Paleontological monument of nature “Mamontova Gora” exposure (Yakutia, Eastern Siberia, Russia)

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Abstract. The Mamontova Gora ("Mammoth Mountain") exposure is the Neogene – Pleistocene key section of Siberia. This outcrop is located in the lower reaches of the Aldan River, 325 km above its mouth and extends for almost 12 km. It consists of an 80-meter structural plateau (80-meter terrace), 50- and 30-meter alluvial terraces. Sediments from the Middle Miocene (16-10 Ma) to the Upper Pleistocene are exposed on the 80-meter terrace. The basement of the 50-meter terrace is composed of Middle Miocene sediments, overlain by Pleistocene sediments. On a younger 30 m terrace, the deposits are dated from the Upper Pliocene to the Upper Pleistocene. The Mamontova Gora outcrop is one of the richest localities of the Neogene flora of Eurasia. There are numerous finds of remains of Miocene evergreen and thermophilic plants (tree stumps, leaf imprints, cones, nuts, seeds). More than 250 genera of fossil plants have been found on Mamontova Gora. This outcrop is also well known to paleontologists due to the abundance of bone remains of mammals of the Middle Pleistocene (early type mammoth, eastern horse, broad-fronted moose, long-horned bison) and Late Pleistocene (representatives of the mammoth fauna: woolly mammoth, woolly rhinoceros, Lena horse, reindeer, saiga-antelope, steppe bison, Arctic fox, wolverine, cave lion, etc.). It was revealed that the ancient frozen sediments on the Mamontova Gora outcrop abound with viable microorganisms and traces of their vital activity. A strain of microbe Bacillus sp. was isolated from ~ 2 - 3 Ma permafrost layers of this outcrop. A large group of microorganisms including fungi was isolated from the ancient ice wedge. Pleistocene permafrost deposits contain invertase, urease, catalase and dehydrogenase enzymes. Mamontova Gora is a unique geological object in Russia. By the decree of the Council of Ministers of the Yakutia Autonomous Soviet Socialist Republic of 18.02.1987 No. 56 Mamontova Gora was given the status of a "natural monument" and a specially protected natural area of regional significance. The article presents the main results of studies of ancient flora and faunas of Mamontova Gora.

1. Introduction
The Mamontova Gora (“Mammoth Mountain”) outcrop is located on the Aldan accumulative plain, this outcrop begins 325 km upstream of the mouth of this river and it stretches for 12 km on the left bank of the river. In the area where this outcrop is located, there is a combination of a number of geological factors: the terracing of the Aldan river valley, well exposed, genetically heterogeneous,
and significant thicknesses of the sediments composing the section. The section is a continuous series of terraces of the Aldan River (Figure 1), cut into the accumulative lacustrine - alluvial strata and is considered a stratotype section characterizing the history of the Pleistocene of Central Yakutia [1 - 3].

![Figure 1. Mamontova Gora outcrop, view of 50-, 30-, 20-meter terraces. Photo by G. Boeskorov.](image1)

The Mamontova Gora section is unique in East Asia in terms of the completeness of its constituent deposits and the abundance of floristic and faunal remains. In this area, two distinct geomorphological levels are traced. The first of them is the denudation plateau (high part of Mamontova Gora, 80-meter terrace), extending in the upper section of the bend up to 6 km (Figure 2). The second level is a 50-meter erosion-accumulative terrace of the Aldan River.

The authors of this article worked on the Mamontova Gora outcrop as part of various expeditions and were engaged in collecting materials on the mammoth fauna mammals bones remains (Boeskorov G.G., M.V. Shchelchkova, 2007, 2009) and studying the enzymatic activity of buried Pleistocene soils (Shchelchkova M.V., 2009).

