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Environmental reconstruction inferred from the intestinal contents of the Yamal baby mammoth Lyuba (*Mammuthus primigenius* Blumenbach, 1799)

Pavel A. Kosintsev[a], Elena G. Lapteva[a], Svetlana S. Trofimova[a,*], Oksana G. Zanina[b], Aleksey N. Tikhonov[c], Johannes Van der Plicht[d]

[a] Institute of Plant and Animal Ecology, Ural Branch, Russian Academy of Sciences, ul. Vos'mogo Marta 202, Yekaterinburg 620144, Russia
[b] Institute of Physicochemical and Biological Problems of Soil Science, Russian Academy of Sciences, Pushchino, Moscow oblast 142290, Russia
[c] Zoological Institut, Russian Academy of Sciences, Universitetskaya nab. 1, St. Petersburg 199034, Russia
[d] Center for Isotope Research, Groningen University, Nijenborgh 4, 9747 AG Groningen, Netherlands

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ABSTRACT

The article presents the results of a complex investigation of the intestinal content of the frozen mummy of a baby woolly mammoth (*Mammuthus primigenius* Blumenbach, 1799) found in 2007 in the Yamal Peninsula (Western Siberia). The mummy belongs to a female mammoth calf approximately 1–1.5 months of age, and it has been named "Lyuba". Analysis of bone tissue yielded a ^{14}C date of 41,910 (+550/−450) years ago. Analysis of detritus material from the large intestine yielded a ^{14}C date of 41,700 (+700/−550) years ago. These dates practically coincide, thus denoting synchronism of the time of the baby mammoth's death and the formation of its intestinal contents. This time correspond to the middle part of MIS 3, or the Middle Weichselian Pleniglacial. Pollen, phytolith, plant macrofossil and mineral analyses of the intestinal content were carried out. Reconstruction of the environment where the baby mammoth lived is given based on the intestinal content analyses. The data suggest that the baby mammoth lived in tundra-like landscapes dominated by grass–sedge communities with forbs and *Betula nana*.

1. Introduction

In 2007, the frozen mummy of a baby woolly mammoth (*Mammuthus primigenius* Blumenbach, 1799) was found on the Yuribey River bank (Western Siberia, Yamal Peninsula), and named "Lyuba". The completely intact corpse only lacked hair and was a female mammoth calf about 1–1.5 months of age. The baby mammoth mummy had well-developed subcutaneous fat. Examination after dissection showed that the baby mammoth had no internal lesions. Dissection of the digestive tract revealed the stomach and small intestine to be empty, and the large intestine partially filled. Up to the present time, there has only been one baby mammoth corpse found with its intestinal tract, namely the baby mammoth "Dima" discovered in Yakutia (Vereshchagin, 1981). However, the intestinal tract of the baby mammoth "Dima" was partly destroyed, so that its contents were contaminated with the enclosing sediments. Thus, the baby mammoth found in Yamal is so far the only find of a baby woolly mammoth with fully intact intestines. The present study aimed to investigate the intestinal contents of the Yamal baby mammoth "Lyuba" and to assess the information for reconstruction of the natural conditions where the baby mammoth lived and died.

2. Regional setting

The baby mammoth mummy was found in the early spring on the surface of the flood-plain terrace of the Yuribey River in the Yamal Peninsula (68°38′ N, 71° 40′ E, Fig.1). Location and time of the discovery (early spring) suggested that the mummy was water-transported during the river flood in the spring of the preceding year (2006). Thus, the mummy had been lying on the river bank for one year. The mummy's original location of burial could not be established based on the field survey data.

The Yuribey River begins at the junction of the Levyi Yuribey and Pravyi Yuribey Rivers flowing from lakes Yaroto-2-e and Yaroto-1-e respectively, and flows into Baydaratskaya Bay of the Kara Sea. The Yuribey River valley is formed by ancient marine and lacustrine terraces stretching eastwards from Baydaratskaya Bay.

The maximum heights in the area where the mummy has been discovered are 80 m above sea level. In that area, the Yuribey River has three higher terraces, and the modern flood-plain. The third

* Corresponding author. Tel./fax: +7 343 2608256.
E-mail address: Svetlana.Trofimova@ipae.uran.ru (S.S. Trofimova).

