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ABSTRACT BOOK

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Strong evidence of Late Glacial mammoth osteodystrophy from the Berelyokh site, Northern Yakutia, Russia

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Berelyokh (N 70o30/, E 144o02/) is the largest site of woolly mammoths in Siberian Arctic. It is located on the left bank of the Berelyokh River, in the Yano-Indigirka lowland. The site contained the remains of 156 mammoths found 1970–1980 during water jetting of the bone-bearing lens (Vereshchagin and Ukraintseva, 1985). The main part of

the recovered materials, more than 7200 bones and teeth, is virtually unexplored, as it was buried back on the river banks. Except for a few dozen samples, the rest of the collection (~1600 specimens), is stored in the Zoological Institute of the RAS (St. Petersburg) in Collection 30957. *Mammuthus primigenius* Blum. samples represent nearly

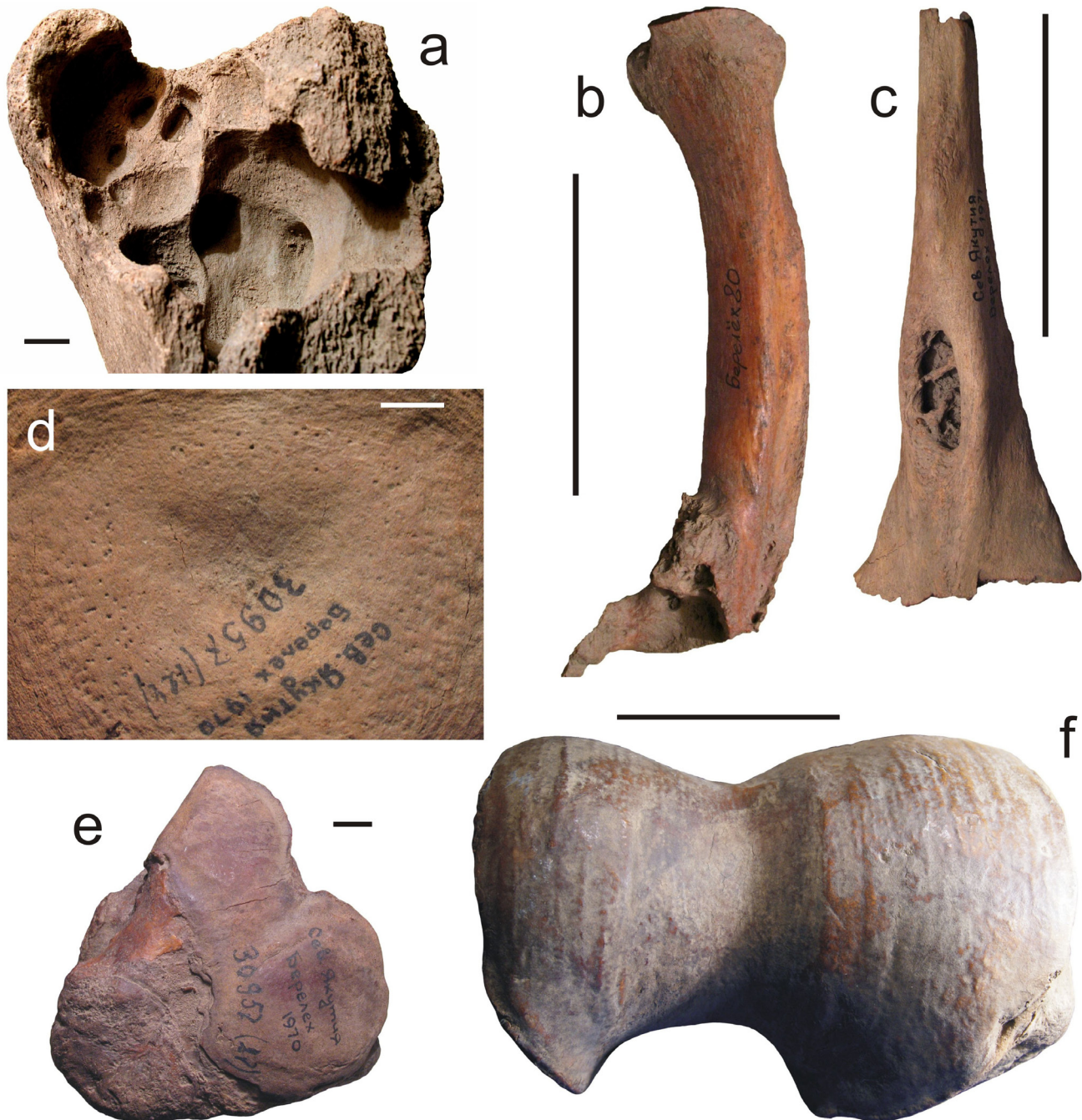


Fig. 1. Evidence of the woolly mammoth osteodystrophy from the Berelyokh site, Northern Yakutia, Russia: a, development of osteoblastomae on the proximal tibia end (without number / sampling in 1971, scale bar equals 1 cm); b, osteoid-osteoma on a rib fracture (without number / sampling in 1980, scale bar equals 10 cm); c, the cavity at the base of the spinous processes of the thoracic vertebra (without number / sampling in 1971, scale bar equals 10 cm); d, large open pores in the body epiphysis of the cervical vertebra (№ 124, scale bar equals 1 cm); e, the ulcer on the articular surface of a cuboideum (№ 87, scale bar equals 1 cm); f, friction grooves on the articular surface of a humerus distal epiphysis (№ 11, scale bar equals 10 cm).

