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Wooly mammoth mass accumulation next to the Paleolithic Yana RHS site, Arctic Siberia: its geology, age, and relation to past human activity

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ABSTRACT

In 2001, the Yana RHS archaeological site was discovered in the lower Yana river valley, Arctic Siberia. Its radiocarbon age is about 28 000 BP. While enormous amount of Pleistocene mammal bones was excavated from the site, the mammoth bones occurred at an unexpectedly low frequency. That was interpreted as an indication of the limited role of mammoths in the subsistence economy of the Pleistocene Yana people. In 2008, next to the excavation local ivory miners opened a mass accumulation of mammoth accompanied by the artifacts. About one thousand mammoth bones from at least 26 individuals, and few wooly rhinoceros, bison, horse, reindeer, and bear bones have been unearthed there. Stratigraphy and radiocarbon dating provide evidence for cultural layer of Yana RHS and the mass accumulation of mammoth to be coeval. The geology and taphonomy of Yana mass accumulation of mammoth indicate its anthropogenic nature. Discovery of the anthropogenic mass accumulation of mammoth next to the Yana site suggests a greater role of mammoth in the subsistence practices of the Pleistocene Yana people than previously thought.

1. Introduction

In 2001, the Yana RHS Paleolithic site was discovered far north of the Arctic circle, some 100 km from the Laptev Sea coast in the Yana river downstream area (Fig. 1). Its age is 28 500–27 000 ^{14}C BP (Pitulko et al., 2004). Along with the Mamontovaya Kurya site (Pavlov et al., 2001), this site represents the oldest evidence of the pre LGM human habitation north of the Arctic circle.

Beginning in 2002 an archaeological expedition led by Pitulko has been conducting excavations at the site and surveying the adjacent area. During this work six loci, situated tens to several hundred meters from each other, have been revealed (Fig. 1):

ASN, studied in 2001–2002;
TUMS 1, studied in 2002;
NP (the main excavation area), studied in 2002–2009;
Yana B, studied in 2003, 2004, and 2008;
SP, studied in 2002–2004, and 2008;
Upstream Point, studied in 2004–2006.

Two localities, ASN and the Upstream Point, are completely eroded and have yielded surface finds only.

Three localities, TUMS 1, NP, and Yana B, contain a well-preserved *in situ* cultural layer. By spatial organization, stratigraphy, and radiocarbon dating, all of these loci represent separate but roughly contemporaneous archaeological sites. There is no cultural difference between them. At the same time, they may have differences determined by seasonality and/or function of the site area (Pitulko and Pavlova, 2007; Pitulko, 2010).

For years, the SP locality yielded numerous lithic artifacts and fragmented bones from merely surface concentrations. It was found that artifacts have sited at different levels of the alluvial, proluvial, and solifluctional fill of the small erosion channels of the terminal Pleistocene and/or Holocene age. These preliminary data suggested that the cultural layer at the SP was reworked and probably no longer exists *in situ*. In 2008 the source horizon of the cultural material at the SP locus was established. It became clear that all *in situ* loci of the Yana RHS belong to the same stratigraphic level. This conclusion became even more firm after the sparse mammal bones and artifacts were found between the occupation spots at the TUMS 1, NP, Yana B, and SP. The quantity of bones and artifacts increases closer to the occupation spots.

Excavations of the cultural layer of Yana RHS have yielded numerous lithic and bone artifacts and more than 80 000 Pleistocene mammal bones (intact and fragmented). Many of them exhibit traces of butchering and/or use. Species composition is dominated

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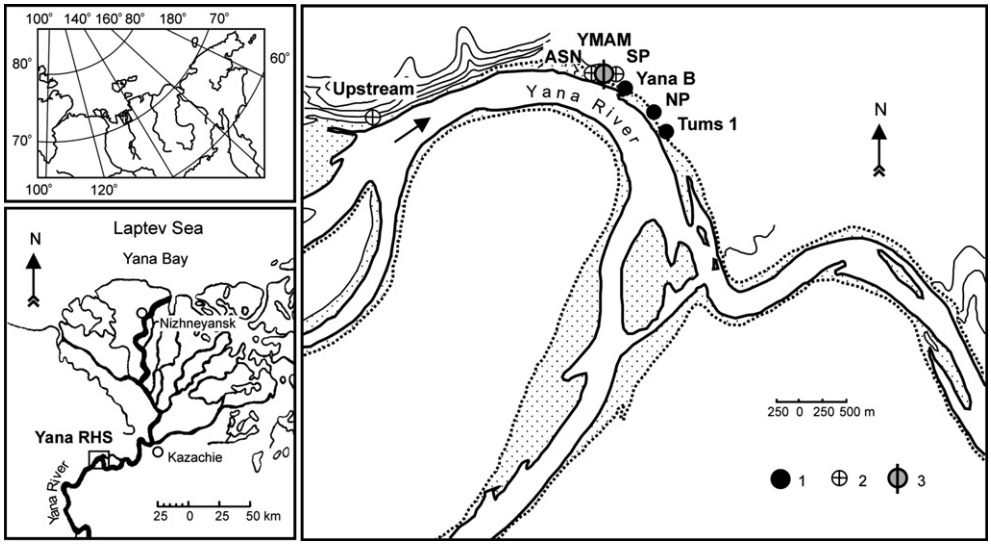

Fig. 1. Schematic map of the Yana RHS site area (modified from Pitulko, 2010). 1 – localities with *in situ* cultural deposits, 2 – localities with redeposited cultural material, 3 –Yana mass accumulation of mammoth (YMAM).

by *Equus caballus* (horse), *Bison priscus* (Pleistocene steppe bison), *Lepus tanaiticus* (Pleistocene hare), and *Rangifer tarandus* (caribou), whereas *Mammuthus primigenius* (wooly mammoth) bones are significantly less numerous, about 3% of the total bone collection (Pitulko et al., 2004; Pitulko, 2010). This percentage of mammoth was much smaller than what was found in the numerous natural Late Pleistocene mammal bone concentrations known within the region. In such natural concentrations (except for a few mass accumulations of mammoth), mammoth bones typically represent from 10% to 25% of the yield (e.g., Sher, 1974; Kuznetsova and Kuzmina, 2000; Kuznetsova et al., 2001, 2006; Nikolskiy, 2002; Nikolskiy, unpublished data). From the low percentage of mammoth bones in the Yana RHS, in comparison to that in most of the regional natural accumulations of bones, and from the fact, that in some Siberian (Ermolova, 1978) and European (see, e.g., Soffer, 1993; Velichko et al., 2008) Upper Paleolithic sites the mammoth bone fraction is much higher than 3%, it was concluded that mammoth played a negligible role in the subsistent economy of the Pleistocene Yana people (Pitulko et al., 2004; Pitulko, 2010). This assumption potentially could be an important argument in the discussion of the human–mammoth interaction in the context of the early human economy, and of the mammoth extinction problem (Nikolskiy et al., 2010b). However, the unexpected discovery of a mass accumulation of mammoth next to the Yana RHS casts doubt on this preliminary conclusion. The history of this discovery is following. Long before the beginning of the Yana RHS excavations, there was intriguing information about the repeated finding of mammoth tusks and bones not far from the place, where subsequently the SP locus have been found. This locality is 400 m upstream from the main excavation area at the NP and approximately 130 m from the Yana B area. In July of 2008, the water level in the Yana River was unusually low and remained at that level for more than a month. This situation allowed a group of local people to start an ivory mine 20 m upstream from SP locus using a powerful jets of water (water monitors). They washed a tunnel that extended for tens of meters inside the frozen deposits of the river bank. Unexpectedly, this tunnel broke into an enormous bone accumulation that also contained lithic and bone artifacts.

This article discuss the first results of the study of the remarkable Yana mass accumulation of mammoth (or YMAM hereafter). Special attention is given to geology, dating, and the role of human in the origin of the YMAM.