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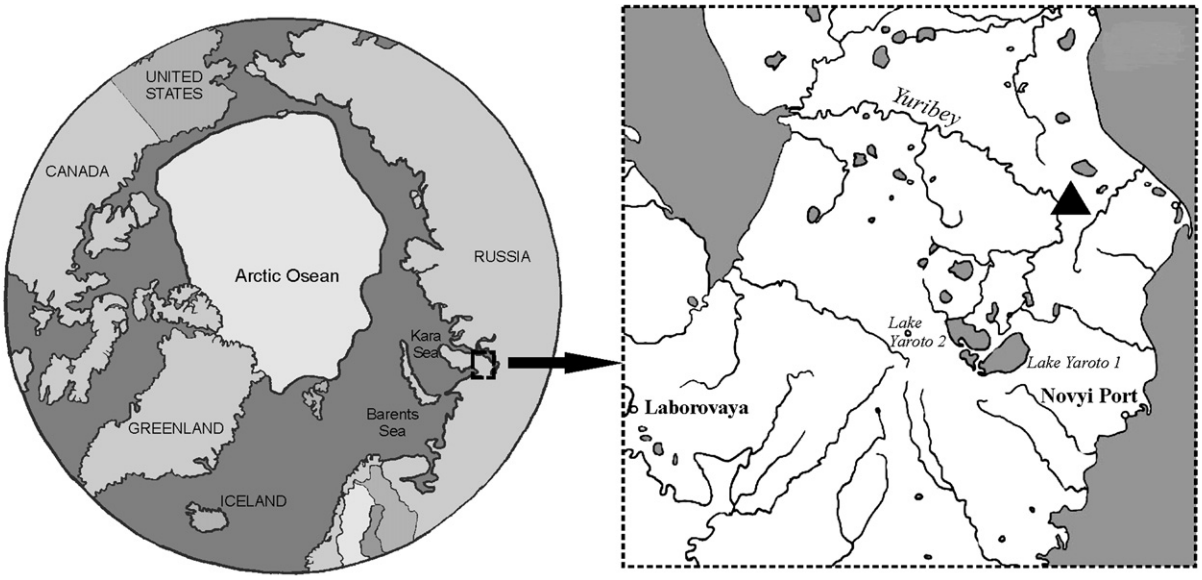

Fig. 1. Location of the place where the frozen mummy of the baby mammoth Lyuba *(Mammuthus primigenius* Blumenbach, 1799) was found in the Yamal peninsula.

terrace achieves a height of 16 m, the second one reaches 12 m, and the first one is about 7 m above the river level. The modern flood-plain achieves the height of 3 m. The terraces are fluvial in origin, and overlie moraine. The third terrace was presumably formed during the Middle Weichselian (MIS 3), the second formed during the beginning of the Upper Weichselian (MIS 2, LGM), and the first formed at the end of the Upper Weichselian (end of MIS 2). The flood-plain is of Holocene age (MIS 1). Dating of the terraces is based on Radiocarbon, OSL, geomorphological, and palaeobotanical data (Korona and Trofimova, 2008; Kosintsev, 2008; Astakhov and Nazarov, 2010). The terraces are formed primarily by sands and silts. Rarely, the deposits include interbeds of autochthonous and allochthonous peat, and plant detritus.

Today, the Yuribey River valley experiences a subarctic climate. The average daily temperature is from −23 to −27 °C in January, and from +3 to +9 °C in July. Average annual precipitation is about 400 mm.

Vegetation in the Yuribey River valley is represented by southern subarctic tundra. Herb-moss tundra with shrubs prevails. Shrubs include *Salix lanata* L., *S. nummularia* Andress., *S. hastata* L., *S. glauca* L., *Ledum decumbens* (Ait.) Lodd. ex Steud., *Betula nana* L., and *Alnus fruticosa* Rupr. Among dwarf shrubs, *Vaccinium vitis-idaea* L. ssp. *minus* (Lodd) Hult., *V. uliginosum* L. subsp. *microphyllum* (Lange) Tolm, and *Empetrum subholarcticum* V. Vassil. are abundant. Herb cover is formed by *Eriophorum polystachion* L., *Carex concolor* R. Br., *Luzula confusa* Lindb., *Festuca ovina* L., *Poa arctica* R. Br., *Calamagrostis neglecta* (Erch.) Gaerth., Shreb. et Mey., *Rubus arcticus* L., *R. chamaemorus* L., and *Valeriana capitata* Pal. ex Link. In the moss cover, *Aulacomnium turgidum* (Wahlenb.) Schwaegr., *Dicranum elondatum* Schleich. ex Schwaegr., *Hylocomium splendens* (Hedw.) B.S.G., *Polytrichum strictum* Brid could be found (Dobrinskiy, 1995; Magomedova et al., 2006).

3. Material and methods

A piece of large intestine was taken after dissection in order to analyze its content. The content represented a mixture of detritus and mineral precipitate; detritus was slightly decayed. Some parts of the intestinal wall and contents exhibited vivianite spots up to 10 mm in diameter.

3.1. Mineral analysis

X-ray diffraction phase analysis of silica components of the mineral precipitate from the intestinal contents was carried out using a DRON-2 diffractometer. To extract mineral content, the sample was dispersed in water. X-ray diffraction patterns were obtained using Cu-anode, a voltage of 20 kV and current of 18 mA; the angle was 1° at a rate of 4°/min. Diffraction patterns were recognized based on intensity (I) of spacing between atomic planes (d) and diffraction angle (2θ).

3.2. Radiocarbon dating

A total of 6 samples from the baby mammoth were Radiocarbon date at the Groningen AMS facility.

