The Jarkov Mammoth: 20,000-Year-Old carcass of a Siberian woolly mammoth *Mammuthus primigenius* (Blumenbach, 1799)

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SUMMARY: The Jarkov Mammoth was discovered in 1997 on the Taimyr Peninsula, Taimyr, Siberia. The remains of this 20,380 year old woolly mammoth (*Mammuthus primigenius*) were extracted from the frozen tundra under winter conditions in September/October 1999. The carcass and the surrounding sediments were taken out of the tundra using heavy equipment. The block in which the woolly mammoth remains are embedded is stored for scientific purposses in an ice cave in Khatanga, Taimyr. To get a better understanding of the environment in which the woolly mammoth was living around 20,000 years BP and about the life and death of this particular woolly mammoth the remains and the organisms collected from the sediment have been studied. The results of this multi-disciplenary research on the Jarkov Mammoth is presented.

1. History

In the summer of 1997, a family of Dolgans (a nomadic people living on the Taimyr Peninsula, Siberia, Russia) named Jarkov, discovered a 30-cm piece of a mammoth tusk protruding from the tundra, ~ 12 km south of the river Bolshaya Balakhnya (73°32' N; 105°49' E). The Jarkovs excavated the tusk, and to their surprise, they discovered the second tusk, too. Both tusks were still in anatomical position, relative to the cranium. The excavation activities of the Jarkovs damaged the cranium, maxilla, and mandible, which were also in relative anatomical position to each other. Only the tusks were removed; all bones were left in the permafrost. This mammoth, *Mammuthus primigenius* (Blumenbach, 1799) was named the Jarkov Mammoth.

A team from CERPOLEX/Mammuthus excavated the remains of the cranium in May 1998. Next to the cranium were (1) a small piece of meat, (2) skin, and (3) large portions of fur and underfur - all of which were saved. We employed a ground-penetrating radar system to see if more remains of the mammoth are present in the frozen ground. Immediately north of the cranium, anomalies in the permafrost were visible on the monitor attached to the radar. The anomalies were interpreted as potential remains of the Jarkov Mammoth carcass. We decided to extract the remains of this carcass in an unusual way: in Sept/Oct 1999, we excavated a huge block of frozen sediment that likely included the remains of the mammoth.

On October 17th, 1999, a 23-ton block of permafrost was successfully airlifted by an MI 26 helicopter from the frozen tundra of the Taimyr Peninsula. In this 13.5-m3 block of frozen sediment, remains of the Jarkov Mammoth are embedded.

2. Tusks and third molars

The Jarkov Mammoth's tusks are beautifully preserved. They are spirally twisted and reach nearly 3 m in length, indicating that they belong to an adult, male woolly mammoth, *Mammuthus primigenius* (Blumenbach, 1799).

Measurements of the right tusk include:
Maximum length (outer curve), 294 cm
Diameter, 13.5-14.5 cm
Weight, 45 kg

Measurements of the left tusk include:
Maximum length (outer curve), 298 cm
Diameter, 13.5-14.6 cm
Weight, 47 kg

The third molars in both the maxillae (M3, left and right) and mandible (m3, left and right) are preserved. The anterior parts of both molars are worn to the base of the crown. The stage of wear of the m3 is equivalent to Laws' Age Group XXV, which means that the Jarkov Mammoth had an age of approximately 47 ± 2 African Elephant Years (AEY) at the time of its death.

3. Radiometric dates

Remains of the Jarkov Mammoth excavated by the first CERPOLEX/Mammuthus expedition (1998) have been radiometrically dated at the R. J. van de Graaff Laboratory, Utrecht University, The Netherlands, by means of the accelerator mass spectrometry method (AMS). Results of these AMS dates are as follows:

Tab.1

Laboratory number (Utrecht University)	Radiocarbon age (^{14}C yr BP)	Sample
UtC 8137	19910 +/- 130	bone
UtC 8138	20380 +/- 140	hair
UtC 8139	20390 +/- 160	skin

4. Expedition 1999

In September/October 1999 about 1 m^2 of the top of the block was melted in the field, for which purpose ordinary hairdryers were used. A large portion of fur and underfur of the Jarkov Mammoth was exposed. We noted that the underfur was extremely long: up to 12 cm. We agreed that this might be the winter pelage of the mammoth.