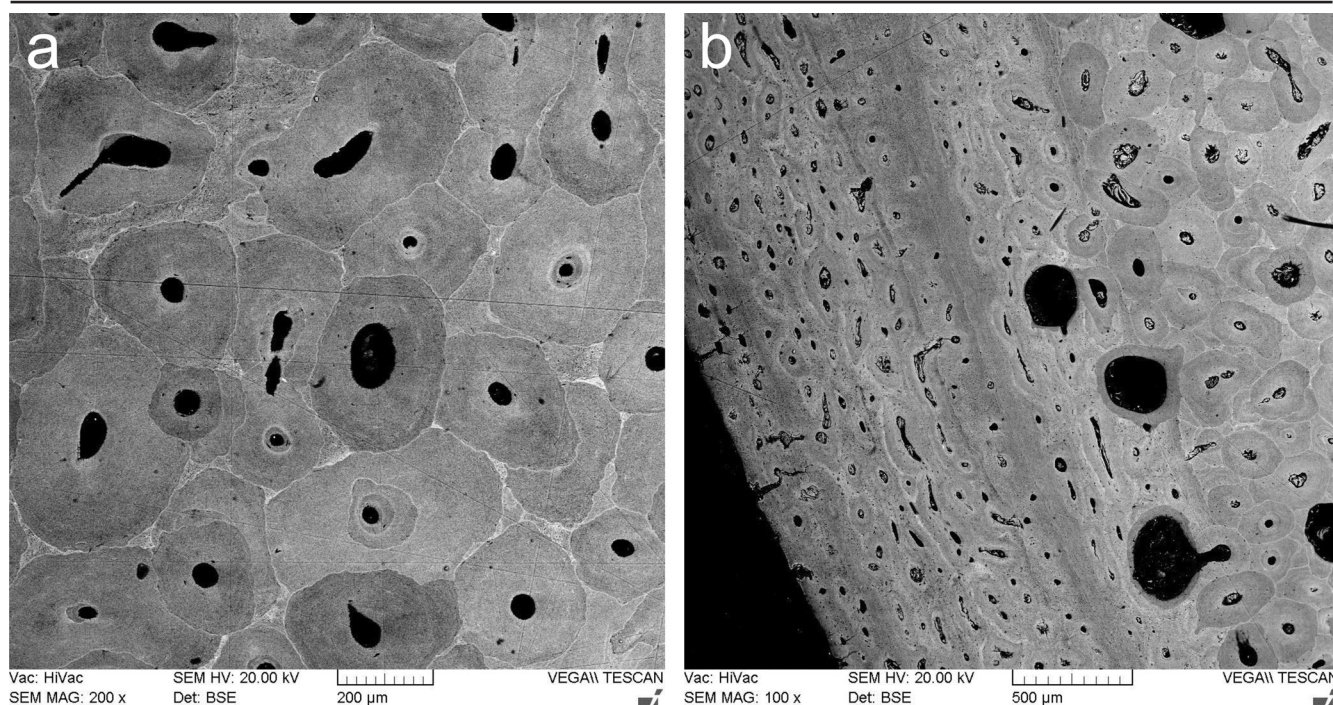


Fig. 2. Scanning electron microscope images of the cross-section of conditionally healthy (a – № 95) and osteoporotic (b – № 112) mammoth ribs from Berelyokh site, Northern Yakutia, Russ.

100% of the large mammals of this collection.

Radiocarbon dating indicates that the bone-bearing lens of the Berelyokh site was formed in the end of Sartan cryochron (~14000-10000 ^{14}C yr BP), which corresponds to the final period of mammoth extinction. The latest research has shown that the site also contains the remains of mammoths and other megafauna of the Karga thermochron that are older than 30000 ^{14}C yr BP (Nikolskiy et al., 2010; Pitulko, 2011). Most of the mammoth bones are dated 13000-12000 ^{14}C yr BP; however, paleoecological research is complicated by the fact that the exact proportion from the Karga remains unknown.

