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Strong evidence for dietary mineral imbalance as the cause of osteodystrophy in Late Glacial woolly mammoths at the Berelyokh site (Northern Yakutia, Russia)

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ABSTRACT

Paleoecological analysis of over 1500 mammoth remains from the famous non-archaeological Berelyokh site (~13–12 ka BP) has demonstrated that ~ 42% show destructive changes (osteoporosis, osteolysis, osteofibrosis, osteomalacia, articular diseases and others). For the first time, non-closure of cervical vertebral foramina transversaria and loose intra-articular bodies have been recorded in mammoths. The overall pathological picture resembles that of Kashin-Beck (or Urovskaya) disease, the etiology of which is associated with mineral starvation. The alimentary (dietary/nutritional) character of the observed osteodystrophy can be explained by the strong acidification of geochemical landscapes, which is manifested in the territory of Northern Eurasia after 30 ka BP and especially clearly during the Late Glacial (~15–10 ka BP). Thus, the Berelyokh site reflects the terminal stage of the last mass extinction of large mammals.

1. Introduction

Berelyokh (N 70°30′, E 144°02′) is the largest of presently-known sites with remains of woolly mammoths in the Siberian Arctic. It is located in the Ugamyt tract of the middle course of the Berelyokh River in the Yana-Indigirka lowland (Northern Yakutia; Fig. 1). The bone-bearing lens with a thickness of 0.5–2 m is traced along the section of the river's left bank, 12–14 m above the floodplain terrace for approximately 180 m. Various authors have placed its base at a depth of 4.5 to 2.5 m from the surface (Vereshchagin, 1977; Pitulko and Pavlova, 2010).

The basic materials of Berelyokh, known from published sources, were obtained during fieldwork between the 1970s and 1980s, largely due to the washout of the outcrop by water cannons. According to these data, the mammoth remains obtained from the bone-bearing lens belonged to 156 or 166 individuals (based on counting of the number of teeth). Moreover, more than 30% of them were from individuals not older than 10 years (Vereshchagin, 1977; Zherekhova, 1977; Vereshchagin and Ukraintseva, 1985). Based on the results of long bone measurements (Baryshnikov et al., 1977), it was concluded that at the Berelyokh site, subadult mammoths of a small size prevail (of which females make up 58–60%), whereas older individuals are very rare. Other large mammals are much less numerous: horse (5 or more individuals), reindeer (5), bison (3), woolly rhinoceros (1), wolverine (5) and cave lion (1). Remains of few mammoths (at least 2 individuals), wolves (4), reindeer (1), horse (1), hares (~850 bones) and birds (96 bones) were also found at the Paleolithic site located in the immediate vicinity of the mammoth site (Vereshchagin and Ukraintseva, 1985; Pitulko and Pavlova, 2010).

Lithofacial characteristics of the sediments and radiocarbon dating place the formation of the Berelyokh bone-bearing horizon at the oxbow lake bottom of the late Sartan cryochron (~14–10 ka BP), which generally corresponds to the final stage of mammoth extinction in Eurasia. However, the latest dates indicate that the location also includes the remains of mammoths and other megafaunal representatives of Karga – Early Sartan, in the range from more than 43 to 16 ka BP. Although the proportion of these older bones is unknown, the majority of scholars agree that the Berelyokh mammoths died mostly within the time range of 13–12 ka BP (Vereshchagin, 1977; Nikolskiy et al., 2010; Pitulko, 2011; Pitulko et al., 2014). Nevertheless, the presence of this redeposited

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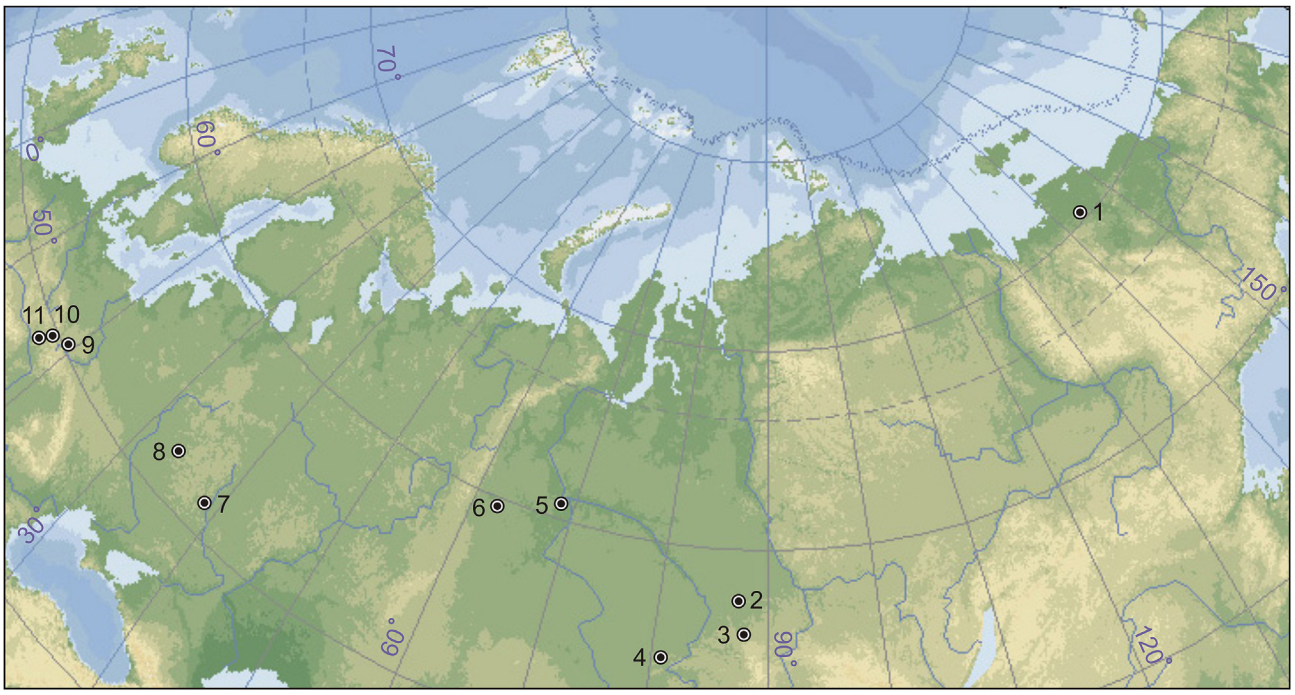