The goal of the CERPOLEX/Mammuthus expedition in 1999 was to extract the block (with the known and potential mammoth remains and the surrounding sediment) and to transport it to an ice cave in the town of Khatanga, Taimyr, approximately 250 km south of the site of discovery. We decided to defrost the frozen block in the safety of the ice cave at a constant temperature of - 15°C, in order to collect the mammoth remains, as well as any micro- and macro-organisms trapped in the surrounding sediments.

5. Remains defrosted to Date (January 2001)

In October 2000 we began defrosting operations within the Khatanga ice cave. We divided the very top of the block (the topography of which is somewhat uneven) into 20 sections, each 55 x 55 cm. The sections on the edges of the block are much smaller. Section 1 is located on the SW corner of the block; section 20 is on the NE corner. So far, defrosting by hairdryers has penetrated approximately 25 cm deep into sections 1 and 16. All sediment explored thus far has yielded fur and underfur of the mammoth, as well as plant macrofossils. Within section 1, part of one rib and, in section 16, four thoracic vertebrae of the mammoth have emerged. Three of these vertebrae were in anatomical position. None is associated with any soft tissues. It is now clear that the carcass is not intact. In the spring of 2001 the team shall return to Khatanga to continue the defrosting process.

6. Initial sediment analysis

Microfossils (pollen, fungal spores, algae) and macrofossils (fruits, seeds, remains of flowers, vegetative plant remains, bryophytes) were found in sediment samples from two loci studied thus far: embedded amongst the hairs of the Jarkov Mammoth, and within the lower part of the block of permafrost. Remains of beetles and Chironomids from the sediment will be studied in the near future.

The preservation of these fossils is excellent and a variety of taxa is present. The pollen spectra are dominated by Poaceae, *Artemisia* and *Papaver*. Also macrofossils of these taxa are present in our samples. The overall picture based on interpreting these fossils, is a landscape dominated by a steppe vegetation as a consequence of dry and cool climatic conditions. Moreover, pollen diagrams produced recently from lake deposits elsewhere in the Taimyr area demonstrated that vegetation during the Late Weichselian glacial maximum was typical for a steppe. This data strongly supports R. D. Guthrie's theoretical considerations in favor of the "Mammoth Steppe" and reject the idea that mammoths were living in tundra-like vegetation.

In addition, on a local scale, mosses such as *Racomitrium lanuginosum*, *Pogonatum* cf. *P. urnigerum* and a hair-cap moss resembling *Polytrichum piliferum* are indicative of a rather dry, sandy, or stony environment, with cryogenic phenomena as well as biodisturbance as a consequence of trampling or grazing. We consider the abundant presence of spores of the dung-inhabiting fungus *Sporormiella* as clear indication of the presence of herbivores.

Among the microfossils and macroremains there are also indicators for wet conditions (e.g., the alga *Pediastrum*; the mosses *Drepanocladus aduncus*, *Calliergon giganteum, Rhizomnium pseudopunctatum*). The mixture of plants from wet and dry sites may indicate that the Jarkov Mammoth was covered by sediment in a depression in the landscape where local taxa were growing under wet conditions (open water and damp sites). Remains of plants from dry places may have been transported to the site by wind, but, considering their excellent preservation, transport of these plant remains by mud streams (solifluction) may have taken place. The Jarkov Mammoth may have been covered by mud after solifluction, so that the mammoth and the associated plant remains soon were under permafrost conditions.

7. Analysis of Tusks

To learn more about the life and death of the Jarkov Mammoth, we extracted a small sample of the left tusk near its growing margin. In life, this sample would have been located deep within the tusk alveolus, spanning the entire thickness of mineralized material from the outer surface of the cementum to the soft tissue located within the tusk pulp cavity. Adjacent to the pulp cavity surface is the last dentin deposited before the animal’s death; extending outward from this surface, in the sample recovered, was a 16 mm deposit of dentin laid down during the few years preceding death. We embedded this tusk sample in epoxy resin and cut it transversely producing three 5-mm thick slabs. One of these slabs was thin-sectioned for structural analysis and the other two were sampled to document changes in dentin composition during the last few years of this animal's life.

