertically (Abramova, 1993) and stick out from the rest of the more or less horizontally distributed bones. Four of them are gnawed on their protruding ends (Fig. 12). At least those were gnawed *in situ*.



Fig. 7. Mammoth skull with open braincase in grid I48 (complex 3).

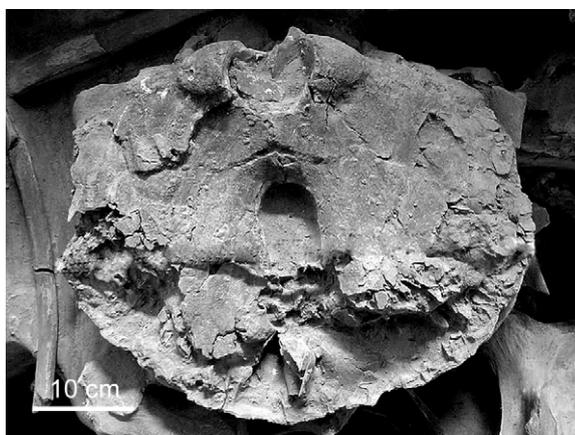


Fig. 8. Skull of a young mammoth with unopened braincase in grid Zh49 (complex 3).

*Weathering of the mammoth bones*

At Yudinovo (pavilion), practically all mammoth bones are slightly weathered, corresponding to Behrensmeyer's (1978) weathering stage 1. Only 11 bones (2.1% NISP) were more weathered, including five tusks. Two of the weathered scapulae and two weathered tusks are worked specimens. Furthermore, it is



Fig. 10. View of complex 3. In front are two scapulae with an artificial hole.

interesting that the bones that protrude the highest in each complex, a humerus in grid A51 and a femur in grid I57, show greater weathering. The femur was also gnawed by carnivores (Fig. 12). The protruding spine of a scapula in grid M51 is highly weathered while the rest of the scapula is only slightly weathered (Fig. 6).

*Frequencies of abrasion and plant root marks*

None of the mammoth bones from the Yudinovo accumulations show abrasion or evidence of plant root action.

*Palaeobiological analysis of the mammoth bone accumulation*

*Sex ratio*

*Tusks.* At Yudinovo (pavilion), 25 tusks or large tusk fragments remain *in situ* (Table 2). They were all found isolated and not preserved in the skulls. The diameter could be measured on 14 specimens. The length could only be taken on a more limited number of tusks, because many were partly hidden under other bones or were covered by loam. The diameters of the Yudinovo tusks were compared with those from Berelekh, Siberia (Vereshchagin and Tichonov, 1986), with tusks collected from Early Glacial and Pleniglacial fluvial sands from the Flemish Valley, Belgium (Germonpré, 1993b), and with those from Sevsik (Maschenko, 1992; Maschenko et al., 2006) (Fig. 13). This latter assemblage is dominated by female mammoths (Maschenko et al., 2006).

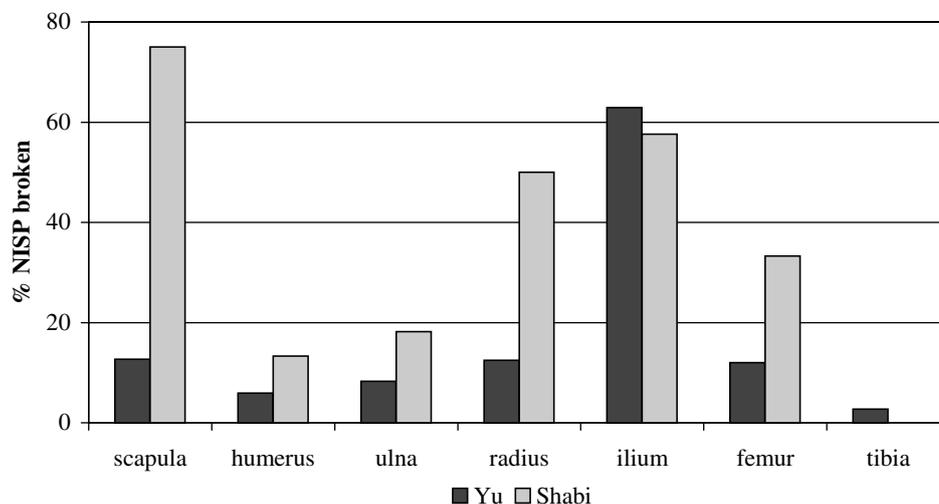


Fig. 9. Comparison of the frequencies of broken bones at Yudinovo (Yu) and Shabi Shabi (Shabi), a recent water source in Zimbabwe (Shabi Shabi data from Haynes (1991)) (NISP: number of identified specimens).



Fig. 11. Gnawing marks by carnivores on the proximal edge of a femur in I52 (complex 3).



Fig. 12. The highly weathered protruding femur in grid I57 (complex 4).

The tusks from both the Flemish Valley and Siberia have a clear bimodal distribution with the slender tusks, from females and young males, separated from the heavy tusks of older males. Siberian tusks with a diameter of more than 110 mm are considered to be exclusively from males (Vereshchagin and Tichonov, 1986). At Sevsk, the tusks are less than 110 mm in diameter, which points to a preponderance of females, as shown by Maschenko et al. (2006). At Yudinovo, many tusks are 110 mm or more in diameter and are therefore derived from older bulls. Furthermore, one maxillary fragment without teeth and one skull fragment have alveoli of the tusks with a diameter of at least 130 mm and both can there-

fore be considered as being from mammoth bulls. Four other skulls had alveoli less than 110 mm wide and can be identified as from cows.

*Postcranial.* The tibia is the only long bone for which measurements could be taken on a relatively large number of specimens. Therefore, the tibia is used here as a reference bone. The Yudinovo tibiae were compared to those from Sevsk (Maschenko, 1992; Maschenko et al., 2006) and the bones from the Early Glacial and Pleniglacial fluvial deposits from the Flemish Valley, Belgium (Germonpré, 1993b) (Fig. 14). Only bones from adult animals with completely fused proximal and distal epiphyses were measured, although at Yudinovo, one subadult tibia, with both its unfused proximal and distal epiphysis missing, that is larger than the full grown tibiae is also included. In another tibia both epiphyses are present, but only the proximal one is partly fused (Fig. 5). It was measured with both epiphyses included. A very large subadult tibia from Sevsk is presumed to be from a male mammoth (Maschenko et al., 2006, p. 158).