Fig. 1. Distribution of the some large Eurasian mammoth assemblages dated to 27(33) – 10 ka BP (1 – Berelyokh; 2 – Krasnoyarskaya Kurya; 3 – Shestakovo, Kochegur; 4 – Volchia Griva; 5 – Lugovskoye; 6 – Gari; 7 – Kostenki; 8 – Sevsk; 9 – Kraków Spadzista Street; 10 – Předmostí; 11 – Dolní Věstonice, Milovice, Pavlov).

material complicates the investigation.

The main reason of the mammoth burial in the Ugamyt tract is considered to be due to the death of animals on the fragile ice of the oxbow lake throughout the centuries (Vereshchagin, 1977) or simultaneous mass deaths in one or several seasons during heavy spring floods under warming conditions (Nikolskiy et al., 2010; Pitulko et al., 2014). In general, this is the traditional description of the extinction process of the mammoths, which according to some authors was complemented by strong pressure from the Arctic Paleolithic humans during tens of millennia (Nikolskiy and Pitulko, 2013; Pitulko et al., 2016). At the same time, new data obtained by me indicate that mammoth extinction was largely due to strong acidification of geochemical landscapes (Leshchinskiy, 2015). Thus, the Late Glacial Berelyokh site is one of the key objects of current studies of the Late Pleistocene mammoth fauna.

2. Material and methods

This paper presents the results of research of available mammoth remains from the lacustrine-alluvial bed (bone-bearing horizon) which are not associated with the activity of ancient humans. These materials, obtained in 1970, 1971 and 1980, are stored at the Zoological Institute, Russian Academy of Sciences (RAS) (Saint-Petersburg, Russia), in the collection No. 30957 where large mammals are almost 100% represented by woolly mammoth, *Mammuthus primigenius* (Blumenbach 1799). Overall, paleoecological and taphonomic analyses were applied to 1538 bones (including fragments and jaws with teeth) and 8 isolated teeth from a minimum of 47 mammoths, and 11 horse bones and 6 bison bones. In the same collection there are several samples collected by N.F. Grigoriev in the 1950s. Scattered minor materials stored in other organizations were they are not studied.

Unfortunately, the bulk of the Berelyokh material (more than 7200 mammoth remains), discovered between 1970s and 1980s, is not available for study. After preliminary analysis, it had been stockpiled on the site of fieldwork in two storage pits (Vereshchagin, 1977), one of which (on the left bank) was eroded by the river (Nikolskiy et al., 2010), and determination of the exact location of the other pit (on the right shore) seems impossible today. In addition, the site was severely damaged by unknown persons who extracted the tusks for commercial purposes between 2004 and 2009 (Pitulko et al., 2014).

Examination of bones and teeth was performed visually using a loupe with magnification of 10×, and selectively under a stereomicroscope to 200×. In addition, a Scanning Electron Microscope (SEM) (apparatus VEGA II LMU at the Tomsk State University) with 10,000×coupled to X-ray microanalyzer (INCA Energy 350) was used for the determination of the content of chemical elements in the compact bone. In the diagnosis of individual ages and destructive (pathological) changes during lifetime, I used normal bone morphology and described diseases of the skeletal system from modern and Pleistocene large mammals, including humans (Logginov, 1890; Rokhlin et al., 1934; Damperov, 1939; Bick and Copel, 1951; Cherkasova, 1954; Chepurov et al., 1955; Plotnikov, 1962; Kovalskiy, 1974; Baryshnikov et al., 1977; Lang, 1980; Schultz and Teschler-Nicola, 1987; Nordin and Morris, 1989; Haynes, 1991; Maschenko, 1992, 2002; Rothschild et al., 1994; Hindelang and Peterson, 1996; Nordin, 1997; Kuzmina and Maschenko, 1999; Lister, 1999; Ytrehus et al., 1999; Zatsepin 2001; Leshchinskiy and Burkanova, 2003; Epstein, 2005; Flueck and Smith-Flueck, 2006, 2008; Leshchinskiy, 2006, 2009, 2012; Rothschild and Martin, 2003; Rothschild and Laub, 2006, 2008; Johnson et al., 2007; Krzemińska, 2009, 2014; Waldron, 2009; Clarke and Goodship, 2010; Egorenkov, 2010; Lee et al., 2012; Haynes and Klimowicz, 2015a; Krzemińska et al., 2015; Krzemińska and Wędzicha, 2015; Shpansky et al., 2015a,b).

For comparison, paleontological specimens were used from mammoth fauna sites in various regions of Northern Eurasia (Fig. 1): Shestakovo, Kochegur, Lugovskoye, Gari, Krasnoyarskaya Kurya, Volchia Griva, Sevsk, Kraków Spadzista, Předmostí, Milovice,