Viewed at 40x, thin sections of dentin display a clear record of hierarchically organized first-order (annual), second-order (approximately weekly), and third-order (daily) lamination, as has been described in other mammoths. The thinnest second-order incremental features tended to occur in well-marked zones, and showed the highest contrast of all the sub-annual dark-light couplets. The recurrence of these zones provided a clear visual record of first-order (annual) features. Nearly four years are recorded in this sample, with annual increments of about 4.5 mm. Comparisons suggest this represents normal tusk growth for an adult male mammoth about the time of the last glacial maximum. Death occurred at the end of the winter, just before the onset of vigorous spring growth.

Compositional profiles through the last three years of life traced isotope variation in carbonate oxygen, carbonate carbon, collagen carbon, and collagen nitrogen. The oxygen-isotope profile showed seasonally varying values that confirmed the annual increments (identified in thin section), with minimum values corresponding to mid-winter and rising values through spring and early summer. This pattern is in phase with expected variation in the composition of local precipitation, suggesting that winter precipitation, presumably snow, was ingested, but that the snow volume was so small that its melting did not dominate springtime surface-water composition. Carbon isotope values were variable, but all consistent with ingestion of C3 vegetation. Nitrogen isotope values suggest brief periods of late-winter nutritional stress about two years before death and in the final months of life, but this was probably a short-term response to seasonal food shortage. In the episode about two years before death, this stress quickly reversed with the onset of spring. The terminal episode of stress was less severe and probably not associated with the cause of death. Year-to-year contrasts in oxygen-, carbon-, and nitrogen-isotope profiles suggest a niennial (about once every two years) migration between lower latitude environments that had a less “open” vegetational structure and slightly greater moisture availability and the higher latitude mammoth steppe, where this animal finally died.

8. Radiocarbon dating and preliminary ancient DNA results

Forty-nine AMS dates were taken on megafaunal remains collected in 1999 and 2000. Of these, 30 are dates on mammoth remains; the rest are on muskox, bison, reindeer, canid and moose. The mammoth dates range from “infinite” ages in excess of 45,000 radiocarbon years before present (BP) to 10,270 ± 40 BP. Sixteen of the dates are in excess of 30,000 BP, which is of interest because we selected for dating only those specimens that seemed in the best condition - which we assumed would mostly be very young. The youngest date is approximately 600 years older than the most recent mammoth date form the Taimyr Peninsula (9670 ± 60 BP; (GIN 1828, uncorrected), based on a tusk from the

Nizhnyaya Taimyra River which flows out of Lake Taimyr 60 km north of Cape Sabler). The large number of well-preserved specimens of substantial age indicates how well organic remains are preserved at this latitude.

On integrating the new AMS dates with previous catalogs of Russian dates for the Taimyr Peninsula, an interesting patttern emerges. Dates are roughly evenly distributed except for three prominent gaps for which there are few or no dates: several thousands years prior to 35,000 (mid-Kargian interstadial), 18-14,000 (immediately after Last Glacial Maximum); and after 10,000 (beginning of Holocene). An unpaired t-test of the grouped data was significant, suggesting that the gaps are real. The last gap is easily explained—mammoths became extinct (except for the Wrangel population) just after 10,000 BP in Eurasia. But mammoth populations recovered after the other two gaps; they must represent periods when the Taimyr was not a favorable habitat for mammoths, or when taphonomic conditions were different. If mammoth populations were able to recover during interstadial conditions as well as after the coldest phase of the the late Weichselian/upper Zyryansk (Sartan) stadial, it seems unlikely that climate change alone can explain their complete loss from the mainland around 10,000 BP.

Five specimens collected from the 2000 expedition, including the Jarkov specimen, have yielded mtDNA. Studies are now underway on cytochrome b sequences from these specimens.