2. Stratigraphy of the YMAM and occurrence of mammoth bones in the deposits

2.1. Location and stratigraphy

The newly discovered mass accumulation of mammoth is located next to the Yana RHS Paleolithic site in the Yana river downstream area at 70° 43′ 25″ N, 135° 24′ 47″ E (Fig. 1). Here, along the left river bank, frozen Quaternary deposits are exposed, building III (40–45 m) and II (16–18 m) stream terraces (Pitulko et al., 2004, 2007).In the terrace II, that bears the cultural layer of the Yana RHS and the YMAM, four geological members can be distinguished (Fig. 2A). These members are separated by stratigraphic unconformities and erosion surfaces that correspond to extensive breaks of sedimentation. The basal, erosional, part of the terrace II (Fig. 2A: Members 1–2) occurs only in the upstream area of the exposure. Its age is proposed to be within the end of the Early Pleistocene and the beginning of the Late Pleistocene (Basilyan et al., in preparation). This ancient alluvium is a remaining of the terrace III fill, that have been partly side-cut and down-cut by terrace II. The Members 3 and 4 build the actual fill of the terrace II (Fig. 2A; Fig. 2B: Bed 1–5). At the top of the sequence there are younger erosional cuts filled with the terminal Pleistocene and Holocene deposits (Bed 5).

The formal description of the terrace II fill provided in the Appendix 1.

Bed 3 of the alluvial fill of the terrace II comprises the cultural layer and the mammoth bone-bearing lens (YMAM).The *in situ* up to 0.4 m thick cultural layer can be distinguished from the sequence of the flood-plain greenish-gray sandy silts by its specific light reddish brown color (possible paleosoil) and also by numerous fragmented bones, lithic debitage, and stone tools. It occurs 7.5 m above the average summer water level and is overlain by 8–11 m of frozen sediments. The paleosoil-like layer is traced for several hundred meters along the river bank up to the SP locus. Thus, paleosoil-like layer, that bears sparse findings of mammal bones and artifacts, spreads out almost to the place where the YMAM was found. In a distance of 50 m from the YMAM, the paleosoil-like horizon starts falling and gradually transforms into channel deposits of a small creek, a side channel of the pra-Yana. The width of its valley was 50–60 m (Fig. 2). At the YMAM locality, this falling layer reaches the modern river water level and then drops below it.

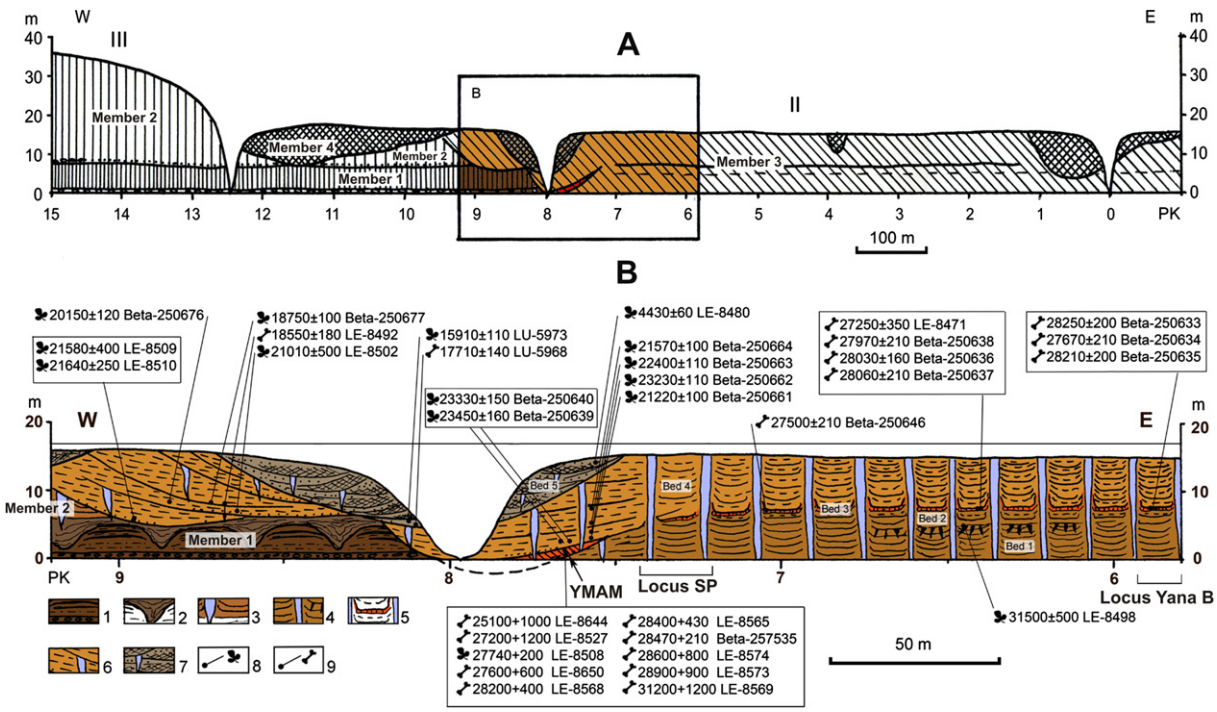

Fig. 2. Stratigraphy of the Yana River left bank bearing the mass accumulation of mammoth and the cultural deposits. A – schematic profile of the II and III river terraces within the limits of Yana RHS. 1–4 – principal members of the Quaternary deposits. Member 1 – alluvium-lacustrine and thaw-lake deposits, end of Early Pleistocene – Middle Pleistocene; Member 2 – alluvium-lacustrine and aeoloian deposits, Early Late Pleistocene; Member 3 – Late Pleistocene alluvium; Member 4 – alluvial and proluvial deposits, Terminal Pleistocene and Holocene. Reference lines: dashed line – contact of Bed 1 and Bed 2; solid line – Bed 3. B – detailed profile of the terrace II. 1 – melted alluvial deposits, end of the Early Pleistocene; 2 – pseudomorphs by ice wedge, Early – Middle Pleistocene; 3 – alluvial deposits, end of the Middle Pleistocene – beginning of the Late Pleistocene; 4 – flood-plain deposits older than the layer that holds YMAM bone-bearing lens with artifacts; 5 – alluvial deposits that hold cultural layer and YMAM bone-bearing lens (Bed 3); 6 – alluvial deposits that overlain the YMAM bone-bearing lens and the cultural layer; 7 – alluvial and proluvial deposits, terminal Pleistocene and Holocene; 8 – radiocarbon dates received on plant macro remains; 9 – radiocarbon dates received on bone collagen. Vertical wedge forms for items 3–5, 6, 7 – ice wedges of different age and genesis.

Paleosurface of the creek bank is clearly marked by lens filled by well sorted small-size pebbles (Figs. 3 and 4).

Most of the mammoth bones were found above this layer whereas few of them occurs in the upper part of the pebble lens. Consequently, it has to be concluded that the human occupation spots were located on the surface of the flood-plain terrace, while at the same time the mammoth bones of the YMAM had been concentrating on the bank of the small stream, that resulted in the YMAM formation (Fig. 5).

2.2. Occurrence of mammoth bones in the deposits

The tunnel was examined immediately after it was cut into the frozen river bank by the ivory miners. A 46-m-long sub-horizontal tunnel, up to 4.5 m width, went through the bone-bearing deposits (Figs. 6 and 7). From the first 20 m of the tunnel, almost all bones were collected except for the tusks of more than twenty mammoth individuals, one mammoth skull and two skulls of wooly rhinoceros that were taken by the miners. Most of the bones from the deeper part of the tunnel were impossible to collect because of a flood resulting from the rising water level and a roof collapse caused by the rapid melting of walls supporting the ceiling of this artificial cave. The spatial distribution of the bones was mapped guiding by the shape of the tunnel, since it was cut only in the limits of the bone-bearing body. Thus the 3D shape of the tunnel made available to outline the spatial distribution of the bones in the deposits. Here

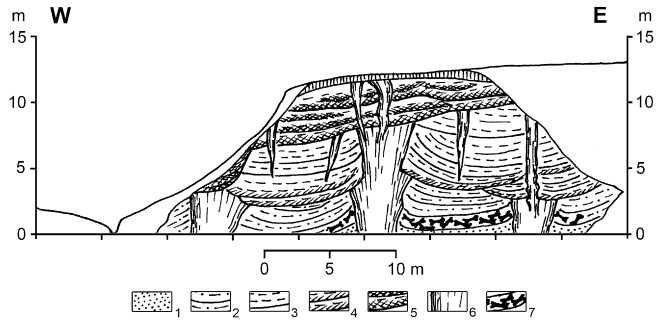

Fig. 3. Detailed stratigraphy of the sequence with YMAM bone-bearing lens at the base. 1- sands; 2 – sandy silts; 3 – silts; 4 – silts with roots of grass plants; 5 – peaty, wood-rich organic silt; 6 – ice wedges; 7 – bone-bearing lens.