1. Bone sample. A piece of rib bone was taken for analysis; the bone showed excellent preservation quality, as did the rest of Lyuba's carcass. The collagen of the bone was used as the datable fraction. The sample was pretreated using the standard Longin extraction protocol (Mook and Streurman, 1983).
2. Wool. A sample of wool was taken for radiocarbon dating before the animal was thawed. This sample was pretreated using the standard AAA (4% HCl, 1% NaOH and 4% HCl) method (Mook and Streurman, 1983).
3. Plant materials from the contents of the intestines. Plant remains from Lyuba's large intestines selected for botanical research were dated in order to obtain extra information on the history of the specimen. Three small samples (around 1 mg of material) were used for AMS dating. The samples were also treated by the standard AAA procedure.

In addition, a large sample of the same large intestine material, using all the available 4.9 g was prepared. The plan was to date this large sample by the conventional method. The sample was treated by AAA as well, but more rigorously. This resulted in only 0.3 g of remaining pretreated material, however. This was too small to be dated by standard radiometry, so this large sample was, after pretreatment in the conventional laboratory, rerouted to the AMS facility.

3.3. Biomorphic and phytolith analysis

Microbiomorph research involves the complex analysis of various microfossils (phytoliths, spores, pollen, sponge spicules, diatoms, plant detritus and faunal micro remains) for the reconstruction of ancient conditions (Golyeva, 2001a). Biomorphs were extracted from contents of the large intestine using standard wet oxidation and heavy flotation techniques (Golyeva, 2001b). For biomorph analysis, specimens of phytoliths and other microfossils were extracted from samples of 15 g.

Phytoliths and other biomorphs were extracted from the sample by centrifugation with water solution of cadmium iodide and potassium iodide, specific gravity 2.2–2.3 g/cm^3. After a centrifugation, the light fraction concentrated in the upper part of the tube was washed with distilled water and dried. Thereafter the phytoliths were examined on slides (24 × 24) in glycerin using optical microscopy at 200× to 400× magnification. The phytoliths were classified on International Code for Phytolith Nomenclature 1.0 (Madella et al., 2005).

3.4. Pollen analysis

The samples for pollen analysis were prepared using standard chemical methods with HF and excluding acetolysis (Faegri and Iversen, 1989). Pollen and spores were extracted from sample of 20 g. Pollen identification was carried out under an Olympus BX51 microscope at 400× magnification. The pollen reference collection housed at the Institute of Plant and Animal Ecology UD RAS (Yekaterinburg), and the pollen atlases (Kuprianova, 1965; Kuprianova and Alyoshina, 1972; Reille, 1995, 1998) were used to aid identification. The pollen concentrations in this sample were very low (frequently 25–35 grains on a slide). Up to 15 slides were counted, and a pollen sum of 473 grains was reached. The pollen sum (PS) used for percentage calculations was based on total terrestrial pollen: AP (arboreal pollen) + NAP (non-arboreal pollen). Spores of mosses and ferns were excluded from the PS. Their representation was expressed as percentages of the PS. Content of non-pollen palynomorphs and reworked pollen was calculated also as percentages of the PS.

3.5. Analysis of plant macrofossils

A sample of intestinal contents for carpological analysis was taken from the large intestine fragment dissected in the laboratory. The sample was water-screened using a set of screens with 0.2, 0.4, 1.0, 2.0 mm aperture, and then air dried. Finally, the sample of detritus (150 ml) was obtained and subjected to microscopic analysis. Identification of seeds was carried out using the carpological reference collection housed at the Institute of Plant and Animal Ecology UD RAS (Yekaterinburg), and atlases of seeds and small fruits.

4. Results

4.1. Mineral analysis

In X-ray diffraction analysis of silica component of the mineral precipitate from the large intestine of the baby mammoth, the following mineral phases were revealed: quartz ($d_I - 3.34_{10}$, 4.24_5, 1.82_9, 1.66_5); potassium feldspar ($d_I - 3.27_{10}$, 2.56_6, 4.21); plagioclase (identified by a line located at 2θ angles of 28°).

The results indicate that terrigenous components prevail in the mineral content of the sample, whereas the products of chemical weathering are practically absent. Absence of chemical weathering products suggests that the minerals constituting the mineral contents have not yet begun to decompose. This indicates that mineral components of the intestinal contents have been recently formed, i.e. they are geologically young.

4.2. Radiocarbon dating

The rib bone was dated to 41.910 (+550/−450) BP (GrA-41246). The stable isotope values are d^{13}C = −21.91‰, and d^{15}N = 8.82‰. The C/N ratio of the bone is 3.2. This bone collagen date of 42 ka BP is considered to be the definitive ^{14}C age of the specimen.

The piece of wool produced a younger result: 37.150 (+280/−250) BP (GrA-35859). This result shows that the skin was contaminated with material of younger ^{14}C age, but the nature of the contamination remains unclear.

Plant materials from the intestine content (small samples subjected to AMS dating) yielded dates which were too young, ranging between 25.9 and 37.6 ka BP. For the large, most strongly pretreated sample of the same large intestine material, the AMS date was measured as 41.700 (+700/−550) BP (GrA-41861). The final date of this sample is consistent with the bone collagen date, and therefore stands as an acceptable result.

Based on both the bone date and the accepted intestine date, the radiocarbon age of the baby woolly mammoth is 42 ka BP. After calibration with the most recent calibration curve Intcal09 (Reimer et al., 2009), this corresponds to *ca.* 45,400 calendar years ago. This date corresponds to the middle of MIS 3 and Middle Weichselian.