It is clear from the graph (Fig. 14) that the distribution of the length of tibiae from the Flemish Valley, Belgium, follows a bimodal distribution that corresponds to cows and bulls. The size ranges of the tibiae from neither Yudinovo nor Sevsk show a bimodal distribution, fall completely outside the distribution of the Belgian mammoths, and are smaller than the Belgian mammoth cows. The tibiae from Sevsk, which come mainly from female mammoths (Maschenko, 1992; Maschenko et al., 2006), are, for the most part, similar in size to those at Yudinovo. From this, it may be inferred that at Yudinovo the adult postcranial material is mainly from cows.

*Body size and body weight.* Fig. 15 displays the shoulder height of the mammoths from the Flemish Valley, ranging between 285 cm and 357 cm, according to the following formula for the skeletal height:  $SkH (cm) = 4.35 \times GL \text{ tibia} (cm) + 12.7 \text{ cm}$  (GL: Greatest Length) (Germonpré, 2003). The shoulder height was obtained by adding 15 cm to the skeletal height (Christiansen, 2004). At Sevsk, the adult females had an estimated shoulder height of from 210 cm to 254 cm, with a mean of 234 cm. The length of the smallest fused tibia gives a skeletal height of 195 cm. This agrees well with the skeletal height of the mounted skeleton of this individual, which is 190 cm (Maschenko et al., 2006). The large subadult male mammoth has an estimated shoulder height of at least 270 cm, judging from its incomplete tibia. The shoulder height of the Yudinovo adult mammoths ranges from 224 cm to 245 cm, with a mean of 233 cm. This mean value is similar to that of the cows at Sevsk. One large subadult animal has an estimated shoulder height of more than 250 cm, judging from its incomplete tibia. One large adult humerus from Yudinovo is derived from a mammoth with an estimated shoulder height of around 285 cm. Judging from its size, it is probably from a male. So, although the assemblage at Yudinovo is clearly dominated by females, possibly two bones (full grown humerus, large subadult tibia) from larger bulls are present. This agrees well with the presence of two skull remains from male mammoths.

Fig. 16 displays the frequency distribution of the mean calculated weights of the mammoths from Yudinovo, Sevsk, and the Flemish Valley. The body weights of the mammoths were calculated using the formulae of Johnson and Buss (1965), Hanks (1972), Laws et al. (1975), and Christiansen (2004). Only complete, fully grown tibiae were used as data, except for the three large subadult specimens from Yudinovo and Sevsk and one large complete humerus from Yudinovo.

The body weight ranges of the mammoths from the Russian Plain are clearly smaller than those of the Early and Middle Weichselian mammoths from the Flemish Valley (Belgium). The

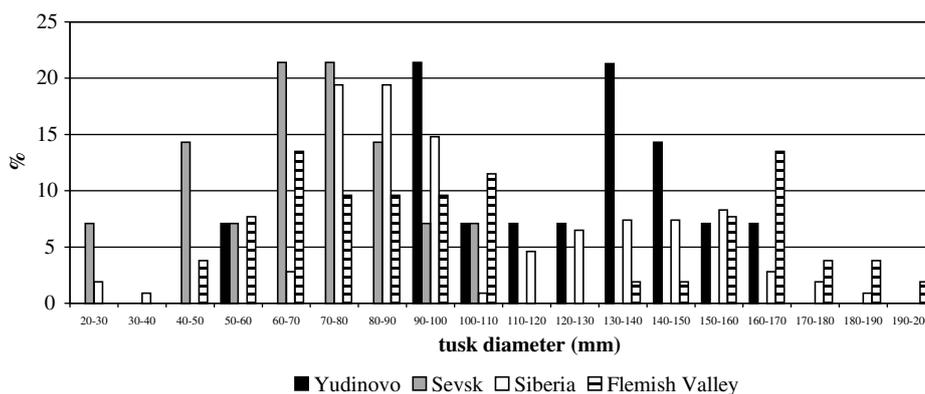


Fig. 13. Frequency distribution of the diameter of mammoth tusks, from Yudinovo (pavilion), Sevs (Maschenko et al., 2006), Siberia (Vereshchagin and Tichonov, 1986), Flemish Valley (Germonpré, 1993b).

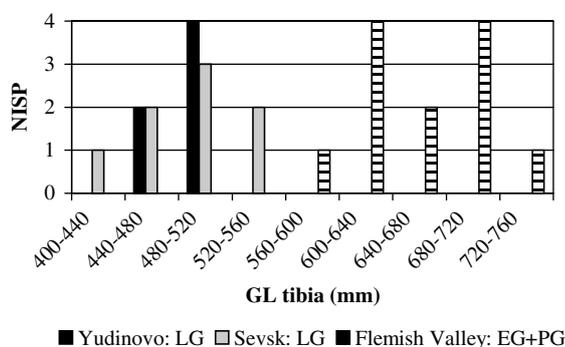


Fig. 14. Size distribution of the greatest length of mammoth tibiae from Yudinovo (pavilion), Sevs (Maschenko et al., 2006) and the Flemish Valley (Germonpré, 1993b), based on the total length of full grown tibiae and three subadult bones (GL: greatest length, LG: Late Glacial, PG: Pleniglacial, EG: Early Glacial, NISP: number of identified specimens).

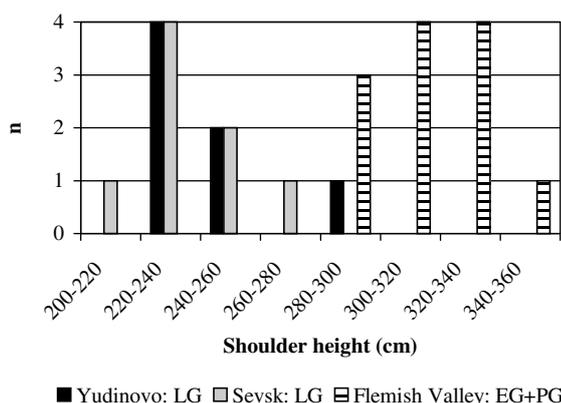


Fig. 15. Frequency distribution of the shoulder height ranges of mammoths from Yudinovo (pavilion), Sevs (Maschenko et al., 2006) and the Flemish Valley (Germonpré, 1993b) (LG: Late Glacial, PG: Pleniglacial, EG: Early Glacial) based on full grown tibiae, three subadult tibiae and one full grown humerus (see text for explanation).

mean weight of the Sevs adult female mammoths is 2.3 ton. The subadult male had a weight of at least 3.2 ton. At Yudinovo, the mean weight of the large male, determined on the basis of its humerus is 3.8 ton. The bulk of the adult mammoth remains at Yudinovo are from cows. Their mean body weight, calculated on the basis of the adult tibiae, is around 2.1 ton. A subadult animal (prob-