Fig. 4. Photography of the stream gravels and pebbles at the base of the sequence – the remnant of the small stream bank. Most of the mammoth bones from the YMAM were found above this layer, few of them occurs in the upper part of the lens.

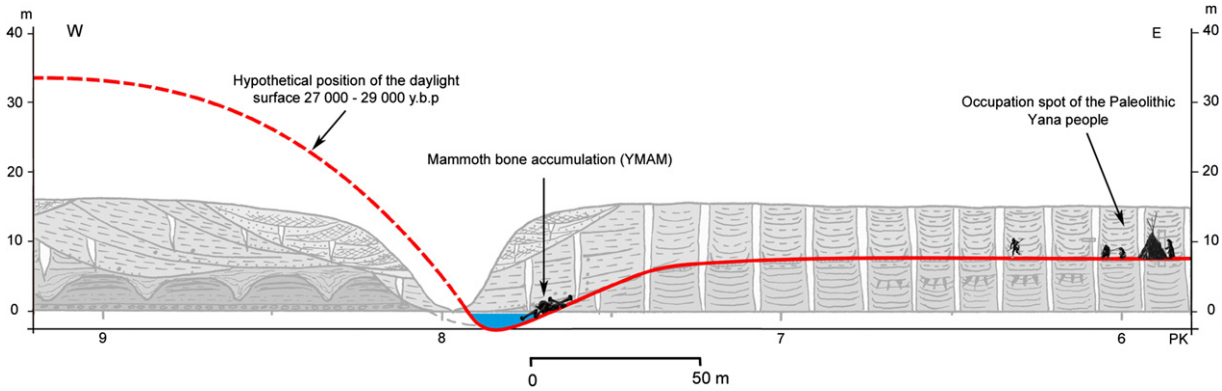

Fig. 5. Possible reconstruction of local topography for the time of human occupation episode.

we should stress, however, that although we have sketched the general shape of the bone distribution in the deposit, the detailed mapping of the most of the individual bones was not possible due to the very short time when the bone-bearing lens was available for study.

As it was mentioned, the bone-bearing deposits at the YMAM cut into underlying sediments to a depth of 7 8 m, filling the buried valley of a small stream that once was a tributary of a larger waterway. The bone accumulation stretches along the eastern side of the buried valley for more than 50 m in the form of a band that is up to 4.5 m wide (Fig. 7). It is oriented by azimuth of 330°–320°. The base part of the bone-bearing deposits has a general inclination westward and rises up to 1–1.5 m toward the former creek bank. Therefore, the bones were accumulated on the left bank of the small stream running in this place from NNW to SSE.

Even a pair of skeletal elements that would be in anatomical order was not found within the studied area. Bone concentration in the YMAM lens is irregular, separate local accumulations, "piles", up to 3 m long are noted (Fig. 7). In the piles, bones are found to be from many different individuals. Skeletal elements of different size, density, weight, and hydrodynamic characteristic occur simultaneously in all of these concentrations (Fig. 6B, 8, 9).

One of the concentrations includes a number of the same skeletal elements from several mammoth individuals, such as mandibles, skulls, and limb bones. The most remarkable peculiarity is that many bones from this local concentration were arranged by skeletal

Fig. 6. A portion of the left Yana River bank where local ivory miners made a 46 m long hole that exposed the mass accumulation of mammoth next to the Yana RHS SP area (A). Mass mammoth accumulation inside view, with numerous bones sticking out of the walls of the ivory mine (B and C). Some of the bones were pushed upward along the ice wedge margins for 4 m by the cryogenic processes. A sort of fog produced by warm air contact with deeply frozen sediments (C) was in some cases an obstacle for the study of the bone lens.

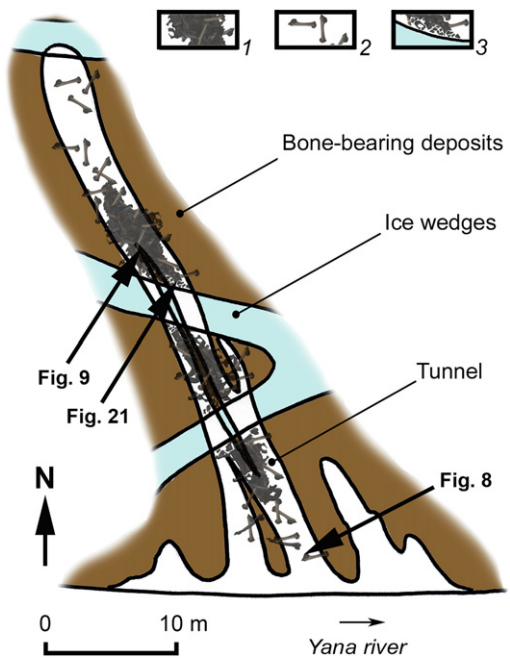

Fig. 7. Occurrence of mammoth bones in the deposits. The horizontal section of the bone-bearing lens is shown. 1 – separate irregular accumulations up to 3 m long "piles"; 2 – dispersed bones; 3 – bone fragments, which have been pushed up from the original position along the ice wedge margin.

elements, including for example five mandibles (Fig. 9). It is important to note that this bunch of bones had been depositing during a long time since it consists from the vertical sequence of bone clusters separated from each others by a definite layers of silty sands, moreover, at least mandibles had been depositing exactly at the same place (Fig. 9).

Many lithic artifacts and worked bone and ivory have been discovered among the mammoth bones (Fig. 9).

3. Paleontological material from the YMAM

3.1. Inventory and abundance of taxa, bone elements count, and the minimum number of individuals (MNI) of buried mammoths

1032 bone specimens (intact bones and bone fragments) have been identified from the YMAM (Fig. 10). This count includes specimens that were withdrawn by miners and were not available for the regular study. Most of the bones belong to mammoth (NISP = 1012), while only a few of them are from the other mammal species (NISP = 20): *B. priscus* – Pleistocene steppe bison, *E. caballus* – horse, *Coelodonta antiquitatis* – wooly rhinoceros, *R. tarandus* – reindeer, and *Ursus arctos* – brown bear (Table 1). A piece of unidentified soft tissue, dung-like masses and disperse mammoth hairs have also been found among the bones.

The estimate of the minimum number of individuals (MNI) of mammoths discovered at YMAM is based on a number of different skeletal elements and size of the bones from the collection. These study lead to an estimate of 26 mammoths. Logic would suggest, however, that the actual number of mammoths that have been

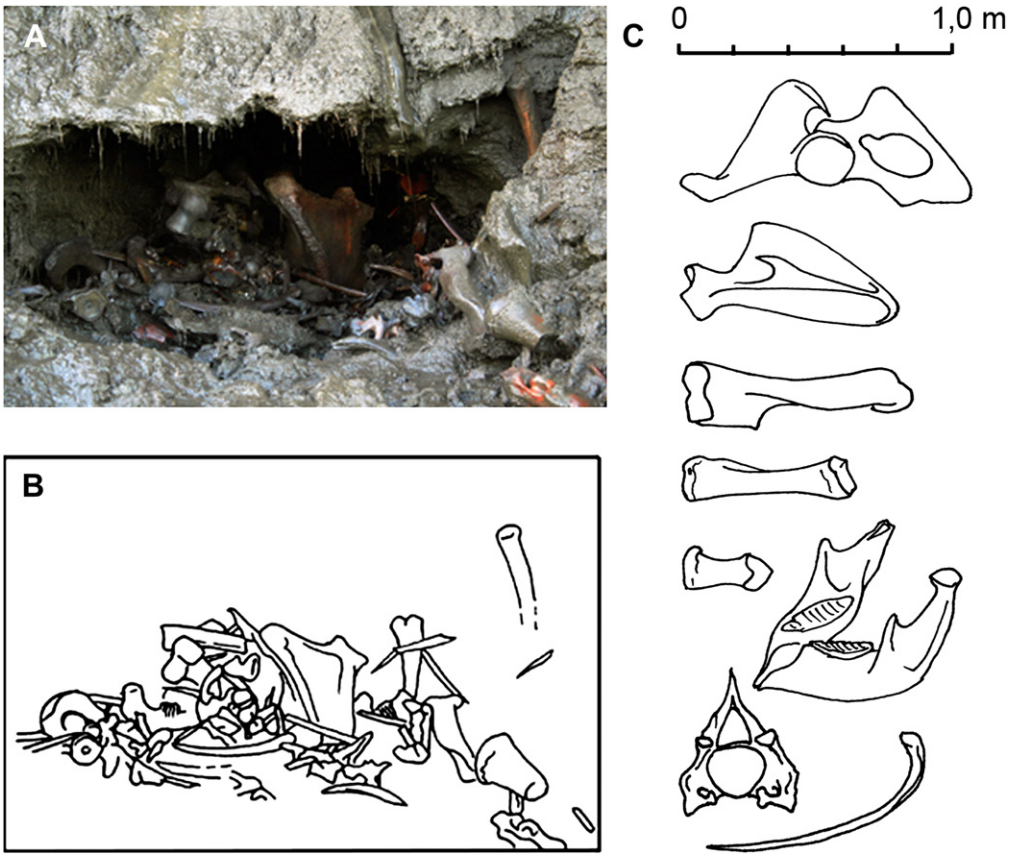

Fig. 8. Appearance of one of the bone concentration revealed within the YMAM (front view). A – photograph; B – drawing of the same profile; C – size classes of skeletal elements from this cluster.