![Figure 2. A section of the 80-meter terrace of the Mamontova Gora. From bottom to top, sediments of the Neogene and Pleistocene are represented. Photo by G. Boeskorov.](image2)

2. Brief geomorphological and paleontological characteristics of the Mamontova Gora sediments

2.1. 80-meter terrace

1. Belogorsk layers. Fine-grained sands and clays with interlayers of lignitized plant detritus. They are sediments of lacustrine or oxbow-lake origin and contain clay-siderite nodules (0.2 - 0.7 m), often with leaf imprints. Thickness of the sediments is 2 - 7 m.
2. The Mamontova Gora formation includes two faciologically varieties of the alluvial system of the PaleoAldan River, which formed an extensive lacustrine-alluvial plain within the Lower Aldan depression. In the upper reaches of the Aldan River, the part of the outcrop of the formation is composed of lacustrine and floodplain sediments. There is an alternation of horizontal and diagonally bedded fine-grained sands and silts. Downstream of the river, on the most part of the outcrop, it is represented mainly by channel facies in the form of alternating sands of different grained sands with different bedding. There are interlayers and lenses of pebbles, including those from the nodules of the Belogorsk layers and plant remains. The latter are especially abundant in the lower part of the formation, where they are found in the form of remains of tree trunks (Figure 3), branches, cones of conifers (Figure 4) and endocarpies of nuts. The layer thickness is 54 - 69 m.

![Figure 3. Remains of a Miocene tree trunk. Low layer of an 80-meter terrace. Photo by M. Shchelchkova](image3.png)

![Figure 4. Remains of woody plants of the Miocene age (about 12 million years). Low layer of a 50-meter terrace. Photo by M. Shchelchkova](image4.png)

The Belogorsk sediments and the Mamontova Gora formation are characterized by representative paleobotanical material. It has been established that there are about 280 species of fossil flora by seeds and fruits, 52 genera by spores and pollen, 70 taxa by leaf prints (Figure 5). Fossil imprints of leaves from the Belogorsk layers are represented by the genera *Populus*, *Salix*, *Comptonia*, *Pterocarya*, *Corylus*, *Betula*, *Alnus*, *Castanea*, *Quercus* and others, as well as the classic Turgai flora species *Osmunda heeri*, *Populus balsamoides*, *Salix varians* and others. *Gliptostrobus*, *Metasequoia*, *Comptonia* and others were identified by fruits and seeds. Thermophilic angiosperms (up to 12%) are represented by *Myrica*, *Comptonia*, *Carpinus*, *Juglans*, *Ilex*, *Quercus*, *Nyssa*, *Carya*, *Aralia* and others. In the palynological complex of Mamontova Gora, the content of thermophilic plants decreases.
with the same dominants. Based on the totality of paleobotanical data, the Belogorsk sediments and the Mamontova Gora formation are dated to the Middle Miocene [1, 4].

![Figure 5](image)

**Figure 5.** Mamontova Gora is the northernmost location in Eurasia of leaf imprints of exotic thermophilic plants of the Neogene flora. Photo by M. Shchelchkova

3. The layer of ferruginous sand is represented by sands of various grains, weakly ferruginous, without plant detritus. The thickness of the layer is 4-15 m.

The palynological complex is characterized by a predominance of *Pinus, Picea, Betula, Alnus*, a depleted composition of thermophilic angiosperms, and a significant content of grasses. The layer of ferruginous sands dates from the early Pliocene.

4. Covering loams of gray and brown-gray color include plant remains and bones of mammals of the mammoth fauna. The layer is saturated with ice wedges. The thickness of the layer is 1-3 m. The radiocarbon dates obtained from this layer are: 36400±600 years, more than 45000, more than 49800 years. As a whole, the layer is dated to the Muruktinian-Sartanian (Zyryanian) time of the Late Pleistocene [2].