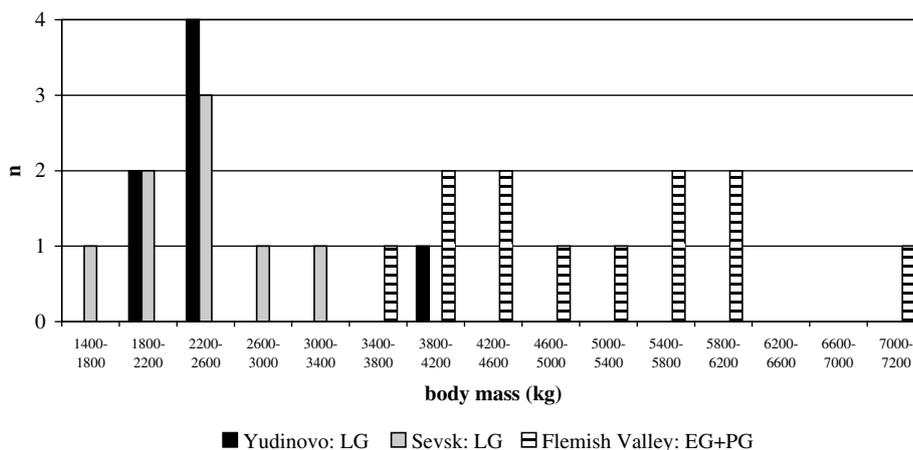
ably a bull) had a weight of at least 2.5 ton, judging from its unfused tibia.

**Age distribution. Dentition.** The molars in 27 skulls and 12 jaws enabled the age at which the individuals died to be estimated. A further 29 skulls and 12 lower jaws could not be aged because the position of the skeletal element in the pavilion was such that the dentition could not be examined in detail, although a rough attribution of age (juvenile or subadult/adult) was possible (Table 3). The assemblage is dominated by age groups ranging from 13 a.e.y. to 48 a.e.y. At least three skulls in the age group 23–34 a.e.y. and one in the age group 35–48 a.e.y. are from cows, judging from the diameter of their tusk alveoli, which is less than 110 mm. One skull, aged 24 a.e.y., has a tusk alveoli diameter of 130 mm and is therefore from a bull. Fig. 17 compares the combined age distribution of skulls and lower jaws of Yudinovo, Mezhirich (Pidoplichko, 1998) and Milovice (Svoboda et al., 2005). Yudinovo differs from both sites in that adult mammoths are well represented, while at the two other sites, young and young adult mammoths dominate the assemblage.

**Postcranial.** The state of epiphysis fusion of mammoth limb bones can be used as an indicator of age. Table 4 groups the limb bones from the pavilion. The groupings are based on the time at which their epiphyses fused, as proposed by Lister (1999). It is interesting that all types of long bone, except for the radius and the fibula, have one or two specimens from a juvenile animal. These specimens probably represent the remains from one young calf (<2 years); all the animal's bones were found in complex 4. In addition, one animal, presumably old, is represented by a completely fused humerus, radius and ulna. Judging from the size of the humerus, it is probably a male. One large unfused tibia, from a mammoth less than 26 a.e.y., is probably from a bull. This agrees well with the presence of a male skull from an animal with an age of 24 a.e.y.

In general, the frequency of the age distribution of the postcranial bones follows, more or less, the frequency of the age groups of the skull and lower jaw, with a large representation of prime adult individuals. However, mammoths of at most 12 years are better represented in the postcranial material. The completely unfused and the distal fusing humeri suggest the presence of at least 12 young mammoths in the assemblage.

**Age distribution of all skeletal elements combined.** Fig. 18 shows the frequency distribution of five age groups, more or less comparable to those proposed by Haynes (1991). The MNI combines those based on the aged skulls, lower jaws, and postcranial elements. Remains of young mammoths and prime adults are best represented, although adolescents are less frequent. Nine individu-

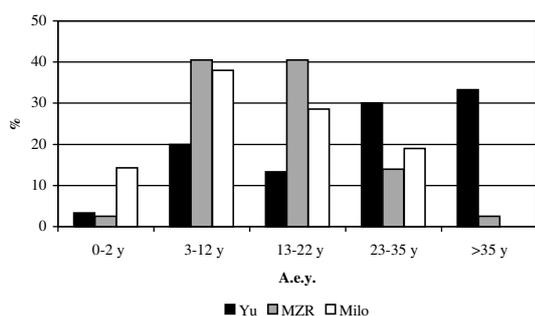


**Fig. 16.** Frequency distribution of the body mass of mammoths from Yudinovo (pavilion), Sevsk (Maschenko et al., 2006) and the Flemish Valley (Germonpré, 1993b), based on full grown tibiae, three subadult tibiae and one full grown humerus (LG: Late Glacial, PG: Pleniglacial, EG: Early Glacial) (see text for explanation).

**Table 3**  
Age distribution of skulls/maxillae and lower jaws from Yudinovo (pavilion)

	NISP		MNI	% MNI
	Skull/max	Lower jaw		
0–2 y	1	0	1	3.3
3–5 y	1	3	3	10.0
6–12 y	3	0	3	10.0
13–22 y	3	4	4	13.3
23–28 y	4	2	4	13.3
29–34 y	5	1	5	16.7
35–48 y	9	1	9	30.0
49–60 y	1	1	1	3.3
Subtotal	27	12	30	100.0
>22 y	1		1	
Juv	1	2	2	
Sad-ad	27	10	27	
Total	56	24	60	

NISP: Number of Identified Specimens, MNI: Minimal Number of Individuals.



**Fig. 17.** Age distribution of the combined mammoth skulls and lower jaws from Yudinovo (pavilion) (Yu), Mezhrich (Pidoplichko, 1998) (MZR) and Milovice (Svoboda et al., 2005) (Milo) (a.e.y.: African elephant years).

als are in the age group 23–34 a.e.y., of which one is probably a bull, judging from the presence of a large unfused tibia and a skull with large tusk alveoli. The age group 35–48 a.e.y. contains nine individuals, all of which probably cows judging from the size of the tibiae. One very old mammoth is present. The very large, completely fused humerus indicates the presence of one old bull.

**Minimum number of individuals.** At Yudinovo (pavilion), the remains of 63 mammoths are preserved *in situ*. At Yudinovo complex 1 and 2, a total of 33 mammoths was estimated (Abramova, 1993).

This brings the total MNI at the whole Yudinovo site to 106 mammoths. At the nearby Epigravettian sites of Mezin and Mezhrichi, the MNI were, respectively, 116 and 110 (Pidoplichko, 1998), similar to the MNI of Yudinovo. At the nearby catastrophic death site of Sevsk, the remains of 33 mammoths were recovered.