4.3. Biomorphic and phytolith analysis

Microfossil content of the baby mammoth's intestine was investigated (Table 1). The microfossil complex comprises phytoliths (51 specimens), spicules (5), diatoms (9), and worm remains (6). The Lyuba sample has a small number of microbiomorphs (71 specimens). The sample contains: a) globular, parallelepiped, acicular, cubic, trapeziform (3D) forms; b) orbicular, oval, elongate, bi-, tri-, n-lobate, lanceolate, square (2D) forms (Fig. 2). Nine phytolith morphotypes have been determined. Among the particles examined, most are strongly corroded on their surfaces.

The phytolith analysis showed that the plant groups included mosses (globular, spherical, elongated forms, with forms with small spines), grasses (bi-, tri- and n-lobate forms, acicular, and lanceolate form), sedges (conical forms) and herbs (elongated smooth forms, varied over a broad range). No arboreal plant remains or lignified tissues have been found. The prevailing groups in the sample are herbaceous plant remains (monocotyledonous grasses and dicotyledonous forbs), conductive tissues of roots, and remains

Table 1
Results of the biomorphic and phytolith analysis of the intestinal contents of the baby mammoth.

Microfossils	Number
Phytoliths:	
Morphotypes	9
Group:	
Dicotyledonous plants	24
Forest grasses	3
Meadow grasses	6
Sedge	2
Mosses	12
Other forms	4
Total	51
Pollen and spores (not identified)	11
Sponge spicules	5
Diatoms	9
Other microfauna remains	6
Total	82

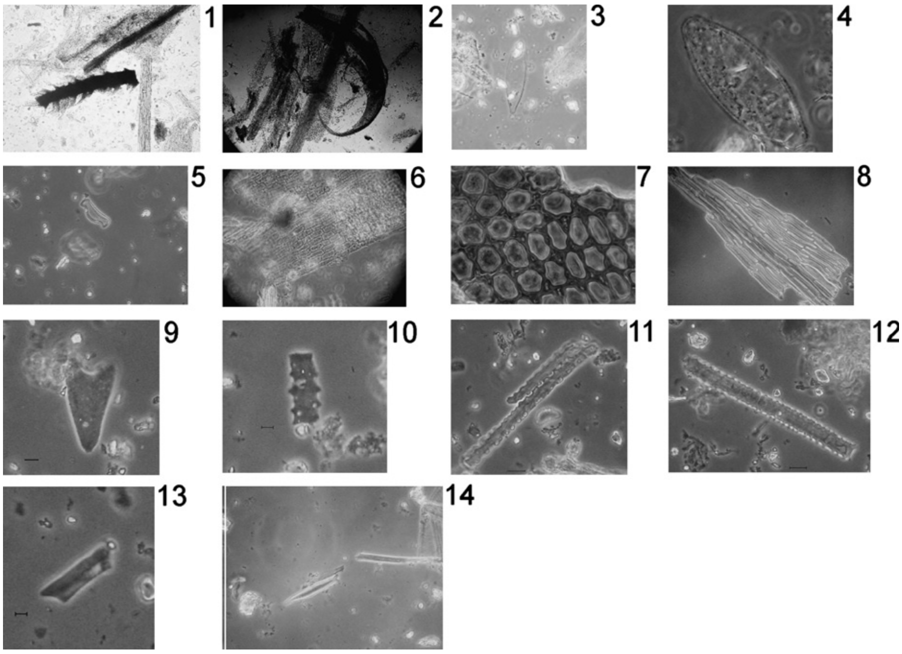

Fig. 2. 1, 2 – General view of the intestinal contents of the baby mammoth showing remains of mosses; 3,4, 5 – diatoms; 6 – epidermis of monocotyledons; 7 – moss tissues; 8 – a moss leaf remain; 9 – trichoma; 10,11,12, 13 – elongate phytolith form; 14 – trapeziform phytolith. Scale bar is 10 mμ.

of various true mosses. Presence of the specific phytolith forms with spiny walls (echinate forms) indicate dry conditions (Twiss, 1992). The sample also contains spicules of sponges and valves of diatoms without signs of transportation or re-deposition. Presence of fungi suggests acid soil or sediment conditions.

Biomorphic and phytolith analysis of the intestinal contents suggest that the large intestine comprises the bottom sediments from a stagnant water body or a slow stream. The vegetation in the vicinity of the water body was dominated by forbs and grasses, with an admixture of sedges.

4.4. Pollen analysis

Pollen grains are at the same stage of fossilization, but the reworked forms are represented by single grains (*Juglans* – 2, *Abies* – 1). Low content of redeposited pollen suggests that the sample studied is of autochthonous origin.