2.2. 50- meter terrace

At the section of the mouth of the Aan-Appa stream, the second level adjoins the 80-meter terrace, the 50-meter erosion-accumulative terrace of the Aldan River (Figure 1, Figure 6). In the series of Aldan terraces, the most informative in terms of stratigraphic position is the 50-meter terrace. It is widespread in the regions of the lower reaches of the Aldan River, the Vilyui River basin, and the middle and lower reaches of the Lena River [2, 5 - 7]. Its base is composed of the Mamontova Gora formation of the Middle Miocene (Layer 1).
Figure 6. The middle part of the 50-meter terrace (dark in color) is represented by Neogene sediments (Miocene). Above are sediments of the Middle and Upper Pleistocene. Photo by G. Boeskorov

The following strata occur on the basement from bottom to top [2]:

Layer 2. Pebbles. The pebbles are medium, small, well rounded. The filler is gray sands of different grains, sometimes forming interlayers and lenses. An abundance of garnet is characteristic. At the bottom of the stratum, pebbles are cemented with iron hydroxides. The thickness of the layer is 8 m. The remains of the brown bear Ursus arctos L. were found here.

The palynological assemblage is dominated by arboreal pollen (Pinus, Picea, Betula sect. Albae, Alnaster); grass pollen (Artemisia, Gramineae, Polygonaceae, forbs) are not numerous; spores are represented by Polypodiaceae, Sphagnum, Bryales, Lycopodium, etc.

Layer 3. The sands are gray, uneven-grained, with interlayers enriched with plant remains. There are redeposited endocarps of Juglans jakutica Dorof. and cones Picea wollosowiczi Sukach. The thickness of the layer is 4 m. The remains of fruits and seeds are represented by Chara and Nitella, Urtica dioica L., Carex sp., Empetrum nigrum L., Elatine hydropiper L., Myriophyllum sp., Menyanthes trifoliata L., Sambucus cf. sibirica Nakai, Pedicularis sp., Polygonum avicularare L., etc. The palynological assemblage is dominated by arboreal pollen (Pinus, Picea, Betula sect. Albae, Betula sect. Nanae, B. sect. Friticosae) with less participation of grasses and spores (Polypodiaceae, Sphagnum).

The remains of the broad-fronted moose Cervalces postremus Vang. et Fler. and long-horned bison Bison priscus longicornis W. Grom. were found here [6, 8]. The absolute age of samples from the upper part of the layer, determined by the thermoluminescent method, is 300000±5700 years [9]. Paleontological and palynological characteristics, data on absolute age allow to attribute the accumulations of strata 2 and 3 to the preglacial Tobolskian time of the Middle Pleistocene [2].

Layer 4. Here the alternation of two layers of dark gray loam 2.5 - 3.2 m thick, with lenses of peat material and sands and two layers of light gray, uneven-grained, cross-bedded sands 4 - 5 m thick with lenticular interlayers of gravel, loam and plant residues was revealed. The total thickness of the strata is 14 - 15 meters. Here were found bone remains of the steppe bison Bison priscus Boj. and the broad-fronted moose Cervalces postremus, cones of Larix dahurica Turcz., Picea obovata Lbd. In the palynological complex, an approximately equal ratio of pollen of arboreal and shrub species (Betula
sect. Nanae, B. sect. Friticosae, Alnaster, less Pinus, Alnus, Betula sect. Albae), and herbaceous plants (forbs, Caryophyllaceae, etc.) were revealed.

Paleontological data and thermoluminescent dating (176000±2000 years) [9] indicated the Middle Pleistocene age of the layer, while loam layers are synchronized with the Samarovian and Tazovian glaciations [2].