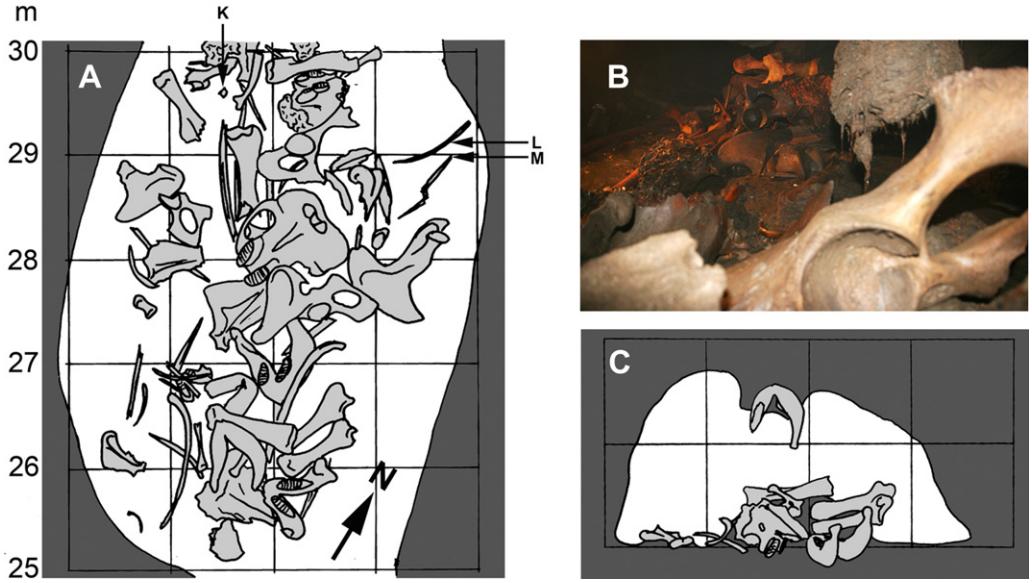

Fig. 9. Upper view (A), vertical crossection in a distance of 26 m from the tunnel entrance (B), and photograph of the most important "bone pile" found from YMAM (see Fig. 7 for general plan). The clusterincludes a number of the same skeletal elements from several mammoth individuals, such as mandibles, skulls, and limb bones. Many bones were arranged by skeletal elements (for example 5 mandibles shown in the sketch). Bones had been depositing during a long time since the bunch consists from the vertical sequence of bone clusters separated from each others by a definite layers of silty sands. The unnatural sorting of the bone elements in this cluster is a key evidence of the artificial origin of the YMAM. Also several artifacts have been found among the bones: lithic artifact (K), and broken ivory foreshafts (L and M).

buried in YMAM must be much bigger. Some observations and suppositions may support that point:

- Only no more than half of the bones have been collected (even from the opened part of the bone lens) because of the raised water level and the collapse of the tunnel roof;
- The bone-bearing deposits did not lens out during the ivory mining up to 46 m inside the river bank, the furthest point reached by the miners, this why many bones remains in the deposits;
- Some bones (particularly tusks) withdrawn by miners could not be count;
- Information or rumors about mammoth bones and tusks found at the exact location have fascinated local fortune hunters for decades. Because we know that lateral erosion near the river occurs as quickly as 5–6 m per a year (as calculated by instrumental observations starting in 2003 (Pitulko, 2010)), we can conclude that a significant part of the originally deposited bones of the YMAM has already been washed out by the Yana River.

Fig. 10. Collected mammoth bones (took out from the bone lens by ivory miners) resting on the gravel beach nearby the expedition camp site where preliminary examination was done.

Thus, although the documented MNI of mammoth from the YMAM is 26, it is definite that YMAM originally held the bone remains of significantly more individual mammoths.

Different elements of the mammoth skeletons occur unequally in the collection (Table 2; Fig. 11). Small limb bones (carpal, tarsal, metapodial, phalanges, and patellae) are poorly represented, as are vertebrae, sternums and fibulae. Ribs and teeth sets as well as mandibles, skulls, ulnare and radiuses are not complete. At the same time, some long limb bones, pelvic bones, scapulae and tusks are represented more in proportion to the estimated minimal number of individuals (Table 2; Fig. 11).

3.2. Bone preservation

Nowadays certain progress is reached in the interpretation of taphonomic observations on fossil mammal bones (Behrensmeyer et al., 2000). In particular an analysis of different features of peri- and post-mortal alterations of an organism tissues sometimes allows conclusions on causes of death, manner and rate of a burial, and environmental conditions around buried remains. These data are important for our investigation therefore we have carefully studied all aspects of mammoth bones preservation.

For YMAM bone collection we distinguish the following features of bone preservation: surface dissolution and/or root etching (Fig. 12); transverse fractures (Fig. 13); gnaw marks (Fig. 14); presence of soft tissues inside and outside of the bones (Fig. 15); surface fissuring (Fig. 16); water rounding (Fig. 17) and cut marks. Percentage of each of this patterns within the YMAM bone collection is shown on Fig. 18. Unfortunately, it was impossible to map spatial distribution of the bones with different preservation degree

Table 1
Mammal bones NISP identified from the YMAM.

Skeletal element	Number of remains/numbers of remains taken by miners
Mammoth remains	
Mammuthus primigenius Blumenbach	
Total	992/20
Skull (fragments)	9 (from 5 individuals)/ 2 (from 2 individuals)
Mandible (fragments)	8 (from 5 individuals)
Teeth	27
Tusk	11/18 (for more than 11 individuals)
Vertebra	189
Rib	342
Sternum (fragments)	5 (from 4 to 5 individuals)
Scapula, left	14
Scapula, right	25
Humerus, left	14
Humerus, right	26
Ulna, left	8
Ulna, right	16
Radius, left	9
Radius, right	8
Pelvis (half-part and fragments)	41
Femur, left	16
Femur, right	15
Tibia, left	21
Tibia, right	21
Fibula	7
Calcanea, left and right	9
Patella, left and right	6
Astragal, left	4
Astragal, right	5
Carpal and tarsal	46
Metapodial	15
Phalanx I, II, III	27
Sesamoidal	11
Unrecognized fragments	37
Non-mammoth remains	
Total	18/2
Bison priscus Bojanus	
Total	6
Coelodonta antiquitatis Blumenbach	
Total	6/2
Equus caballus L.	
Total	3
Rangifer tarandus L.	
Total	2
Ursus arctos L.	
Total	1
Total mammoth plus non-mammoth	1010/22

and specific damage features along the mine because of the potential danger of the tunnel roof collapse.

The revealed features of bone preservation suggest the following taphonomic conditions (Fig. 18):

1) Fast burial and transfer to the permafrost. Such conditions are clearly indicated by the bones of perfect preservation (14% of the yield) and bones that retain portions of soft tissues (13%);
2) Long stay under subaerial conditions followed by conservation in fresh water and/or frozen ground. This category is formed by three groups of bones: bones with gnaw marks (23%), bones with chemical and/or root etching of the surface (63%), and bones with surface cracks with different degree of crack opening (10% of the total). It has to be stressed that here we consciously do not follow classical approach for evaluation of bone weathering and preservation developed by Behrensmeyer (1978) because it was worked out for southern landscapes, in which all taphonomic factors obviously affect different than they do in the Arctic.
3) Long stay under subaqual conditions in the running water. Only 9% of bones belong to this category.
4) Destructive permafrost and/or human impact. Significant mechanic damages caused by application of force perpendicular to the long axis of bone are observed on many non-weathered bones. Both permafrost and human impact might have led to that. 37% of bones from the collection bear this peculiar pattern.
5) Human impact. It is clearly visible on the lowest number of bones within the collection. Bones with clear cut marks make only 3% of the yield.