Permafrost conditions ensured excellent preservation of the Berelyokh samples. Visual examination with a magnifying glass (up to 10 \times) and selectively with a stereo-microscope (up to 200 \times) and a scanning electron microscope (up to 10,000 \times) revealed that more than 700 mammoth remains have signs of growth destructive changes of skeletal and connective tissue, which constitutes more than 40 % of the total. One of the main signs of osteodystrophy in the Berelyokh mammoths is osteofibrosis and similar bone changes. Particularly complex osteoid-osteomas of up to 5 \times 2.5 \times 1 cm and osteoblastomas of up to 10 \times 5 \times 5 cm are present in the vertebrae and long bones of the limbs (Fig. 1 a). Perhaps osteoid-osteomas also developed on rib fractures (Fig. 1 b), which led to false joint formation. Diagnosis and etiology of these pathologies is, however, ambiguous. Typical (stable) osteoid-osteoma has a well defined peripheral zone of osteosclerosis, whereas a typical osteoblastoma does not have such a zone. Diagnosis of the intermediate forms is difficult. Because these destructive changes have identical histological structure (Zatsepin, 2001) they are combined into one group of benign tumors. Malignant tumors are hard to identify in the paleontological material; however, they are unlikely to constitute a significant proportion of the findings. The same applies to abscesses, tuberculosis, and other similar disorders. Studies indicate that osteofibrosis may occur as a result of rickets – a disease that is largely associated with mineral starvation (Urazaev, 1978).

A special feature of the pathoanatomical spectrum of the Berelyokh population is strong spine damage. It is represented by osteofibrosis, osteoporosis, and other destructive changes. The spinous processes of vertebrae have holes and cavities of up to 3.8 \times 1.7 cm that are possibly associated with osteoid-osteomas (Fig. 1c). A.Krzemińska (2008) considers the poor diet to be the possible cause of this disease. E.Maschenko (2002), on the other hand, suggests that it is a genetic abnormality.

It is also interesting to note that there are vertebrae with large open pores in the body epiphyses of up to 1.5 \times 1 mm (Fig. 1d). Identical epiphyses belonging to subadult and adult mammoths were discovered in Krasnoyarskaya Kurya, Lugovskoye, Gari, and other Sartan sites of Western Siberia (Leshchinskiy, 2006). Even though studies indicate that the most likely cause of these changes is osteoporosis, paleoecological analysis has generally shown relatively low level of osteoporosis in Berelyokh mammoths. Scanning electron microscopy of compact bone of the ribs confirmed that in general the microstructure is healthy with more or less even osteons and Haversian canals less than 0.1 mm (Fig. 2a). Some of the osteoporotic samples demonstrate signs of Haversian canals dilatation to up to 0.6 \times 0.7 mm and flattening osteons which leads to internal delamination of compact bone (Fig. 2 b). Such changes can not be explained by taphonomic processes. Chemical and microbial degradations of bone have different appearances, which is evident in the bones of mammoths from the subaerial site of Kraków Spadzista Street (Leshchinskiy, 2012). The Berelyokh bones were buried in permafrost conditions, where physical and chemical weathering were reduced and the activity of soil bacteria in the bones is not observed at all. In turn, this indirectly confirms the subaqueous genesis of the site.

Because of the rarity of paleontological samples containing preserved connective tissue and cartilage at a zero stage weathering of the articular surfaces, the diagnostics of joint disease is usually difficult. That is why the well-preserved

bones of the Berelyokh collection have become reference point samples. Ulcers (Fig. 1e) and fissures, particularly on the bones of the manus and pes, constitute the most common type of lesions. These defects developed as a result of atrophy, necrosis and hyaline cartilage resorption, and osteolysis of subchondral bone. The articular surfaces of some of the long bones are entirely covered with grooves from friction (Fig. 1f), indicating complete absence of cartilage. Such lesions are typical of osteoarthritis, which is a polyetiologic multifactorial disease; however, some scientists support the popular infections hypothesis (e.g., Rothschild and Laub, 2006). Abiotic relationships are rarely considered, even though modern foci of enzootic diseases are well known, the etiology of which is associated with adverse geochemical landscapes (Kovalskiy, 1974).

In addition to the evidence of osteodystrophy in Collection 30957, exostoses, ossification of ligaments, fractures and bony unions, and other pathologies have been found. Consecutive series, the high occurrence, and confinement of the destructive changes to certain elements of the skeleton identify the nutritional nature of these diseases. All of this does not support the view that the destructive changes in the remains of later mammoths of Northern Eurasia are rare.

Unfortunately, accurate paleoecological comparison of various mammoth populations is problematic because of the incompleteness of faunal collections. Nevertheless, a significant proportion of osteofibrosis and severe joint damage in connection with a relatively low level of osteoporosis connects the Berelyokh mammoths with their west-Siberian relatives of similar geological age from the Lugovskoye site. This significantly distinguishes them from mammoths that lived in Eurasia during the Last Glacial Maximum and somewhat earlier. For example, the proportion of osteoporosis in the Krasnoyarskaya Kurya and Kraków Spadzista Street populations could exceed 60-80%. Also, the Berelyokh and Lugovskoye mammoths were ~ 2 times smaller than those that lived ~ 24-17 ka BP. Apparently, the reduction of size was an adaptive mechanism to the deterioration of the geochemical environment due to abrupt landscape acidification. Thus,

the 30957 collection demonstrates unique evidence of the geochemical stress mammoths experienced during the period of mass extinction also recorded in other sites of Northern Eurasia (Leshchinskiy, 2006, 2012).

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