Layer 5. Covering loams and sandy loams from dark gray at the bottom and brown at the top, indistinctly and clearly horizontally layered, with lenses of humus material and scattered plant remains. The layer is saturated with ice wedges. The thickness of the layer is 10 - 12 m. Large plant remains belong to Betula sp., Alnus sp., Populus sp. The palynological complex is dominated by pollen of grasses and shrubs (Artemisia, Ericales, Caryophyllaceae, Cramineae, and others), slightly fewer spores (mainly Bryales, as well as Polypodiaceae, Sphagnum, etc.) and even less (up to 12%) pollen of trees (Betula, Alnus, isolated Pinus, Larix). Abundant remains of mammalian fauna are represented by woolly mammoth Mammutthus primigenius Blum., reindeer Rangifer tarandus L., woolly rhinoceros Coelodonta antiquitatis Blum., Lena horse Equus lenensis Russ. and other representatives of the Upper Paleolithic complex. Numerous radiocarbon dates of the Karginian time were obtained from the layer: from 26800±600 and 40600±550 years to more than 56000 years [2, 9]. The cover layer is dated to the Zyryanian time of the Late Pleistocene and correlates with the Yedoma Formation of northeastern Yakutia. In some outcrops, it seems possible to subdivide it into the Muruktinian, Karginian, and Sartanian horizons. Thus, in the first (upper) section of the 50-m terrace, the Karginian horizon corresponds to a buried dam built by the beavers Castor fiber L. on a small stream cut into the Muruktinian sediments and overlain by Sartanian loams [6]. In other places, more or less persistent interlayers of plant detritus were observed, which can be interpreted as reduced paleosols that developed during the period of cessation of sedimentation in the Karginian time [2].

2.3. 30-meter terrace
A 30-meter erosion-accumulative terrace is directly adjoined to a 50-meter terrace, forming a clearly defined coastal ledge.

The terrace has the following section (from top to bottom) [2]:

Layer 1. Covering loams of dark gray color at the bottom and brownish at the top, silty, spotty ferruginous, including lenses and interlayers of humic material, as well as roots of herbaceous plants, branches and wood fragments. These deposits are rich in ice and have numerous manifestations of cryoturbations. The thickness of the layer is 9 m.

The layer contains bone remains of Equus lenensis Russ., Mammutthus primigenius Blum., Rangifer tarandus L. and other mammals of the mammoth fauna. Freshwater mollusks Gyraulux gredleri (Gred.), Valvata aliens (West.) were found in the lower part of the layer. In the palynological complex, grass pollen sharply prevails, such as: forbs, Asteraceae, Caryophyllaceae, Ericales, etc., less pollen of the arboreal and shrub group present (mainly Betula sect. Nanae, Alnaster, less often Larix, Pinus subgen. Diploxyton), Selaginella sibirica, Lycopodium alpinum, Botrychium borealis, etc. The radiocarbon age of 35300±1500 years was determined from wood from the lower half of the stratum. According to the obtained data, the mantle loams are dated by the Karginian time of the Late Pleistocene.

Layer 2. Sands are light gray, uneven-grained, cross-bedded, with thin and uneven interlayers of loam and lenses of plant remains with cones of Larix dahurica Turcz. The thickness of the layer is 7.5 m.
Layer 3. Pebbles of medium and small size filled with mixed-grained sands and gravel. In the middle of the layer, there is an interlayer of gray coarse-grained cross-bedded sands 0.5 m thick. The thickness of the layer is 10 m.

Layers 2 and 3 represent the alluvial part of the 30 m terrace section. Bone remains of *Equus lenensis* Russ., *Rangifer tarandus* L., and others were found in layer 2. Also the bone remains of some small mammals were found, such as: Siberian lemming *Lemmus sibiricus* Kerr, root vole *Microtus oeconomus* Pall., North Siberian vole *Microtus hyperboreus* Vin. The palynological complex of the alluvial strata is dominated by the pollen of the arboreal-shrub group (40-70%) - *Pinus* subgen. *Haploxylon*, *Pinus* subgen. *Diploxylon*, *Betula* sect. *Albae*, *Betula* sect. *Nanae*, *Alnus*, *Alnaster*. Less (10-30%) at the very top up to 60%) pollen of grasses and shrubs, such as: *Ericales*, *Polygonaceae*, *Caryophyllaceae*, *Onagraceae*, *Umbelliferae*, *Asteraceae*, etc. Spores are present in the subordination: *Polypodiaceae*, *Sphagnum*, *Lycopodium*, *Selaginella sibirica*, etc.