It is important to consider that all specified patterns are found on the bones in different combinations. Thus, it is very typical that a perfectly intact surface on the one side of the bone appears with significantly weathered surface on the other side (Fig. 19). In many cases different sides of the bones had, in addition, different color. These features indicate long stay of the bones on the daylight surface in the past.

Thus bones from the YMAM demonstrate very different pattern of preservation – from intact bones with soft tissues, to significantly weathered and water-rounded specimens, with clear indications of different agents affect – atmospheric, aquatic, permafrost, carnivore and human impact. Before burial most of the bones for a long time had been resting on the open air or the shallow water under positive temperature (during the summers). It could be said that the bones were on the boundary of three environments – daylight surface, water, and permafrost, where the weathering was going different ways. A little number of bones bears clear traces of human impact in a form of cut marks, and implicit traces that are much more frequent (as implicit traces of human activity we assume broken bones for which human contribution into damage is uncertain).

Taphonomic data themselves (with no involvement of ^{14}C dating) do not allow to unequivocal answer for how long animals had been dying, was it gradual or instant event. By its taphonomy, YMAM can be of a long-term accumulation pattern, or be a result of relatively isochronic multiple death way of formation. At the same time, it can be definitely said that the deposition of bones took place near a running water within a narrow strip along the river bank, which is in agreement with paleo topography reconstruction of the YMAM locality.

4. Archeological material found from YMAM

The YMAM lens contained scattered lithic artifacts and worked bone and ivory. This small collection includes lithic debitage and stone implements common for the Yana RHS lithic industry.

It was previously noted that the Yana RHS lithic industry features many Middle Paleolithic elements that could be found both in knapping technology, tool set, and tool morphology (Pitulko et al., 2004; Pitulko, 2010). This finding is typical for Early Upper Paleolithic sites across Siberia and is well known even for much younger Late Paleolithic assemblages (Abramova, 1989). Although the Yana RHS lithic industry does not have a direct analogy in archaeological contexts of the same age, some peculiarities of it do suggest that their roots can be found to the south and southwest of the Yana river in the Trans-Baikal area and in the Yenisei river valley (Pitulko, 2006, 2010).

Generally speaking, the raw material of Yana RHS industry comes from the local beach gravels (the material was unlimited) that contain aleuroliths, argillites, and poor quality chert whose flaking characteristics contribute to some archaic appearance of the Yana RHS chipped stone technology. The material is dominated by multidirectional, discoidal (identified so by general spatial

Table 2
Completeness of skeletal elements presented in the mammoth bone collection from the YMAM.

Skeletal element	Number of each element in a complete mammoth skeleton	Estimate of skeletal elements that should be in 26 complete skeletons (as MNI = 26)	Actual number of skeletal elements that was count in the YMAM collection	Completeness of skeletal elements expressed as skeletal element percentage of elements expected for number of skeletons = MNI (MNI = 26)
Vertebra	56	1456	189	13
Rib	38	988	342	35
Sternum (combined)	1	26	5	19
Skull	1	26	11	42
Mandible	1	26	8	31
Teeth	8	208	47	23
Tusk	2	52	29	56
Scapula	2	52	39	75
Humerus	2	52	40	77
Ulna	2	52	24	46
Radius	2	52	17	33
Pelvis	2	52	41	79
Femur	2	52	31	60
Tibia	2	52	42	81
Fibula	2	52	7	13
Patella	2	52	6	12
Metapodial	20	520	15	3
Phalanx I, II, III	46	1196	27	2
Carpal and tarsal	30	780	46	6

organization of knapping), and pyramidal cores. Relatively small, narrow-faced cores also exist, but these are few in number. In many cases, Yana RHS knapping technology lacks regularity and might even be called opportunistic. The industry is totally dominated by flake blanks which is not totally due to low quality raw material. Preference was given to citrus-slice flakes, a technique seen clearly in some categories of formal tools such as large backed side-scrapers. At the same time, some irregular blade blanks and bladelets appear, but no blade cores have ever been found.

The lithic tool set is strongly dominated by side-scrapers. Particularly numerous are backed and convergent forms as well as scrapers with multiple working edges. In general, most tools are asymmetric plano-convex forms produced on citrus-slice flakes or with flat radial flaking. There are also limaces, end-scrapers, combination tools, notches, chisel-like tools, pick-like tools, rough bifacial artifacts of varying degrees of completeness, and choppers and chopping-tools. Most of these are made of siliceous argillite pebbles, the most common material in the local beach gravels.

These forms were found in the deposits bearing the mass accumulation of mammoth. There are medium-size and large flakes (417 pieces), flaked rock debris, discoidal cores (19), and side-scrapers, represented mostly by massive backed tools (27). Worked ivory presents in the form of differently sized chunks, slivers, flakes, flaked pieces, and worked tusks. In addition, three points made of ivory and a foreshaft made of rhinoceros horn were found. Foreshafts (or beveled rods) represent a peculiar feature of the Yana bone industry. Typically, they are made of mammoth ivory. However, it is interesting that one of the previously found foreshafts was also made of rhinoceros horn (Pitulko et al., 2004). It was individually dated to 27 440 ± 210 (Beta-173064). This tool set, both

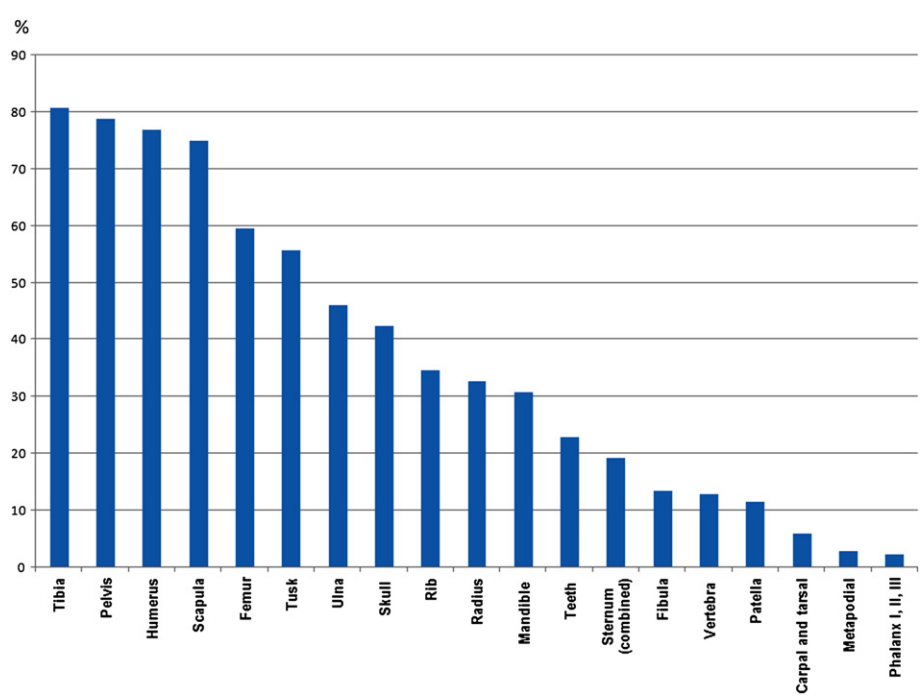

Fig. 11. Histogram showing percentage of skeletal elements of mammoth in proportion to MNI = 26.

Fig. 12. Photograph of bone with surface dissolution and root etching.

lithic and ivory, is well known in the Yana RHS since the beginning of the excavation (Pitulko et al., 2004). Therefore, it would be logical to conclude that the artifacts that come from the YMAM are culturally the same and left by the humans who created and/or exploited the mass accumulation of mammoth.

5. Radiocarbon age of the YMAM and its relation to habitation episode(s) at Yana RHS

All dated materials come from the permafrost deposits. Therefore, since the burial the materials have spent most of the time at low temperatures within deeply frozen sediments. This conditions guarantee a good preservation and low contamination of organic substances that were used for radiocarbon dating.