The pollen spectrum is dominated by tree and shrub pollen (Table 2) including abundant pollen of Pinaceae (*Pinus sylvestris* type, *Pinus sibirica* type, Picea), and birch pollen (*Betula pubescens* type, *Betula nana* type). It is not possible to reject the possibility that the abundant Pinaceae pollen include redeposited Quaternary forms. In general, the arboreal pollen could be regarded as long-transported. It represents a regional component of the pollen spectrum because the high levels of arboreal and shrub pollen are characteristic of the subfossil pollen spectra known for the study area (Jankovska, 2007). The pollen of *Betula nana* type is a local component of the pollen spectrum because the major part of the pollen grains produced by the species accumulates within the areas where the dwarf birches grow (Vasil'chuk, 2005a). Among herbaceous plants, anemophilous pollen of Poaceae and Cyperaceae is prevailing. Small amounts of entomophilous pollen of *Artemisia*, Asteraceae, Apiaceae, Caryophyllaceae, *Polemonium boreale* type, Polygonaceae, Ranunculaceae, Rosaceae, *Valeriana capitata* type (Fig. 3) are present, which are also present in modern vegetation of the study area. Among spores, the mosses (Bryales and *Sphagnum* type) and ferns (Polypodiales) are found.

Table 2
Percentage of pollen and spores in the intestinal contents of the baby mammoth.

Groups of pollen and spores		Percentage
AP (trees and shrubs)	*Alnus glutinosa* type	0.6
	Betula nana type	1.3
	Betula pubescens type	10.2
	Picea	10.9
	Pinus sibirica type	7.1
	Pinus sylvesris type	34.2
	Σ AP	64.5
NAP (herbs)	Apiaceae	1.0
	Artemisia	4.8
	Asteraceae Liguliflorae	0.4
	Asteraceae Tubuliflorae	3.1
	Caryophyllaceae	0.6
	Chenopodiaceae	0.6
	Cyperaceae	9.6
	Ericaceae	0.2
	Poaceae	12.1
	Polemonium boreale type	0.2
	Polygonaceae	0.6
	Ranunculaceae	0.4
	Rosaceae	0.6
	Valeriana capitata	1.0
	Σ NAP	35.5
Pollen sum (pcs.)		473
Pteridophyta	Polypodiales	0.8
Bryophyta	Bryales	2.5
	Sphagnum	0.8
Algae	*Botryococcus pila-neglectus* type	0.2
	Pediastrum integrum type	0.2
Fungi	Ascospores of coprophilous fungi	25.3
	Microthyrium type	1.0
Tardigrada	*Macrobiotus hufelandi* type	0.4
Reworked pollen	*Abies, Juglans*	0.6

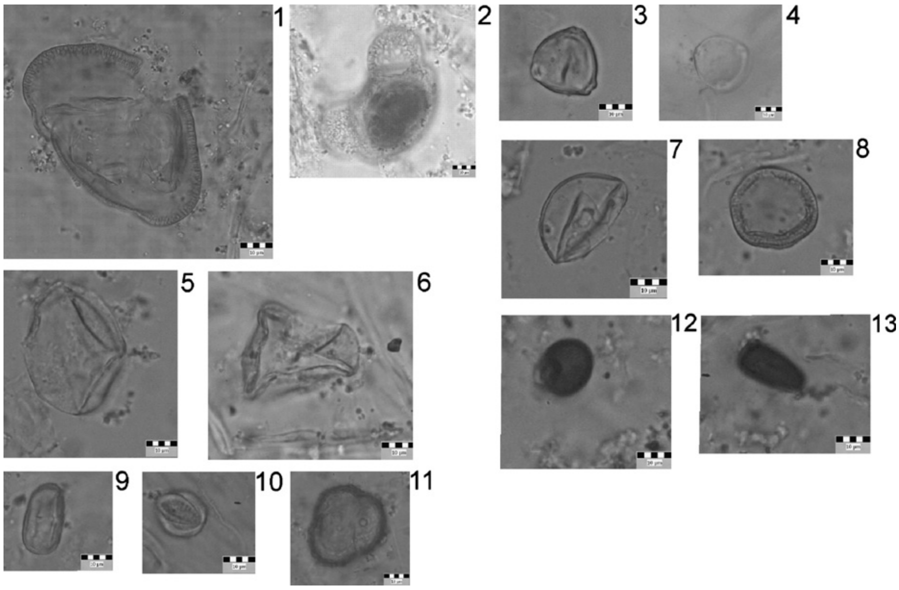

Fig. 3. Pollen from the baby mammoth's large intestine: 1 – *Picea*, 2 – *Pinus sylvestris* type, 3 – *Betula pubescens* type, 4 – *Betula nana* type, 5, 6 – Cyperaceae, 7 – Poaceae, 8 – Caryphyllaceae, 9 – Apiaceae, 10 – *Artemisia*, 11 – *Valeriana capitata*.