Based on the data presented, the alluvial strata (layers 1 and 2) is dated to the Kazantsevian time of the Late Pleistocene [2].

Layer 4. The basement of the terrace (5.5 m thick) is composed of yellow, uneven-grained, horizontally stratified sands with rare wood remains and small scattered pebbles. According to palynological data [2], the deposits are attributed to the Mamontovogorskian horizon of the Miocene.

### 2.4. Other terraces of the Mamontova Gora

The 20-meter terrace joins the 30-meter one and extends from it downstream of the Aldan River for 1 km. From bottom to top it is composed:

Layer 1. Sands, yellow, cross-bedded, uneven-grained, with interlayers of loam in the upper part and small pebbles at the base. The thickness of the layer is 7.0 m.

The layer characterizes the alluvial part of the terrace. The composition of the palynological complex is dominated (up to 60%) by pollen of the arboreal and shrub group (mainly *Betula* sect. *Nanae* and *Alnaster* with a significant participation of *Pinus* subgen. *Haploxylon*, *Pinus* subgen. *Diploxylon*, *Alnus*. Less (up to 30%) pollen of grasses and shrubs (forbs, *Ericales*, *Caryophyllaceae*, etc.). Spores (mainly *Bryales*) are subordinate. In the upper part of the layer, the content of grass pollen and spores is slightly increased, but the tree-shrub group is still abundant (up to 30%). The layer dates from the Karginian time of the Late Pleistocene.

Layer 2. Covering loams of brownish color with rusty spots of ferruginization, non-layered, silty, with humus lenses, wood fragments. Includes an interlayer (0.3 m) of black lacustrine silt with thin horizontal stratification, enriched with freshwater molluscs. The thickness of the layer is 12 m.

The layer contains bone remains of the narrow-skulled vole *Microtus (Stenocranius) gregalis* Pall. and large mammals bones of *M. primigenius* Blum., *Alces* sp., *R. tarandus* L., etc. The palynological complex is dominated (up to 60%) by spores (mainly *Bryales*, less *Sphagnum* and *Polypodiaceae*. Significant amounts (up to 40% and more) contain grass pollen (forbs, *Polygonaceae*, etc.). Pollen from trees and shrubs are rare. This composition of the palynological complex indicates the degradation of forest vegetation and the harsh climatic conditions of the formation of layer 2, which corresponds to the Late Pleistocene (Sartanian horizon).

5 - 6-meter terrace is the lowest above-floodplain terrace of the Aldan River. It is developed everywhere, and in the area of the Mamontova Gora it adjoins directly to a 20-meter terrace. The terrace is composed of gray loams and sandy loams, which have a well-pronounced horizontal stratification and include numerous plant remains. The deposits do not contain bone remains of fossil
mammalian fauna, and the palynological assemblage characterizing them reflects the modern composition of vegetation (Holocene) [2].

3. Mammoth fauna of the Mamontova Gora

The collection of fossil material at Mamontova Gora and its study were carried out by E.A. Vangengeim [10], B.S. Russanov [6], A.K. Agajanyan and A.N. Motuzko [8], P.A. Lazarev [11], G.G. Boeskorov and M.V. Shchelchikova [12] and other researchers.

In July 2009, we found the following remains of mammoth fauna on the 50-meter terrace of Mamontova Gora (Figure 7): 1). woolly mammoth - two fragments of tusks, three fragments of molars, a fragment of a humerus, a fragment of an ulna, two tibiae, fragments of three femurs, two fragments of tubular bones, fragments of three ribs, a calcaneus, a fragment of a calcaneus; 2). woolly rhinoceros - fragment of the lower jaw, second cervical vertebra, fragment of the cervical vertebra, fragment of the scapula, two fragments of the humerus, fragment of the pelvic bone, talus; 3). Lena horse - metacarpal bone, a fragment of a scapula, a fragment of a femur; 4). moose Alces sp. - the lower jaw, a fragment of the femur; 5). steppe bison - thoracic vertebra, a fragment of the tibia.