Radiocarbon dating was performed in three radiocarbon laboratories. Two labs used the liquid scintillation counting method (the Radiocarbon Laboratory of the Institute for the History of Material Culture, RAS, St. Petersburg, Russia, and the Isotopic Laboratory of Geography Faculty, St. Petersburg State Univ., St. Petersburg, Russia), and one lab used AMS dating technique (Beta Analytic, Florida, USA).

Radiocarbon dates ($n = 42$) for the YMAM, for the archeological sites, and for the deposits, that bear, underlie, and overlie the cultural layer and mass accumulation of mammoths are reported in Table 3. They are all consistent. Instrumental error varies from 100 to 1200 years for Pleistocene dates and 60 years for a single Holocene date that comes from the recent sediment patch.

Fig. 13. Photograph of bone with transverse fractures caused by human activity and/or permafrost (the condition of the bone substance is perfect).

Fig. 14. Photograph of bone with gnaw marks.

Eight mammoth bone collagen samples were dated from the YMAM. The cross-dating is excluded as all samples come from mandibles. Samples of brown bear bones and plant macro remains (grass) collected from the YMAM bone-bearing deposits were also radiocarbon dated.

Ten ^{14}C dates from the YMAM cover the interval from 31 200 ± 1200 to 25 100 ± 1000 radiocarbon years. Eight of them make a cluster from 28 900 ± 900 to 27 200 ± 1200 ^{14}C BP (Fig. 20). A similar time span (28 570 ± 300 to 27 140 ± 180) was found for radiocarbon dates coming from different occupation areas within the Yana RHS (Table 3; Fig. 20) (see also Pitulko and Pavlova, 2007; Pitulko, 2010). The oldest date of 31 200 ± 1200 from YMAM was never replicated by ^{14}C dates that come from the cultural layer of Yana RHS. It could be redeposited or human collected from the earlier deposits, i. e., most probably it is asynchronous to the event of the YMAM formation.

Fig. 15. Photograph of intact bone with soft tissues attached.

Fig. 16. Photograph of bone with tiny cracks net (fissuring).

Therefore, these ^{14}C data suggest fully synchronous formation of the mass accumulation of mammoths and site areas.

The Member 3 of the terrace II dated by multiple radiocarbon dates (Pitulko and Pavlova, 2007; Pitulko et al., 2007). The accumulation is found to have started before 31 000 ^{14}C years ago. Fluvial deposition terminates at 17 000 ^{14}C BP or shortly after.

The dating of deposits that overlay and underlie the bone-bearing lens provided the additional proof for the YMAM ^{14}C dating reliability. All dates received for YMAM are within the interval given by radiocarbon ages of underlying and overlying deposits (Table 3; Fig. 20). It is notable that all of the eleven ^{14}C dates from the deposits that overlie the YMAM bone-bearing lens are in complete agreement with their stratigraphic position. These observations convince us of the quality of the radiocarbon dating results.

The top part of the terrace includes young cuts filled during terminal Pleistocene and Holocene (Fig. 2: Bed 5).

Thus, radiocarbon dating confirms that formation of cultural layer at Yana RHS site and accumulation of bone material at YMAM were synchronous. Almost total overlap (except for two ^{14}C dates from YMAM) found for both sequences of ^{14}C dates, is of special importance (Fig. 20). Furthermore it can be concluded, by uniform distribution of the ^{14}C dates over time scale, that the accumulation of archaeological materials at the site and accumulation of bones at YMAM had been going more or less gradually, with no accelerations or delays.

Fig. 17. Photograph of weathered and water-rounded bones.

6. Discussion

The unexpected discovery of the *in situ* mass accumulation of mammoth near the Yana RHS site requires investigation of question whether it was related to the human activity in the past. First of all, two questions have to be responded, i.e. are the accumulation of bones and the cultural remains from the site synchronous and, if so, to which extent the human activity is expressed in the formation of YMAM. In other words, is this accumulation natural, like other mass accumulations of mammoth known within the region, such as Berelyokh and Achchaghyi-Allaikha (Nikolskiy et al., 2010a; Pitulko, 2011), or the Yana mass accumulation of mammoth has anthropogenic origin. Consequently, if it is the case, the role of mammoth in the subsistence economy of the Yana people has to be re-evaluated.

Stratigraphy and radiocarbon chronology provide the answer for the first question. The YMAM bone-bearing lens and the cultural layer of the Yana site belong to the same layer, although they occur at different elevations, according to paleo landscape (Fig. 2). Therefore, the stratigraphy of the site suggests synchronous accumulation of the Yana RHS cultural layer and the YMAM. Even better evidence for that can be found from comparison of radiocarbon dates obtained for YMAM bone-bearing lens and for the cultural layer of Yana RHS. Results given in Table 3 and Fig. 20 clearly demonstrate that ^{14}C dates from bone collagen of mammoth from the YMAM and organic materials from the Yana RHS site (including two dates on mammoth remains that belong to the cultural layer) are of the same age. It has to be stressed that ^{14}C dating strategy for Yana RHS cultural layer was based on dating of plant remains, charred materials, and bones of animals which were clearly hunted by humans, in order to avoid artificial dating results (e.g., on wood macro remains and mammoth bones and ivory because both wood and mammoth remains found in the site cultural layer may be a result of human activity and then be asynchronous to the event of formation). Thus, ^{14}C dating of wood macro remains from Yana RHS produced open dates that are in complete disagreement with the age of the site since they are older than 40 000 ^{14}C years (Pitulko and Pavlova, 2007). For dating of mammoth remains from archeological sites it was shown by Sulerzhitsky (2004) that they are normally 2000 years older than the estimated ^{14}C age of the site.

Anyway, we have enough radiocarbon dates to demonstrate that both YMAM and Yana RHS cultural layer have the same age of formation. Validity of such a conclusion is supported, with no exception, by multiple ^{14}C dates of organic from underlying deposits, matrix sediments of YMAM and cultural layer of Yana RHS, and overlaying deposits. All dates of YMAM and Yana RHS cultural layer are synchronous to ^{14}C dates that belong to different portions of level 3 (Figs. 2 and 5). The date from underlying sediments at YMAM is older than dates of YMAM and Yana RHS cultural layer (Figs. 2 and 5), while ^{14}C dates that come from overlaying deposits are consistently younger (Table 3, Fig. 20).

Thus, both the stratigraphy and the radiocarbon chronology show that accumulation of bone remains at YMAM was synchronous to the formation of the cultural layer of the Yana site. This suggests that dozens of mammoths were being lost and buried by sedimentation process in the vicinity of the Yana Upper Paleolithic site, or the animals were perished somewhere else, but their bones, for some reasons, were concentrating near the site. Is it possible that Yana people were not involved in that? This arises the question of anthropogenic or natural origin of YMAM.

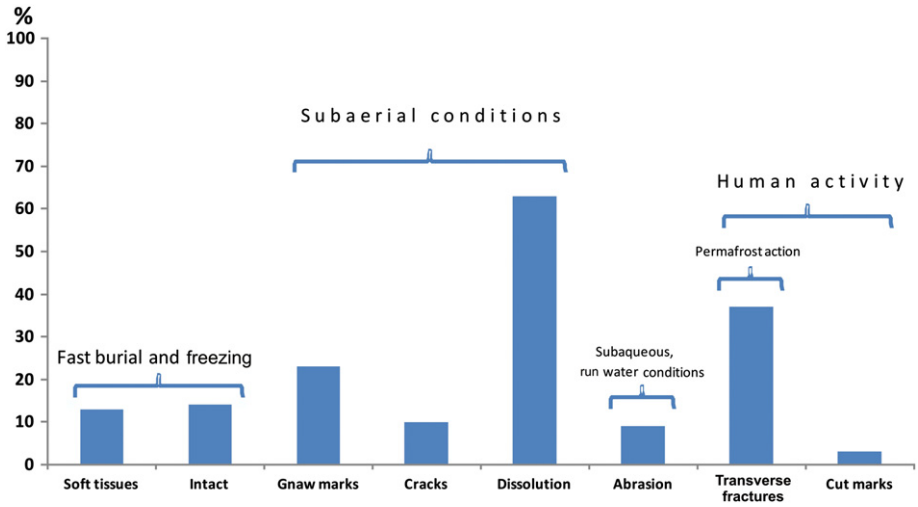

Fig. 18. Percentage of bones bearing different patterns of post-mortal processes.