### Discussion

In this section, we will argue that the mammoth bone accumulations at Yudinovo (pavilion) are not related to the presence of a natural death site, the gathering by humans of mammoth bones from natural mammoth death sites, or the exploitation of mammoth remains from buried bone beds deposited by running water. The only remaining explanation is, therefore, the use of mammoth bones from actively hunted and killed mammoths. Following this, we will provide a more speculative, though not completely unfounded, treatment of the context in which the mammoths could have been hunted and killed. These more speculative remarks will serve two purposes: (i) to offer a fuller picture of the context of mammoth hunting and (ii) to serve as hypotheses for further investigation.

#### The nature of the human involvement at Yudinovo

The argument here goes by process of elimination. There are only four possible explanations of human involvement with the mammoth bone accumulations at Yudinovo. The available evidence shows that three of them can be eliminated. Therefore, the remaining explanation must constitute the truth of the matter, pending further evidence.

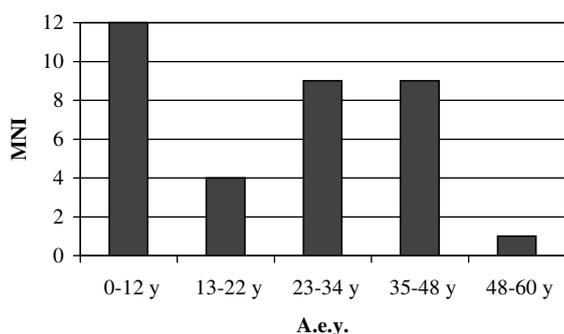
The possibility that Yudinovo is a natural death site can be eliminated for the following reasons: (i) the site has a high density of one mammoth per 1.4 m<sup>2</sup>, (ii) there are few foot bones and small, slender, or fragile elements, (iii) there are no foetal bones, (iv) the frequency distribution of the bones differs from the one at the death site of Sevsk, (v) there are no articulated skeletons, (vi) certain skeletal elements have been sorted, (vii) the breakage pattern of the bones speaks against trampling by mammoths, (viii) there is no abrasion, and (ix) the frequency of mammoths younger than 12 years is well below 85%.

The possibility that Yudinovo is composed of bones scavenged from natural death sites by people can be eliminated for the following reasons: (i) the weathering of the bones is very homogeneous, (ii) the breakage pattern of skulls is from human origin and the fragmentation of postcranial bones is not due to trampling,

**Table 4**  
Age distribution of the mammoth postcranial elements from Yudinovo (pavilion) based on the timing of the fusion of the epiphyses as proposed by Lister (1999) (juv: juvenile)

Humerus			Radius			Ulna			Femur			Tibia			Combined MNI	
Age	NISP	MNI	Age	NISP	MNI	Age	NISP	MNI	Age	NISP	MNI	Age	NISP	MNI	Age	MNI
juv	2	1	juv	—	—	juv	1	1	juv	2	1	juv	1	1	juv	1
<12 y	17	9													<12 y	9
±12 y	3	2													±12 y	2
12–40 y	7	4				<34 y	6	3	<34 y	10	5	<26 y	24	12	±26 y	2
—	—	—				±34 y	10	6				±26 y	3	2	±34 y	6
—	—	—	<45 y	7	4	34–45 y	4	2	34–43 y	7	4	>26 y	5	3	34–45 y	7
>41 y	1	1	>45 y	1	1	>45 y	1	1	>43 y	—	—				>41 y	1
?	4	2	?	—	—	?	2	1	?	6	3	?	5	3		
Total	34	19	Total	8	5	Total	24	14	Total	25	13	Total	38	21		28

NISP: Number of Identified Specimens, MNI: Minimal Number of Individuals, y: African elephant year.



**Fig. 18.** Age profile based on the aged mammoth skulls, lower jaws and postcranial elements combined from Yudinovo (pavilion) (a.e.y.: African elephant years) (MNI: minimum number of individuals).

(iii) the lack of abrasion on the bones, and (iv) the high number of individuals.

The possibility that the Yudinovo site contains bones that were gathered from natural mammoth bone beds can be eliminated for the following reasons: (i) there are several articulated bones from at least four individual mammoths, (ii) humans broke the skulls to obtain the fresh fatty brain, (iii) traces of carnivore gnawing are limited and occur only in certain parts of the site, (iv) the weathering of the bones is homogeneous, and (v) the elements lack abrasion and marks of plant roots. Furthermore, there appear to be no bone beds present near Yudinovo (Soffer, 2003).

However, the taphonomic and palaeobiological analyses show that the exploitation of bones from hunted mammoths is indicated for the following reasons: (i) the site has a high density of one mammoth per 1.4 m<sup>2</sup>, (ii) there are isolated elements and articulated body parts, (iii) the frequency distribution of the bones is similar to the one of the mammoth bone dwellings at Mezhirich, (iv) the breakage pattern of the skulls and scapulae suggests human involvement, (v) there is a tibia displaying cut marks, (vi) chewing by carnivores is very slight, (vii) the bones are weathered homogeneously, (viii) the elements lack of abrasion and marks of plant roots, (ix) the remains indicate an important frequency of prime-aged animals, and (x) there is a preponderance of cows in the remains of adult animals.

#### Yudinovo is not a natural death site

In Africa, water sources attract large numbers of elephants during drought years and many die there from drought-related stress. At these recent natural elephant death sites, the density ranges from one elephant carcass per 35 m<sup>2</sup> for the Shabi Shabi die-off site to one animal per 6 m<sup>2</sup> for the Lememba site (Haynes, 1991: table 4.6). The density is also very low at the catastrophic death site of

Sevsk with one mammoth per 24 m<sup>2</sup>, using data from Maschenko (2002) and Maschenko et al. (2006). In contrast, the density at Yudinovo is very high, well outside the range that occurs at natural elephant death sites, with one mammoth individual per 1.4 m<sup>2</sup>.

Mammoth foot remains, slender and fragile elements, and foetal bones are very well represented at Sevsk (Maschenko et al., 2006). At Yudinovo (pavilion), the absence of these types of bones seems not to be caused by poor bone preservation, since the recovered small fox bones were in good condition. Furthermore, fragments of such mammoth bones can be found elsewhere on the site. Rather, their absence suggests that these types of bones were not deposited at the pavilion but dumped elsewhere.

The frequency distribution of the bones at Yudinovo (pavilion) differs significantly from the one at Sevsk, indicating that for this characteristic Yudinovo can not be compared to a catastrophic death assemblage.

Haynes (1991) remarked that natural death sites of recent African elephants regularly contain articulated body parts. This is in line with the catastrophic death site of Sevsk, where complete articulated skeletons of mammoth calves and many partially articulated skeletons of mammoths in different age categories were preserved *in situ* (Maschenko, 2002). By contrast, at Yudinovo, most bones occur in an isolated state. A number of the bones have been sorted to skeletal element, indicating human involvement.