The pollen spectrum includes remains of some non-pollen palynomorphs (algae, fungi, and microscopic animals). Green algae include *Botryococcus pila-neglectus* type and *Pediastrum integrum* type, which are typical in cold, pure, fresh waters (Jankovska and Komarek, 2000). *Microthyrium* type fungal fruit bodies are present in the pollen spectrum. The ascospores of coprophilous fungi (*Sordaria* type and *Sporormiella* type) have been found. These fungi are cosmopolite, occurring predominantly on feces of

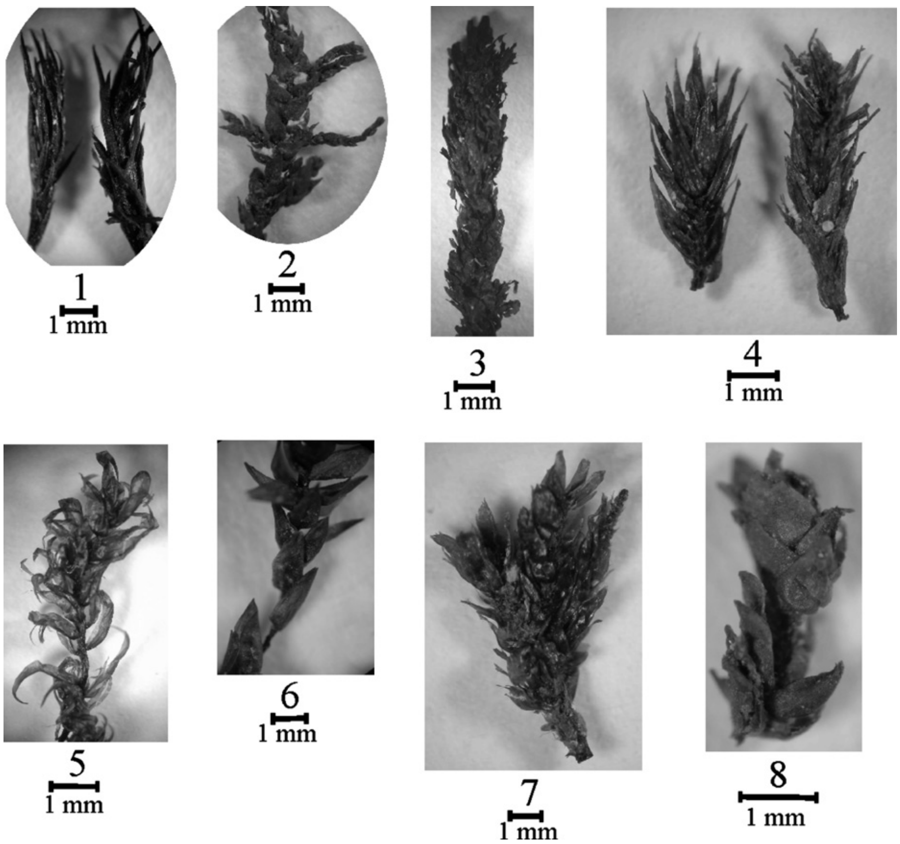

Fig. 4. Remains of mosses found in the baby mammoth's large intestine. 1 – *Polytrichum* sp., 2 – *Abietinella abietina* (Hedw.) C. Muell., 3 – *Aulacomnium turgidum* (Wahlenb.), 4 –*Tomentypnum nitens* (Hedw.) Loeske, 5 – *Drepanocladus* s.l., 6 – *Calliergon richardsonii* (Mitt.) Kindb., 7 – *Hylocomium splendens* (Hedw.) B. S. G., Schwaegr., 8 – *Sphagnum* sect. *Sphagnum* (*Palustria*).

herbivorous animals (Aptroot and van Geel, 2006). The baby mammoth may have swallowed them when eating its mother's feces as modern baby elephants do, or feces could be washed off the ground surface to the water body, and ascospores settled at the bottom. The eggs of Tardigrada (*Macrobiotus hufelandi* type) were also found. These microscopic invertebrates live in various water and terrestrial habitats, and the majority of the species are cosmopolite, occurring in water bodies, on mosses and lichens (Biserov, 1990).

Composition of the pollen spectrum obtained from the intestinal contents of the baby mammoth is similar to those described for subfossil pollen spectra of the Yamal Peninsula (Jankovska, 2007). This allows reconstruction of the vegetation type in which the baby mammoth lived and died. Sedge–grass dominated communities with a small contribution of forbs formed the basis of the vegetation cover. Dwarf Arctic birch also occurred. Arboreal vegetation was absent from the valley of the Yuribey River, and the northern border of arboreal vegetation was located a little south of it.

4.5. Analysis of plant macrofossils

The detritus obtained from the baby mammoth's intestine consists of branches of mosses. Remains of herbaceous plants are scarce. Among mosses, the following species are identified (Fig. 4): *Polytrichum* sp., *Abietinella abietina* (Hedw.) C. Muell., *Tomentypnum nitens* (Hedw.) Loeske, *Calliergon richardsonii* (Mitt.) Kindb., *Hylocomium splendens* (Hedw.) B. S. G., *Aulacomnium turgidum* (Wahlenb.) Schwaegr., *Drepanocladus* s.l., and *Sphagnum* sect. *Sphagnum* (*Palustria*). Presently, representatives of the species found in the baby mammoth's intestine are widespread from Arctic tundra to southern taiga. Among the bog species are *Drepanocladus* s.l, *Sphagnum* sect. *Sphagnum*, *Polytrichum* sp. and *Calliergon richardsonii*. The latter is an Arctic and subarctic species, which is very rare in the taiga zone. *Tomentypnum nitens* and *Aulacomnium turgidum* occur in wet habitats, whereas *Abietinella abietina* and *Hylocomium splendens* are inhabitants of relatively dry habitats.