It was already noted that because of the risk of water flood of the bone accumulation opened by the ivory miners and high risk of the collapse for the roof of the tunnel made by them in the frozen river bank, we had very limited time to study the Yana mass accumulation of mammoth. This did not allow us to study the planimetry of the location as needed. In particular, spatial pattern for bones with different type of preservation remained unknown. However, some taphonomic and geological observations had been done (it should be stressed, at the same time, that in this particular article we do not investigate the question of mammoth hunting potentially practiced by Yana people, but study taphonomy of the remains and geology of the site in order to answer the question on natural or anthropogenic origin of YMAM, with no involvement of paleobiology and archaeological data). The most important of them are the following:

1. Mammoth bones are spatially organized as a narrow strip that goes along the bank of the small stream which was running at a time of human activity at the Yana site area (Fig. 5);
2. Bones are spread uneven within this strip and form several well visible concentrations (Figs. 5, 8 and 9);
3. Skeletal elements of different size, density, weight, and hydrodynamic characteristic occur simultaneously in each of these concentrations (Figs. 8 and 9).
4. At least one of the concentrations includes a number of identical massive skeletal elements from several mammoth individuals, such as mandibles, skulls, and limb bones. And the most important fact is that some of these skeletal elements were grouped within this local concentration. Some of the skeletal elements, for example five mandibles, had been consistently placing one above the other during a very long time (Fig. 9).

Fig. 19. Different degree of weathering seen on one bone.

Then we can discuss all possible causes that may (or may not) lead to described peculiarities of formation processes that have created YMAM bone lens. As even a pair of skeletal elements that would be in anatomical order was not found within the studied area, it has to be concluded that bones were moved or transported after the animals died. Post-mortal move of bones may have took place as a result of the following processes:

- water transportation;
- colluviation and/or solifluction;
- ice drift;
- cryoturbation;
- moving by animals;
- trampling by large animals;
- human activity.

Redeposition and sorting by water can be definitely excluded because of the small grain size observed for gravels and sands that make matrix deposits bearing the YMAM. Fine sorting together with linear-parallel lamination pattern of the sediments suggest low energy hydrodynamics that took place during the sedimentation. This kind of hydrodynamics is incompatible with transportation of large skeletal elements of mammoth and piling them into several clusters as shown on Figs. 8 and 9. Easy to see that different kinds of bones are present in such concentrations. Differences in size, shape, and weight suggest different hydrodynamics needed for sorting by size/weight/shape classes and therefore mixing of them is not of water sorting nature.

Post-mortal redeposition of the skeletal elements that breaks anatomical order of the bones and their chaotic mixing may have took place as a result of colluviation, solifluction, or ice drift. However, none of these processes could lead to the formation of local concentration of bones in which a number of the same skeletal elements from different individual animals are present. There are mandibles, skulls, and limb bones that belong to different mammoth individuals, and these bones are grouped by element class. Thus, colluviation, solifluction, and ice drift should be excluded from the list of possible processes that could lead to the registered spatial organization of the bones.

Some of the mammoth bones from the YMAM are clearly moved by cryoturbation. During the ice wedge grow bones next to the polygon margin were moving up for several meters along the contact with the ice wedge (Figs. 6 and 21). This specific pattern is well documented during excavations of the Yana RHS (Pitulko,

Table 3
Radiocarbon chronology of the YMAM and the Yana RHS geoarchaeological objects. Laboratory codes: Beta – Beta Analytic, Inc. (Miami, Florida, USA), LE – Institute for the History of Material Culture, Russian Academy of Sc. (St. Petersburg, Russia), LU – St. Petersburg State Univ. (St. Petersburg, Russia). All dates run by Beta are ^{14}C AMS, LU and LE dates are conventional ^{14}C. Reference: 0 – this report; 1 – Pitulko et al. (2004); 2 – Pitulko and Pavlova, (2007); 3 – Pitulko et al. (2007); 4 – Pitulko (2010).

Lab. no.	Material dated	^{14}C date	Source
Yana mass accumulation of mammoth (YMAM)			
LE-8644	bone collagen from mammoth mandible	25 100 ± 1000	0
LE-8572	bone collagen from mammoth mandible	27 200 ± 1200	0
LE-8650	bone collagen from mammoth mandible	27 600 ± 600	0
LE-8508	plant macro remains/grass	27 740 ± 200	0
LE-8568	bone collagen from mammoth mandible	28 200 ± 400	0
LE-8565	bone collagen from mammoth mandible	28 400 ± 430	0
Beta-257535	bone collagen from bear limb bone	28 470 ± 210	0
LE-8574	bone collagen from mammoth mandible	28 600 ± 800	0
LE-8573	bone collagen from mammoth mandible	28 900 ± 900	0
LE-8569	bone collagen from mammoth mandible	31 200 ± 1200	0
Reddish brown horizon (paleosol?) between SP locus and the Yana B area (corresponding to the stratigraphic position of cultural layer at about 7,5 m a.w.l.)			
LE-8471	bone collagen from mammoth vertebra	27 500 ± 350	0
Beta-250646	bone collagen from horse mandible	27 500 ± 210	0
Beta-250638	bone collagen from mammoth rib	27 970 ± 210	0
Beta-250636	bone collagen from reindeer mandible	28 030 ± 160	0
Beta-173064	mammoth ivory artifact/foreshaft	28 250 ± 170	2
LE-8808	ivory	27 700 ± 270	0
Yana B locus of the Yana RHS (cultural layer)			
Beta-250633	bone collagen from reindeer metacarpal bone	28 250 ± 200	4
Beta-250634	bone collagen from horse pelvic bone	27 670 ± 210	3
Beta-250635	bone collagen from arctic fox mandible	28 210 ± 200	4
Beta-250637	bone collagen from bison metacarpal bone	28 060 ± 210	0
NP locus of the Yana RHS (cultural layer)			
Beta-191326	bone collagen from bison phalange	28 500 ± 200	2
Beta-191322	bone collagen from hare humerus	28 570 ± 300	2
Beta-191332	plant macro remains	27 510 ± 180	3
Beta-223413	charred organic material from the hearth	27 250 ± 230	3
Beta-191321	bone collagen from musk-ox metacarpal bone	27 140 ± 180	3
TUMS 1 locus of the Yana RHS (cultural layer)			
Beta-173067	bone collagen from horse mandible	27 300 ± 270	1
Sediments which underlain the YMAM			
LE-8498	peat	31 500 ± 500	0
Sediments which overlain the YMAM			
Beta-250677	plant remains	18 750 ± 100	0
LE-8492	bone collagen from mammoth scapula	18 550 ± 180	0
Beta-250676	plant remains	20 150 ± 120	0
LE-8502	plant macro remains/grass	21 010 ± 500	0
LE-8509	plant macro remains/grass	21 580 ± 400	0
LE-8510	plant macro remains/grass	21 640 ± 250	0
Beta-250640	bone collagen from bison vertebra	23 330 ± 150	0
Beta-250639	bone collagen from caribou antler	23 450 ± 160	0
Beta-250661	plant macro remains/grass	21 220 ± 100	0
Beta-250662	plant macro remains/grass	23 230 ± 110	0
Beta-250663	plant macro remains/grass	22 400 ± 110	0
Beta-250664	plant macro remains/grass	21 570 ± 100	0
Materials from the fill of recent erosional cuts in the top of terrace II			
LE-8480	wood	4430 ± 60	0
LU-5973	grass and moss	15 910 ± 110	0
LU-5968	bone collagen from wooly rhino humerus	17 710 ± 140	0

2008; Pitulko and Pavlova, 2007). Bones moved by cryoturbation are easy to recognize by planimetry and preservation – they are located along the ice wedge and they are heavily fragmented. Inside of the ground polygons bones should be intact and should not be displaced, but they definitely are. Therefore cryoturbation could not play a significant role in the formation of bone concentrations inside the polygons where bones are well preserved. For instance, none of the bones presented in Fig. 21 would remain intact if their movement inside the sediments would be a result of cryoturbation.

Finally, transportation of bones by animals (by carnivores) and/or mammoth trampling may have certainly led to disturbances of anatomical order of skeletal elements of dead mammoths, but it is hard to imagine that these events may result in several local concentrations of mammoth bones, some of them, in addition, are sorted by skeletal elements.