At Yudinovo (pavilion), the breakage patterns of the skulls are probably of human origin (see below). The postcranial breakage differs from that of recent elephant die-off sites, where most fractures of the bones are created by elephants trampling on bones (Haynes, 1991) as shown by Fig. 9. Furthermore, the mammoth bones from Yudinovo complexes 3 and 4 do not show abrasion. On the flood plain, bones can be abraded via trampling (Lyman, 1994). The lack of abrasion speaks against the possibility that the bones were trampled upon.

In the die-offs sites in Africa, most of the dead elephants are very young (Corfield, 1973). According to Haynes (1991, Table 4.7, Fig. 4.42) the frequency of elephants younger than 12 years reaches at least 85% at such natural die-offs. At Yudinovo, in the combined age profile, which was determined on the basis of the dental and postcranial material, only 34% of the mammoths are very young. This is a much lower percentage than can be expected for a natural die-off site.

The high density of mammoth individuals at Yudinovo (pavilion), the absence of foot bones, slender and fragile bones, and foetal elements, the frequency distribution of the bones, the isolated state of most of the bones and the sorting of some elements, the breakage patterns of the skulls and the fragmentation of the postcranial bones, the lack of abrasion and the frequency of the young mammoths in the age profile show that Yudinovo (pavilion) was not a natural die-off death site nor a catastrophic death site.

*Yudinovo is not composed of bones scavenged from natural death sites*

At Yudinovo, practically all bones show the same weathering rate; they are all, with a few exceptions, slightly weathered. Therefore, they were probably exposed for equal lengths of time at the surface or subsurface. Furthermore, they were covered relatively rapidly. The greater weathering of the tusks could be related to the fact that the weathering of ivory proceeds differently from that of bone; or it might be that these elements were collected from surface finds. The fact that 97% of the bones at Yudinovo (pavilion) show the same degree of weathering (Behrensmeier's (1978) stage 1) indicates that it is unlikely that the bones were collected from a variety of different locations, such as die-offs sites or surface scatters of mammoth carcasses. According to Haynes (1991, p. 313), recent die-off sites of African elephants contain a mix of fresh and weathered bones. If the Yudinovo bones had been collected from a variety of locations, and hence had been exposed for varying periods of time on the surface and in different conditions before transport and burial, the bones would display a wide range of weathering.

At Yudinovo (pavilion), the broken skulls indicate that humans searched for the fresh fatty brain, which could only be obtained from recently dead mammoths (see below). Most probably the breakage pattern of the postcranial bones at Yudinovo is not due to trampling (see above). Furthermore, the mammoth bones from Yudinovo complexes 3 and 4 do not show abrasion (see above).

At Yudinovo (pavilion), the total MNI is 63; when the mammoths from complex 1 and 2 are included the MNI amounts to 106. This is similar to the MNI (110) of the Epigravettian Mezhirich site. According to Pidoplichko (1998), the bones from the mammoth bone dwellings of this site were extracted from hunted mammoths. In contrast, the MNI at the natural catastrophic death site of Sevsk is much lower with 33 individuals (Maschenko et al., 2006). The Sevsk catastrophe happened during spring or early summer. It is difficult to imagine that the high number of mammoth individuals at Yudinovo could have been obtained by scavenging catastrophic death sites. If that would have been the case, it should be accepted that in the neighbourhood of Yudinovo that was occupied during winter, several catastrophic death assemblages occurred, which were then soon after the death of the animals (cf. the breakage of the skull for fresh brain, the homogeneous weathering) scavenged by the Epigravettians. This seems highly improbable.

The homogeneous state of the mammoth bones, the breakage pattern of the bones, the lack of abrasion and the high MNI speak against Yudinovo' being composed of bones scavenged from natural die-off sites or catastrophic death sites.

*Yudinovo is not composed of bones gathered from bone beds*

At Yudinovo (pavilion) a small number of the mammoth bones occur articulated, corresponding to body parts of at least four individuals. It is obvious that at least these elements were deposited when soft tissues were still connecting the bones and that they were obtained from recently dead mammoths. They could not have been collected from old mammoth bone scatters or buried bone beds. Also at the Gravettian Dolní Věstonice site, interpreted as a mammoth butchering site (Svoboda et al., 2005) and the Epigravettian Mezhirich site, where the bones from the mammoth bone dwellings were obtained, according to Pidoplichko (1998), from hunted mammoths, a small number of the mammoth bones were found in anatomical association.

The broken skulls indicate that humans searched for the fresh fatty brain, which could only be obtained from recently dead mammoths (see below).

Only 2.9% of the bones at Yudinovo (pavilion) show traces of being gnawed by carnivores. The large carnivores that could have scavenged the mammoth remains were wolverines, wolves, bears,

lions, and possibly domestic dogs. (Cave hyena was not present in the Russian Plain at c. 15,000 BP.) At Mezin, the frequency of chew-marked mammoth bones is much higher than at Yudinovo (pavilion), reaching 10.3%. It is thought that the bones at Mezin were gnawed by carnivores before their use in the construction of the dwelling (Pidoplichko, 1998). The limited carnivore chewing at Yudinovo (pavilion) occurs mainly in complex 4, especially near the western wall, and is present on protruding bones, which indicates that the carnivores gnawed these bones *in situ*. Apparently, most of the mammoth bone accumulations were protected in some way or were quickly covered by sediment. It may be assumed that if the bones had originated from several sources, the frequency of the damaged bones could be higher and the spatial distribution of the gnawing traces would be more disparate.

As discussed above most of the weathering of the bones at Yudinovo is very homogeneous. By contrast, in the fluvial assemblages from the Flemish Valley the frequency of bones that are in weathering stage 2 or higher fluctuates between 2% and 20% (Germonpré, 1989). Further, in the Pleniglacial fluvial assemblage of Lynford, UK, 99% of the mammoth bones are in stage 2 or higher, which indicates that the bones were exposed for quite a long time before they were buried in the palaeochannel (Schreve, 2006). Given the heterogeneous weathering at the fluvial assemblages, the homogeneous weathering of the mammoth bones at Yudinovo indicates that it is doubtful that the bones were extracted from buried bone beds.

The mammoth bones from Yudinovo complexes 3 and 4 do not show abrasion. By contrast, in the fluvial assemblages from the Flemish Valley, the frequency of abraded bones ranges from 0% to 40% (Germonpré, 1993a). At Yudinovo, plant root traces are lacking. In the fluvial assemblages of the Flemish Valley, root etching on mammoth bones occurs on between 0% and 8% of the bones (Germonpré, 1993a). Given the differences between Yudinovo and the fluvial assemblages with respect to abrasion and plant root traces, it is doubtful that the Yudinovo bones were extracted from buried bone beds.