Seed remains belong to the following species and genera: *Festuca* sp. – 3 spikes, *Carex* sp. – 1 seed, *Ranunculus* cf. *flammula* – 2 seeds, *Ranunculus* cf. *acris* – 1 seed (Fig. 5). All seed remains belong to herbaceous plants. They are common in both tundra and boreal zones. *Ranunculus* cf. *flammula* have not been found in the modern flora of Yamal (Magomedova et al., 2006). Representatives of *Carex* and *Ranunculus* are typical for wet habitats, whereas those of *Festuca* are confined primarily to relatively dry habitats.

The detritus sample comprises animal microfossils and 26 spherical particles, less then 6 mm in diameter, of a pitch-like substance. The nature and origin of those particles are not clear and need further study.

4.6. Analysis of animal macrofossils

Animal macrofossils found in the large intestine of the baby mammoth comprise ephippia of *Daphnia* sp. (28 specimens), 6 specimens of worm remains including 2 nematode remnants, a few fragments of insects and arachnids, and a single bone of a micromammal. Single fragments of insect chitin exhibit well-preserved surface sculpturing without any sign of damage. Among the insects are widespread species and genera: *Diptera* indet. (2 puparia), *Omaliinaea* gen. sp., Staphylinidae indet. (1 pronotum, 1 head), and *Trichoptera* indet. (a fragment of a head-capsule). One

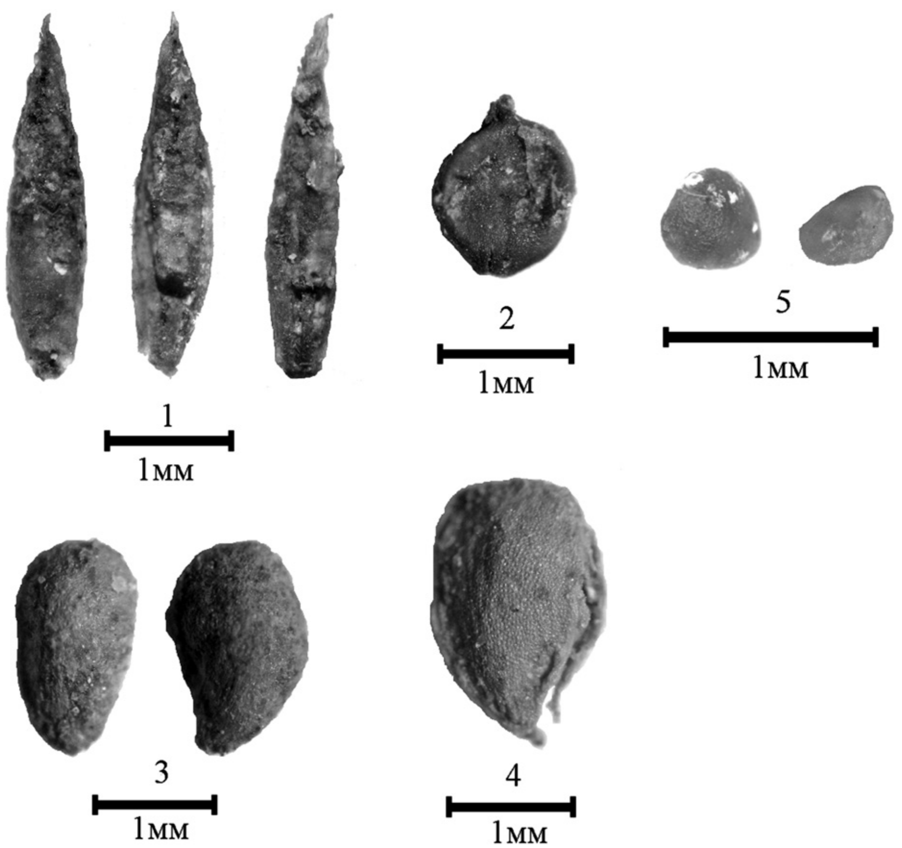

Fig. 5. Seed remains and small pitch-like particles found in the baby mammoth's large intestine. 1 – *Festuca* sp., 2 – *Carex* sp., 3 – *Ranunculus* cf. *flammula*, 4 – *Ranunculus* cf. *acris*, 5 – pitch-like substances.

fragment of *Oribatei* indet. (Arachnida) was also identified. The small mammal bone was an ulna and identified as *Microtus* sp. (Arvicolinae, Rodentia).

5. Conclusions

The baby mammoth mummy is not an in-situ find. However, the data obtained allow establishment of the location of its original burial. The time of the baby mammoth's death coincides with the time of the third terrace formation in the Yuribey River valley, and refers to the Middle Weichselian (MIS 3). Thus, it is possible to hypothesize that the mummy was originally buried in the deposits of the third terrace of the Yuribey River. In the spring of 2006, the burial site was washed out, and the mummy was transported onto the flood-plain surface. Probably, the mummy was partially or completely thawed in the summer of 2006. In the winter of 2006–2007, the mummy was refrozen, and it was discovered in that condition in the early spring of 2007.