On the Aan-Appa stream, dividing an 80-meter terrace with a 50-meter terrace, in July 2009, in the Upper Pleistocene sediments, we found the remains of mammoth fauna mammals, such as: 1). woolly mammoth - two fragments of tusks, fragments of five ribs, calcaneus, a fragment of the calcaneus, tibia, fragments of two femurs; 2). woolly rhinoceros - fragment of the thoracic vertebra, fragment of the humerus, fragment of the radius, talus, fragments of two anterior phalanges, 3). Lena horse - a fragment of a molar, a fragment of a femur, a metatarsal bone; 4). red deer - a fragment of an antler; 5). reindeer - a fragment of an antler; 6). bison - a fragment of the lower jaw, radius, tibia and metatarsal bone (Figure 8).

Some bone remains of mammals of the mammoth fauna that we collected were radiocarbon dated: moose (50-meter terrace; 18730±235 (SOAN-7839), woolly rhinoceros (Aan-Appa stream; 18240±230 (SOAN-7842), woolly mammoth (Aan-Appa stream; 19110±250 (SOAN-7843). These dates refer to the time of the maximum of the Sartanian glaciation and indicate that during this cryochron, this region was inhabited by various species of large mammals of the Mammoth fauna.
The bones of *Bison priscus* cf. *crassicorinis* and *Cervalces postremus* were found in the middle part of the lower stratum of the 50-meter terrace, dated by the thermoluminescent method at 300000±5700 years. In the upper part of the same layer, the absolute age of which according to the thermoluminescent method is 176000±2000 years, remains of *B. priscus* cf. *crassicorinis* and other mammals of the Middle Pleistocene were found.

Numerous remains of mammals of the mammoth fauna originate from the upper layers of 80-, 50- and 30-meter terraces, consisting of mantle loess-like sediments. These layers have several radiocarbon dates: for the 80-meter terrace more than 45000 and 36400±600 years, for the 50-meter terrace 44000±1900 and 40600±550 years [6, 8, 9].

The fauna of mammals of the early Pleistocene from Mamontova Gora is represented by *Mammuthus* sp., *Cervalces latifrons*, *Rangifer* sp. The remains of *Ursus arctos*, *Panthera spelaea* cf. *fossilis*, *Mammuthus primigenius*, *Coelodonta antiquitatis*, *Equus orientalis*, *Cervalces postremus*, *Bison priscus* cf. *crassicorinis* are associated with the Middle Pleistocene sediments. The megafauna of the Late Pleistocene is most fully represented on the Mamontova Gora, such as: *Canis lupus*, *Ursus arctos*, *Panthera spelaea*, *Mammuthus primigenius* (late type), *Coelodonta antiquitatis*, *Equus lenensis*, *Cervus elaphus*, *Alces* cf. *americanus*, *Rangifer tarandus*, *Bison priscus* cf. *occidentalis*, *Ovibos pallantis* [6, 8, 10, 11, 13 - 15].

4. Ancient microorganisms of Mamontova Gora and the remains of their vital activity.

Soil microorganisms are characterized by the best preservation state in permafrost. Some eucaryotes (Chlorophyta, *Chlorococcum* sp.) and procaryotes (cyanobacteria, yeast, micromycetes, and Gram-negative and Gram-positive bacteria) could be found viable in ancient permafrost [16 - 21]. A microorganism was isolated from frozen wood from an exposure of permafrost at Mamontova Gora, which is probably more than 2 million years old (Figure 9). Isolates are able to grow at -5°C and are most related to *Bacillus* sp. based on 16S rRNA gene analysis. This study provides a direct evidence of a cold-adapted *Bacillus* strain is capable of long-term survival in conditions of permafrost [22].

