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The Zhenya Mammoth (*Mammuthus primigenius* (Blum.)): Taphonomy, geology, age, morphology and ancient DNA of a 48,000 year old frozen mummy from western Taimyr, Russia

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ABSTRACT

This paper reports the results of an in-depth analysis of the frozen remains of a woolly mammoth (*Mammuthus primigenius*) named Zhenya, which has been dated to 48,000 cal BP. The carcass, found near the mouth of the Yenisey River in eastern Siberia, was a juvenile male whose ontogenetic age at death was 8–10 AEY. Its reconstructed live height at the shoulders (pSH 227.4 cm) was the equal of some adult female woolly mammoths and extant elephants. The large stature and a flaked off tusk tip that matches breaks on tusks of male African elephants are indirect indications that this mammoth most likely had reached sexual maturity, had been expelled from its maternal herd, and had been in at least one fight with another male.

The mammoth's bones were relatively healthy, although some had minor lesions. Rudimentary upper second molars (M2/m2) were present, but no lower second molars were found in the alveoli, and the left tusk had never developed. Despite the abnormal development of the upper and lower second molars, the cheek teeth which were in wear (Dp4/dp4 and M1/m1) showed normal function without any indications of developmental delay.

The completed growth of the light-colored dentin bands on the tusk strongly suggests the Fall of the year was the season of death. This season is also supported by accumulated fat in the upper parts of the torso, indicative of physiological preparation for the winter ahead. The few minor traces of carnivore scavenging, the little disturbed condition of the carcass, and the absence of bone modifications made by human actions, along with the social status of this young male animal, are interpreted here as highly probable evidence that the Zhenya Mammoth died from unrecoverable injuries inflicted during a bull-to-bull fight.

Abbreviations: PIN, Borissiak Paleontological Institute; Russian Academy of the Sciences, Moscow; Russia, ZIN; Zoological Institute, Russian Academy of Sciences; St. Petersburg, Russia.

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The mineralogical analysis of site sediments revealed that the mammoth's burial *in situ* took place in the Yenisey River valley seasonally inundated by the river, which together with Fall's freezing temperatures protected the carcass from scavengers. An analysis of ancient DNA provides strong support for Zhenya's mitochondrial lineage within the deeply diverging clade III haplogroup B.

1. Introduction

This paper summarizes the results of studies made on the well preserved frozen remains of a woolly mammoth (*Mammuthus primigenius*) which was recently discovered near the mouth of the Yenisei River in arctic Siberia. The significance of this find is exceptional because of its completeness and good preservation.

The woolly mammoth, *Mammuthus primigenius* (Blumenbach, 1799), has been studied for over 200 years (Cuvier, 1799; Blumenbach, 1799; Garutt, 2001). Of fundamental importance are the discoveries and studies of frozen corpses found in Siberia, which have provided valuable data on anatomy, physiology, diet, ecology, biology, parasites, and causes of death (Zalenskii, 1903; Maschenko, 2002; van Geel et al., 2011; Fisher et al., 2012; Rountrey et al., 2012; Maschenko et al., 2013; Fisher et al., 2014; Glamazdin et al., 2014a, b).

The northern territories of Western Siberia, particularly the Yamal, Gydan, and Taimyr Peninsulas, are known for several major mammoth discoveries. Among them was the first find of a woolly mammoth carcass ever reported from Siberia (Lower Yenisey River) by Ysbrand Ides in 1692, which was sent by Tsar Peter the Great to China (Tolmachoff, 1929). About three centuries later discoveries of frozen woolly mammoth corpses and skeletons became more common in this region. These discoveries included two baby mammoths, nicknamed Masha and Lyuba (Vereschagin, 1999; Kuzmina, 1999; Fisher et al., 2012), the adolescent (10–12 year old) Yuribei Mammoth (Dubrovo, 1982), and a few adults. Among the adults are skeletons of the neotype individual of *M. primigenius* (the Taimyr Mammoth) (Garutt and Dubinin, 1951; Garutt et al., 1990), the Trofimov Mammoth, the Kutomanov Mammoth (Averianov, 1994), and the Kastatyakh Mammoth (Kirillova et al., 2011).

The mammoth find reported here has been named the Zhenya Mammoth (Fig. 1), and it is the most complete skeleton of a woolly mammoth presently known (Maschenko et al., 2014a, b; Maschenko et al., 2015). It also has been claimed to bear marks on the bones indicative of human activity (Pitulko et al., 2016); a detailed geological description and analysis of the Zhenya Mammoth site, the methods of excavation which shed light on some bone modifications, and a morphological description of the carcass had not previously been provided. Here we present the available field data and first full description and analysis of the sediments of the site and this unique specimen, focusing on geology, taphonomy, morphology, genetics, and the carcass condition and handling in the field and laboratory.

2. Material and methods

2.1. Field work

The carcass named the Zhenya Mammoth (also referenced as "Sopochnaya Karga Mammoth"; Gusev et al., 2015) was found on August 28, 2012 (Maschenko et al., 2014a, b; 2015) in the terrace slope of Sopochnaya Karga Cape, Yenisei River mouth, western Taimyr (Fig. 2). At the time of discovery, only the hind limbs and part of the pelvis were visible. The hind feet and tibiae were detached from the carcass and scattered down the slope (https://www.youtube.com/watch?v=WIuwWoAW8C8&feature=youtu.be).

The salvage excavation of the mammoth was headed by Dr. A. Tikhonov and lasted about a week in early September, in daytime temperatures between 0 and +4C, with snow showers occurring during the last days of the field work. Near the carcass, the field crew set up a barrel with water heated by fire that supplied steam to a gun directed at the slope for thawing the frozen sediments (Supplementary Fig. S1, A). The excavation tools included spades, trench shovels, pick-hoes, axes, along with the "zastup" (an axe welded to a long metal pipe for breaking ice for fishing) and "pashnya" (metal pike on a long metal shaft) (Supplementary Fig. S1, B-E; see also https://www.youtube.com/watch?v=YklnU5mF1iA). Before removal, the carcass was propped up by logs (Supplementary Fig. S1, C), and most of the sediments that filled the body cavity were scooped out by a trench shovel (Supplementary Fig. S1, A-C). To get better access to the corpse and facilitate its excavation and removal, the cranium was separated from the carcass, to which it had been loosely attached. The cranial bones had large multiple cracks, with one of them across the tusk alveoli's base, making it possible to transport the detached alveoli bones with tusk separately from the carcass. The rotted soft tissues in the right alveoli allowed the tusk extraction. On the last day of the excavation, the rest of the articulated carcass was dragged down the slope by ropes tied to it (https://www.youtube.com/watch?v=wSaxC3GtekU). The cranium with the attached right hemimandible was rolled down the slope. On the river beach, the excavated mummy's torso, cranium, mandible, as well as the distal hind limbs collected from the slope scree, were loaded onto a sled and pulled to the Sopochnaya Karga helicopter landing site. Unloaded from the sled, the cranium was tied with ropes and dragged on the ground to be

Fig. 1. The mounted skeleton of the Zhenya Mammoth (photo courtesy of Yu. Starikov).