Judging from the presence of the articulated body parts, the skulls broken for access to the fresh brain, the limited occurrence of carnivore gnawing, the homogeneous weathering of the bones, the lack of abrasion and traces of plant roots, it is unlikely that the Yudinovo mammoth bones were collected from bone beds.

*Yudinovo is composed from bones extracted from killed mammoths*

As already discussed above, at Yudinovo (pavilion) the mammoth bones occur in a dense pattern resulting in a mean density of one mammoth per 1.4 m<sup>2</sup>. This density is comparable to the high frequency of one individual per 1.9 m<sup>2</sup> at Krakow-Spadzista Street (B), which is a mammoth butchering site (Kozłowski, 2003).

The isolated state of most of the bones and the sorting of several skeletal elements at Yudinovo show that it was not a natural death site. On the other hand, the presence of body parts of at least four individuals indicates that they come from recently dead mammoths.

The frequency distribution of the skeletal elements from Yudinovo (pavilion) is similar to that of the mammoth bone dwellings at Epigravettian site of Mezhirich (Fig. 3). The bones of these dwellings were, according to Pidoplichko (1998), obtained from hunted mammoths. The distribution at Yudinovo (pavilion) differs from that of the skeletal elements at the catastrophic death site of Sevsk. It is also different from the distribution at the Gravettian Dolní Věstonice site (Fig. 3). Dolní Věstonice was interpreted as butchering sites (Svoboda et al., 2005). This indicates that Yudinovo (pavilion) is not a typical mammoth butchering site.

The breakage patterns of the mammoth skulls at the pavilion indicate that the skulls were probably broken intentionally by humans. All skulls that are visible have their tusk alveoli broken and

the tusks removed. Many ivory processing areas were discovered at Yudinovo, especially outside the pavilion. The prehistoric inhabitants probably used the freshly extracted tusks to make ivory tools and ornaments.

The systematic way in which the mammoth braincases were opened suggests that this was done by people in order to gain access to the fatty brain (Fig. 7). Analyses of the plant–animal subsistence ratios amongst recent northern hunter–gatherers show that subsistence is derived mainly from animal foods since in northern latitudes, where there are fewer plants, gathering is limited (Binford, 2001, Table 5.10). However, the inclusion of large amounts of animal food requires greater ingestion of fat or carbohydrate to prevent protein toxicity (Speth, 1991; Cordain et al., 2000), especially to the outcome of the consumption of large amounts of lean meat. Muscle tissue contains less than 3% fat, but other animal tissues, such as adipose fat, bone marrow, organs, and brain, which have a higher fat content, are also consumed (Cunnane, 2000). Fat constitutes 60% of the brain structural matter. The polyunsaturated fatty acid (PUFA) composition of the mammalian central nervous system is nearly completely composed of two long-chain polyunsaturated fatty acids (LC-PUFA), docosahexaenoic acid (DHA) and arachidonic acid (AA) (Broadhurst et al., 2002). Abundant LC-PUFAs, and in particular DHA and AA, are considered as absolute requirements for the advanced neural development in humans (Milton, 2000). Mammalian brain tissue is one of the richest terrestrial sources of LC-PUFAs, including both DHA and AA (Broadhurst et al., 2002). According to Shoshani et al. (2006), in adult recent elephants the ratio of brain to body weight is about 1/700. This implies that a mammoth weighting around 2.1 ton would have a brain mass of about 3 kg. Assuming that Epigravettian hunter–gatherers derived about the same percentage of their subsistence from animal food as recent northern hunter–gatherers, eating mammoth brain would have been very useful to compensate for the large amount of protein in the Palaeolithic diet. Furthermore, the mammoth brain would have been their most important terrestrial source of DHA and AA.

The man-made holes found in more than 40% the scapulae (Table 2) are typical for cultural mammoth sites of the region. Such holes in the scapulae were found at Gontsy, Berdyzh, and Mezhirich. The phenomenon has been interpreted as an architectural feature that is involved in the use of these bones for construction purposes (Soffer, 1985; Iakovleva, 2003). Other, complementary, uses may also be imagined. For example, the shoulder blades could have been perforated to allow a better grip on the meat of this quarter for transport, processing, or storage.

Only one bone, a tibia found in grid Z56, displays cut marks; it is from an animal with a reconstructed shoulder height of about 220 cm. Cut marks that indicate butchering are also absent at Dolní Věstonice II (Svoboda et al., 2005). However, the low incidence of human cut marks on the mammoth bones does not show that the mammoths were not butchered by prehistoric people. Crader (1983) observed recent single elephant killing and butchering sites by the Bisa in Zambia. On these elephant bones, cut marks are almost absent; probably because there is so much meat available, the cutting does not go into the bone (Crader, 1983). Haynes (1991) p. 185 surveyed several mass elephant kills in the Hwange National Park (Zimbabwe); no bones were ever cut during meat removal by experienced crews. In addition, Frison (1989) noticed during his experimental butchering of recent elephants with prehistoric tools that the butchering did not leave cut marks on the bones.

The low frequency of carnivore traces is discussed above. The carnivores only had access to a few bones, probably after the construction of the complexes. The rest of the material seems to have been protected from the carnivores in some way or was already covered by sediment.

The low weathering stage of the bones indicates that the remains were covered by sediment relatively quickly after the death of the animals. It is worthy of note that the ends of the most protruding bones in each bone complex show greater degrees of weathering, which indicates that weathering occurred after these bones had been placed in their location in the complexes (Fig. 12). The tips were not yet covered by sediment, while the deeper lying parts were.

The lack of abrasion and plant root traces suggest that the remains were deposited at the pavilion shortly after the death of the animals.

At Yudinovo, calves and young mammoths (<12 a.e.y.) are very well represented together with prime-aged individuals (Fig. 18). The age profile at Yudinovo differs from those at the Gravettian Krakow-Spadzista Street (B), Milovice, Dolní Věstonice I (Svoboda et al., 2005) Krems-Wachtberg (Fladerer, 2003) sites, and the Epigravettian Mezhirich site (Pidoplichko, 1998) (see also Fig. 17). In these sites, the assemblages are dominated by mammoth calves and young mammoths. This may reflect selective predation on juveniles and subadults in these sites (Svoboda et al., 2005). The postcranial remains from adult mammoths at Yudinovo are clearly dominated by cows, judging from the size of the tibiae. The age profile from Yudinovo (pavilion) cannot be explained by killing single bulls that strayed away from the herd. Although bulls could occasionally have been hunted as individual animals, we believe that the large number of adult cows suggests that cows were killed and that their offspring were slain at the same time. Furthermore, it is interesting to note that in the combined age profile of Yudinovo (Fig. 18) the class of young adult mammoths contains fewer individuals. The lowered frequency in the age class 13–22 years at Yudinovo could reflect the lack of males of this age category in the mammoth herds. In culled African elephant samples also, males from about 10–20 years are underrepresented due to their lower frequency in breeding herds (Lindeque, 1991). This is also shown by Haynes (1991, Table 3.1). The percentage of young adult bulls in the Hwange culled herds fluctuates from 10% to 15%, while the percentage of young adult cows ranges from 22% to 24%.