Radiocarbon dates obtained on material from the intestine content (large sample) and bone collagen of the mummy are close to each other, although the small AMS samples have yielded dates which are too young. Three small AMS samples from the intestine content (not pretreated as strongly as the large sample (GrA-41861)) could give biased results due to contamination by bacterial activity in the intestines, based on survival of live, but 'dormant' microbes from Lyuba's life. She lay exposed on the bank of the river from May 2006 to May 2007. Supposedly, this enabled the uptake of modern carbon by these microbes. Such phenomena have been observed before, for example in 12,000 years old Mastodon remains (Rhodes et al., 1998). The AMS radiocarbon date obtained for a properly treated large sample (41,700 (+700/−550) BP) is accepted as a final date for the intestinal contents of a baby mammoth. Based on both the bone date and the accepted intestine date, the radiocarbon age of the baby woolly mammoth is 42 ka BP (*c*. 45,400 calendar years ago). This date corresponds to the middle of MIS 3 and Middle Weichselian. Radiocarbon dates obtained on material from the intestinal content and bone of the mummy are identical within error, suggesting the possibility of reconstructing the environmental circumstances under which the baby mammoth lived based on its intestinal content.

The intestinal content represents a mixture of detritus and mineral matter. The results of X-ray diffraction phase analysis suggest fast rates of formation of the mineral component of the intestinal contents of the baby mammoth. This allows consideration of the mineral contents of the intestine as the sediments of a water body that have accumulated during a short time period, thus synchronous to the time when the baby mammoth lived and died. The presence of sponge spicules, diatom valves and *Daphnia* ephippia in the intestine suggests that its contents comprise the bottom sediments of a fresh water body. The spicules and valves are not damaged, and the seeds and insect chitin are well-preserved, suggesting no substantial water flow in the water body. There are only a few reworked forms recovered in the pollen spectrum. Thus, the results of phytolith and pollen analyses suggest that the bottom sediments comprised in the baby mammoth's intestine have not been redeposited.

The plant fraction is represented by slightly decayed detritus. The major part of plant remains is crushed and fractured into separate fibres. Such disruptions of plant tissues result from chewing activity of animals, suggesting that the plant macroremains might have been eaten by adult animals. Anatomical analysis of the mummy (Fisher et al., in press) has shown that the dentition of the baby mammoth was not developed enough to feed on plants. Hence, the plant macrofossil remains might have been ingested by the baby mammoth while eating the feces of adult animals. Other evidence that the baby mammoth might have eaten feces is the abundance of ascospores of coprophilous fungi in the pollen spectrum. A similar conclusion has been drawn by other researchers (Fisher et al., 2010; Rounterey et al., 2010, van Geel et al., 2010). Coprophagy has also been revealed in earlier studies of the intestinal content of adult individuals of the Pleistocene mammoths found in Siberia (Aptroot and van Geel, 2006; van Geel et al., 2008; Clementz et al., 2009; van Geel et al., 2010).

Among plant macrofossils, the remains of mosses prevail. The major part of the mosses remains is represented by damaged plant tissues that might have entered the baby mammoth's intestines while eating feces. A part of moss remains might have been ingested by the baby mammoth as the first experience of grazing. Among the mosses remains in a satisfactory state of preservation, species occurring in all the floral regions (*Hylocomium splendens*, *Abietinella abietina*, *Tomenthypnum nitens*, etc.), and the arctic and hypoarctic elements of moss flora (*Aulacomnium turgidum*, *Calliergon richardsonii*) are identified.

The grass seed remains found in the baby mammoth's intestines belong to taxa with wide ecological range (*Festuca*, *Carex*) occurring in different types of plant communities, from tundra to steppe. Seeds of *Ranunculus* cf. *flammula*, which is not recorded in the modern flora of the Yamal Peninsula, were found. This species grows primarily in wet meadows of the Boreal zone.

Low pollen concentrations, the dominance of Poaceae and Cyperaceae pollen and relatively high amounts of *Artemisia* pollen characterize the sample of intestinal contents. The pollen spectra reflect grass–sedge communities with few other herb taxa and *Betula nana* that occupied the area during the life and death of the baby mammoth. *Artemisia* pollen may indicate rather xerophytic vegetation, and disturbed soils in the area. Arboreal vegetation was absent in the close vicinity, but the woody formations might have been present further south. The climate was relatively cold and dry.

Environmental reconstruction based on the intestinal content analysis of the baby mammoth yielded results which corroborate the paleoenvironmental inferences from the MIS 3 assemblages in the well-studied sections near Marresale Polar Station in the western coast (Forman et al., 2002; Andreev et al., 2006), and in the Seyakha section in the eastern coast of the Yamal Peninsula (Vasil'chuk and Kotlyakov, 2000; Vasil'chuk, 2005b). According to the data available, the interval 30–45 ka calendar years BP (or 28–33 ka radiocarbon years BP) in the Yamal Peninsula was characterized by predominance of tundra-like landscapes and sedge–grass communities with admixtures of forbs, dwarf Arctic shrubs, and willows (Vasil'chuk, 2005b; Andreev et al., 2006).

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