Together with microorganisms soil enzymes are well preserved in the permafrost. Soil enzymes mainly have bacterial and plant origin. Bacteria in contrast to other living organisms use extracellular digestion. They extrete extracellular enzymes in the environment and destroy large polymeric molecules (proteins, lipids, nuclear acids, polysacharids) using these enzymes. The products of destruction (aminoacids, sugars, nucleotids) goes inside the bacterial cells. So, the soils are constantly
enriching by the extracellular enzymes. And there is another way of soils enriching by enzymes. After death and destruction of bacterial and plant cells their intracellular enzymes enter soils.

In soil the enzymes are in different conditions. Part of the enzymes are in unbound condition in a soil solution. Most part of the enzymes is bound with humus molecules and clay minerals. They are called as bound or immobilized enzymes. Another part of the enzymes is bound with the alive and dead cells of bacteria and plants. They are mainly membrane enzymes. Immobilized enzymes are characterized by high stability to unfavourable factors of environment, such as, high and low temperatures and proteolysis.

Studies of enzyme activity in sedimentary deposits composing the Mamontova Gora 50-meter terrace, carried out by M. Shchelchkova in 2009, showed that the activity of some of the studied enzymes is found in permafrost strata dating from 30 thousand years to 12 million years. Invertase activity was detected in all studied samples. The highest activity of invertase was revealed in the sediments of the Upper and Middle Pleistocene. In absolute terms, it is comparable to the invertase activity in the mineral horizons of modern permafrost soils. Urease activity was found only in samples belonging to sediments of the Upper and Middle Pleistocene. Dehydrogenase activity was recorded in samples from sediments of the Middle Pleistocene. Samples of the Upper Pleistocene and Middle Pleistocene age exhibited catalase activity. The results obtained show that invertase is best preserved in permafrost sediments. The activity of this enzyme is detected in samples of the entire age spectrum, from the Miocene to the Upper Pleistocene. Compared to invertase, other enzymes (urease, dehydrogenase, and catalase) are less preserved. The activity of the last mentioned three enzymes was revealed only in the sediments of the Upper and Middle Pleistocene, and it was not recorded in all the samples studied [23].

Thus, the low temperatures of permafrost sediments contribute to the preservation of microorganisms in a viable state for hundreds of thousands of years and even millions of years, as well as immobilized enzymes.

Figure 9. The moment of sampling for microbiological, enzymological, and spore-pollen analyses on the Mamontova Gora outcrop. From left to right: Dr. Marina Shchelchkova, Prof. Anatoly Brouchkov, Dr. Vladimir Repin. Photo by G. Boeskorov
5. Conclusions

Mamontova Gora is a unique geological and paleontological object in Russia, the Neogene – Pleistocene key section of Siberia. The Mamontova Gora outcrop is one of the richest localities of the Neogene flora of Eurasia. There are numerous finds of remains of Miocene evergreen and thermophilic plants (tree stumps, leaf imprints, cones, nuts, seeds). This outcrop is also well known to paleontologists due to the abundance of bone remains of mammals of the Middle Pleistocene and Late Pleistocene. It was revealed that the ancient frozen sediments on the Mamontova Gora outcrop abound with viable microorganisms and traces of their vital activity. A strain of microbe Bacillus sp. was isolated from ~ 2 - 3 Ma permafrost layers of this outcrop. A large group of microorganisms including fungi was isolated from the ancient ice wedge. Pleistocene permafrost deposits contain invertase, urease, catalase and dehydrogenase enzymes. By the decree of the Council of Ministers of the Yakutia Autonomous Soviet Socialist Republic of 18.02.1987 No. 56 Mamontova Gora was given the status of a "natural monument" and a specially protected natural area of regional significance.

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