Then discussion of all possibilities allows well-based conclusion that described peculiarities of deposition and sorting of the mammoth bones within the YMAM bone lens may have been only the result of human activity. Also, conclusion on artificial formation of the YMAM inevitably indicates that the role of mammoth for Yana people was much more important than previously thought (Pitulko et al., 2004; Pitulko, 2010).

Several big Late Pleistocene mammoth accumulations are attached to certain known cultural layers across Eurasia. In Siberia, these are the Malta and Afontova sites (Ermolova, 1978; Astakhov, 1999); in Europe, these are Kostenki (Praslov and Rogachev, 1982), Mezhirich (Pidoplichko, 1976), Milovice, Kraków Spadzhista (Soffer, 1993; Svoboda et al., 2005), Yudinovo (Abramova, 1995), and others. For some of these sites, this material was used for the construction of dwelling structures, whereas at the others it was scattered across the habitation spot or placed into storage pits. However, for some of the sites, bone material was found outside cultural deposits. Such concentrations of mammoth bones that are not related to the cultural layer of archaeological sites provide the most important

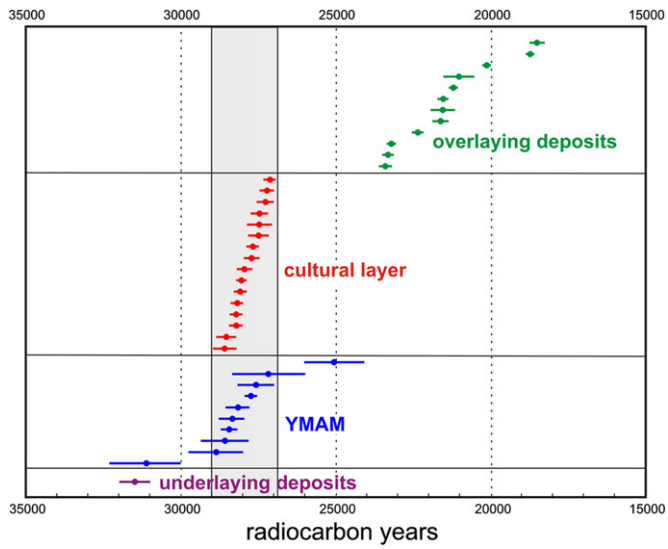

Fig. 20. Over time scale distribution of radiocarbon dates of organic remains from the YMAM, the cultural layer, the underlaying, and the overlaying deposits. For each date the instrumental error is shown.

comparative material for our study. These concentrations are well known in different areas of the continent: Volchyia Griva (Zenin, 2002), Shestakovo (Derevianko et al., 2000, 2003), Lugovskoe (Leschinsky et al., 2006), Berelyokh (Nikolskiy et al., 2010a) in Siberia and Milovice (Oliva, 1988, 2000), and Dolni Véstonice I and II (Klima, 1963, 1983; Svoboda, 1986) in Europe. Gmelin, the first scientist to study mammoth accumulations at Kostenki in 1768, claimed to have excavated the same kind of concentration of bones from the Don River low terrace. The Don river concentration contained a number of bones with missing elements, all from different individual mammoths, so that Gmelin was unable to assemble even a single

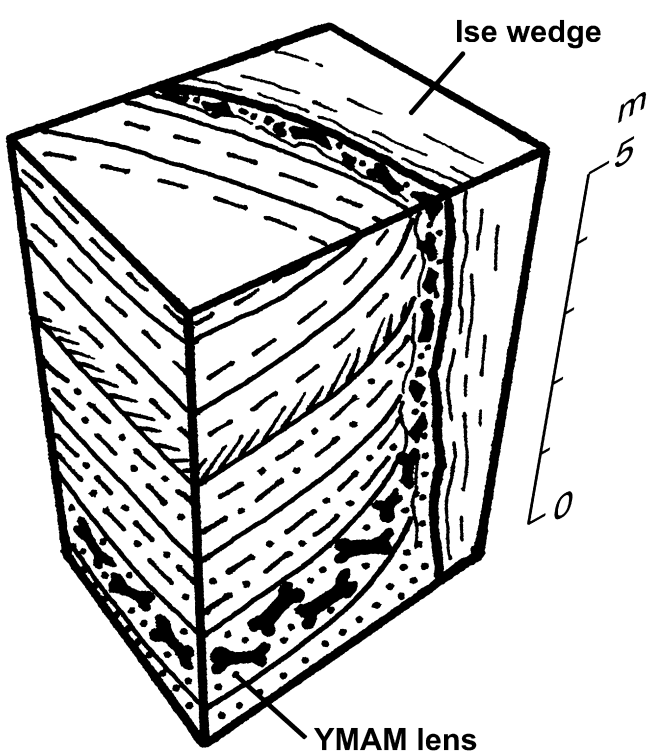

Fig. 21. Post-sedimental cryogenic vertical displacement of fossil remains. See Fig. 3 for legend.

mammoth skeleton (cited in Anikovich et al., 2010). In all cases, such bone accumulations are attached to shallow depressions of paleo daylight surface. Sediments that contain these accumulations are deposited in shallow water conditions such as a pond or temporal low energy stream. The accumulations include almost no other species but mammoth and are located at a distance of 30–100 m from the occupation spot or a dwelling structure. Normally, they are interpreted as midden concentrations. However, this presumes that the mammoth was hunted by Upper Paleolithic man, which has not yet been proven despite of more than 150 years of efforts of scientists over the world. Observations on mammoth exploitation at Milovice (Brugère and Fontana, 2009) and Yudinovo (Germonpré et al., 2008) are still not giving a full support for the hunting of mammoth at these sites while the possibility for that still exists). Paying attention to the common geology of these concentrations, Soffer (1993) suggested that they may have a natural origin related to mass death and/or long accumulation in areas rich in minerals that helped the mammoth maintain a mineral balance (also she acknowledged a possible human contribution to the formation of these bone concentrations). This conclusion was later developed by Leschinsky (2001) into the "beast solonetz" theory for the origin of mass mammoth accumulations.

The YMAM looks much like Moravian sites Milovice and Dolni Vestonice. It is clear that in both cases we see the features of specific human behavior. Spatially, YMAM is organized in the same way – a concentration of human sorted mammoth bones kept in shallow water a short distance away from the habitation spot. Traditionally, the YMAM would be considered a midden. However, we think that the placing of these bones (and ivory) into the water was an important part of some technological process. It is well known that humans used mammoth remains widely in their everyday life as a valuable raw material for constructions and also for the manufacturing of tools and decorations (Pitulko et. al., in preparation). This material is difficult to work on, so it requires preliminary preparation. In addition, before it is used for any purpose, a full maceration of bones and degreasing must be completed. Warm shallow water that contained a number of extraneous biological agents (such as bacteria and micro organisms) probably provided necessary conditions for that process. This possibility can be inferred from the high number of long bones and tusks found in YMAM, along with a number of by-products of ivory tool production. Because a full maceration of tusk alveoli would be necessary to facilitate the extraction of tusks, the discovery of mammoth skulls within the concentration is highly suggestive.

7. Conclusions

The history of the discovery of the YMAM calls attention to the question of the protection and preservation of natural, archaeological, and geological monuments that are almost totally undeveloped in certain regions of the Russian Federation. The amount of unique scientific information recorded in the permafrost sediments that is destroyed every year due to uncontrolled ivory mining across Yakutiya can only be guessed at. Only by chance the information on the Yana mass accumulation of mammoth was rescued.

The discovery of Yana mass accumulation of mammoth allows us to draw some important conclusions. The purposeful sorting of the bones, the taphonomy of the accumulation, and the radiocarbon dating results that firmly link the mass accumulation of mammoth to the habitation episode suggest the anthropogenic origin of the accumulation. Importantly that such concentration of mammoth bones constitutes a part of the spatial structure for the whole Yana RHS site area. It would be too premature, however, to discuss YMAM as evidence of mammoth hunting practiced by the Pleistocene Yana people.

Observations made during the study of YMAM show that at least some of the mass accumulations of mammoth known across

Eurasia could be of the same nature, i.e., reflect human behavior and/or specific activity rather than natural processes. The archeological context of the bone and ivory discovered at the YMAM can lead us to conclude that the accumulations are the result of a technological requirement for manufacturing bone and ivory specimens among the Pleistocene people.

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Appendix. Supplementary material

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.jas.2011.05.017.

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