One very old mammoth represents 3% of the age profile (Fig. 18). One old male can be recognized from the presence of a large adult humerus and the presence of two bulls is indicated by the large size of the alveoli for the tusks in two cranial fragments. In addition, the large diameter of a number of tusks indicates the presence of tusks from bulls (Fig. 13). Given the more advanced weathering stages of the tusks compared to the rest of the bone material, it is possible that part of these tusks were surface finds.

The arguments above show that most of the mammoth bones from complexes 3 and 4 at Yudinovo are derived from freshly killed mammoths, taken down as family units or nuclear mother–calf units.

#### *The surrounding context of mammoth hunting*

We will now offer a more complete picture of the ways in which mammoths were hunted and transported, and their products used. The purpose of the argument is to build a plausible picture of the context of mammoth hunting. More concrete confirmation of this narrative is a matter for future investigation.

Ethnographic sources and experimental work confirm that recent African elephants can be killed with spears or projectile points. According to Trilles (1932), Forest People from Gabon hunted elephants by sneaking under a standing elephant and thrusting a spear into its belly; the elephant could also be killed by arrows. Trilles (1932) also mentions the intention of the hunters to kill several unsuspecting elephants gathered together nearby. According to Janmart (1952), the Ituri hunted elephants by creep-

ing under an elephant and plunging a spear into its belly. The Ogiek people from Kenya hunted with dogs and used spears to kill elephants (Hobley, 1903). In Malawi, elephant hunters used arrows (Stannus, 1910). Frison (1989) showed experimentally that Clovis projectile points used with atlatl and darts or thrusting spears can penetrate the thick hide of African elephants and inflict lethal wounds on elephants of all ages and both sexes. The hunting strategy should include several persons.

Comparison of the size of recent African elephants and mammoths shows that it is plausible that prehistoric hunters used the same techniques for hunting mammoths as recent hunter use to kill elephants. Recent African elephants have heights that range from 2.3 m to 3 m for the cows, and from 2.9 m to 3.7 m for bulls (Lee and Moss, 1995). Hanks (1972) gives a weight of 2.5 ton for cows and a weight from 4.7 ton to 6 ton for the bulls. The Late Glacial mammoth cows of the Russian Plain probably had a shoulder height ranging from 2.1 m to 2.5 m and had a mean body mass of about 2.2 ton. One bull was 2.85 m high and had a body mass of around 3.8 ton. The fact that the mammoths from the Russian Plain were somewhat smaller than the recent African elephants, which were traditionally hunted with spears and/or arrows (see above for references), shows that the killing, handling and processing of the Yudinovo mammoths must have been feasible. In addition, the mammoths from the Russian Plain were much smaller and lighter than the Pleniglacial and Early Glacial mammoths from Western Europe (Figs. 14–16). They were also smaller than the Late Glacial mammoth found in Shrewsbury (UK), which has a skeletal shoulder height of 3.1 m (Coope and Lister, 1987), resulting in a shoulder height of about 3.3 m and a body mass of around 5.5 ton. Maschenko et al. (2006) remarked that during the Late Glacial differences in shoulder height existed between Western and Eastern European and Western and Eastern Siberian mammoths, which reflect true differences in stature amongst isolated populations of the woolly mammoth at the end of the Last Glacial. According to Lister and Sher (2001), the Late Glacial mammoth populations in Eastern Siberia demonstrate a sharp decrease in body size. On the other hand, the Late Glacial mammoths from Vochya Griva, a site from western Siberia, had shoulder heights reaching 3.7 m (Leschinsky, 2003). The mammoths of Yudinovo are amongst the smallest mainland mammoths, and were small enough to be hunted.

Interestingly, two cases of direct evidence for mammoth hunting during the Upper Palaeolithic exist at two Russian sites. At Kostenki I, Russian plain, dated to around 21,000 BP (Sinitsyn et al., 1997), a mammoth rib with a fragment of a silex point testifies to direct contact between the animal and a prehistoric hunter (Praslov, 2000). At Lugovskoe, a site in western Siberia, a thoracic vertebra from an adult mammoth cow, found in stratum 2, shows a penetrating injury with quartzite inserts stuck into the vertebral body. The wound was probably inflicted by a point with two slots for blade inserts (Zenin et al., 2006). According to Zenin et al. (2006), the projectile was thrown from within 5 m of the animal, so the mammoth was killed at close range. The damaged vertebra was dated directly and has an AMS age of  $13,465 \pm 50$  BP (KIA-19643) (Zenin et al., 2006), which suggests that stratum 2 of Lugovskoe is comparable in age to Yudinovo. These two cases clearly demonstrate that Upper Palaeolithic people were capable of hunting mammoths.

On the basis of his experimental work on elephant hunting, Frison (1989) postulated that if prehistoric people had developed a strategy of eliminating the matriarch, the other members of the family unit could then have been killed more easily.

We concluded that the Epigravettian people of Yudinovo were able to take down nuclear mother–calf units and family units of mammoth. It was postulated above that the mean size of family units of mammoth cows in the age group 23–34 a.e.y. was around

three individuals and the mean size of family units led by older matriarchs (>35 a.e.y.) was about six individuals. If that is the case, the family units led by the nine older matriarchs, including three two-generation groups, would have contained around 54 mammoths and the units led by younger cows would have delivered around 15 individuals, yielding a total of about 69 individuals. This latter figure is quite close to the MNI of 63 found at the Yudinovo pavilion and seems to confirm the assumption that mammoth family units were smaller than units of extant elephants.

Frison (1989), in his experimental work on recent elephants, also butchered several elephant bodies with Clovis tools. He found out that the main effort required lies in cutting the hide. Once this is done it is relatively easy to remove the skin. It was also relatively easy to strip the flesh from the carcass and to disarticulate the major long bones. However, several butchers are necessary to facilitate the processing of skinning, meat removal, and dismemberment (Frison, 1989).

With respect to the potential number of persons that lived at the complex base camp of Yudinovo, we can appeal to recent studies of hunter–gatherers societies. According to Hamilton et al. (2007), the population structure of hunter–gatherer societies within and across cultures and continents is a self-similar network with the number of individuals belonging to each successively higher level of organization showing a ratio of about 4. The number of individuals in an aggregated group, defined by Binford (2001) p. 117 as a residential group during the most aggregated phase of the yearly cycle, is about 54 (Hamilton et al., 2007). From available data for which they list references, Byers and Ugan (2005) found that an adult African elephant can be processed by eight to 35 persons in 2.5–10.5 h. If we assume that Binford's figure of 54 people per aggregated group can be applied to Yudinovo, pro rata butchering times for the smaller adult mammoths and for the calves must have been feasible. However, the butchering undoubtedly required the efforts of all capable inhabitants. It is likely that the hunting took place during the autumn and/or winter, so that the large quantities of meat, fat, organs, skulls with brains, and fatty bones could be stored relatively easily in frozen condition. No unequivocal storage pits have been recognized on the site. However, ethnographic data show that high arctic and boreal peoples commonly kept their winter stores in aboveground facilities (Binford, 1993). Hence, it may be supposed that the mammoth hunters at Yudinovo did the same.

It is feasible that dogs were present at Yudinovo, although no skeletal element of this animal has so far been found. That it is possible that dogs were present is established by the fact that dogs existed at the time and were already domesticated. Three Epigravettian mammoth dwelling sites on the Russian Plain have yielded evidence of the presence of dogs. At the nearby site of Eliseevich, two dog skulls have been recognized (Sablin and Khlopachev, 2002, 2003). Pidoplichko (1998) interpreted the small Mezin canid skull 5490 as being from a dog, judging from its relative small size and the shortening of its snout. According to Pidoplichko (1998), a number of indirect signs, such as specific gnawing marks on some mammoth bones, suggest that dogs were present at Mezhirich. Furthermore, the Gravettian site of P  $\subseteq$  edmosti yield indications that dog domestication dates from an age earlier than the Epigravettian. Here, several canid skulls with short snouts point to wolves being kept in captivity as a first step towards domestication (Benecke, 1995). In addition, according to Lindblad-Toh et al. (2005) an ancient genetic bottleneck accompanying the domestication of dogs occurred around 27,000 years ago. Finally, when humans entered the New World 12,000 to 14,000 years ago, they were accompanied by dogs (Fiedel, 2005; Leonard et al., 2002). At that time the ancestral population of dogs in Eurasia was probably already large (Leonard et al., 2002). Given the foregoing, it is possible that dogs were present at Yudinovo. In that

case, it is probable that the dogs were used for tracking, hunting, and transport. Transport could have been organized using the dogs as pack animals (cf. Balikci, 1970; Morey, 1986) as has been proposed for the North-American Palaeoindians (Fiedel, 2005).

We can also construct a picture of how the mammoths were hunted. Proboscideans make trails between important places, such as water points, forage patches, mineral sources, and socializing sites (Haynes, 2006). Late Glacial mammoth tracks found in Alberta Province, Canada, followed the eastern bank of a palaeo-river valley floor and occur through 60 cm of aeolian sediments, which indicates that mammoth herds used the same trails over a time span of about 200 years (McNeil et al., 2005). It is likely that the mammoths from the Russian Plain also followed traditional trails for generations. The Yudinovo hunters could have used these trails to track the animals.

The hunting of a mammoth herd would have taken place at the most a few times during the cold season. It is possible that the animals were killed near the palaeo-Sudost River, while they were concentrated on feeding in the thickets along the river or drinking water from the river. The prehistoric hunters could have used the shrubs for cover to approach the occupied mammoths. The mammoths could have been searching for the branches or bark of trees and shrubs of alder or willow (cf. Olivier, 1982) or they might have gone to the river to drink. Remnants of willow and alder were found in the dung preserved in the gastrointestinal tract of several frozen mammoths (van Geel et al., 2008). According to Vereshchagin and Baryshnikov (1982), mammoths used their tusks to break river ice to reach the unfrozen water for drinking. In recent musk ox, eating snow requires much more handling time than drinking liquid water in relation to food intake (Crater and Baboza, 2007). Given that mammoths probably spent a large part of the day grazing (Guthrie, 2001) just as recent African elephants do (Owen-Smith, 1992); it is likely that they preferred to drink cold water rather than to eat snow in order to gain time. The Yudinovo hunters could have moved towards the occupied mammoths through the shrubs, to cover their approach as they crept as close as possible. They could have aimed for the matriarch first and afterwards killed off the younger members of the herd. The initial butchering of the killed mammoths probably took place on the kill site. The body parts would then have been moved to the nearby Yudinovo site, maybe with the help of large dogs.

In our opinion the hunting of adult and juvenile mammoths at Yudinovo was possible thanks to a combination of the small body size of the mammoths, the low number of individuals in the mammoth family units, and the presumed presence of large dogs.

That mammoth hunting existed in the past is shown by Nogués-Bravo et al. (2008). Through combined climate envelope and population models, these authors demonstrate that hunting pressure is clearly involved in the extinction of this pachyderm. Furthermore, Mussi and Villa (in press) show that the woolly mammoth was hunted during the Mousterian.

According to Svoboda et al. (2005), one argument in favour of intentional mammoth hunting uses the faunal composition of a mammoth site as a basis. Besides the high frequency of mammoth bones, such sites are characterized by important occurrences of smaller animals. The latter could not have supplied the prehistoric inhabitants with sufficient food resources. Taking into account the low plant–animal subsistence ratio in northern hunter–gatherers, the Palaeolithic diet was probably dominated by animal food, especially during the cold season when plant resources decline. Hence, the meat and fat content of the mammoth bone deposits should be considered when assessing the food consumption of the prehistoric people. The high frequency of both mammoth and fox remains at Yudinovo goes along with the argument of Svoboda et al. (2005) (Table 1). Surplus mammoth meat could have been used to feed dogs, if they were present, or traded or shared with other groups.

## Conclusion

The taphonomic and palaeobiological characteristics of the abundant mammoth bones from complexes 3 and 4 at Yudinovo (pavilion) were examined in detail. The most likely explanation of the presence of mammoth bones and the human involvement with them is that they originated from freshly killed mammoths. We have shown that the bone complexes are not natural death sites, that the bones from the complexes were not “scavenged” from natural death sites, and that mammoth remains were not exploited from natural bone beds. We have demonstrated by process of elimination that, pending further evidence; mammoth hunting is the only plausible explanation for the presence of mammoth bones at Yudinovo. The selection of bones found in the pavilion accumulated as a result of the extraction of certain skeletal elements and body parts from the freshly killed mammoths. Using available evidence, we have proposed a possible context in which mammoth hunting could have taken place.

We hope our study can widen the discussion on the possible existence of mammoth hunting during the Upper Palaeolithic and that we could provide a context against which future researchers can measure their findings.

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