What our frozen past tells us about the Ice Age diet of the woolly mammoth

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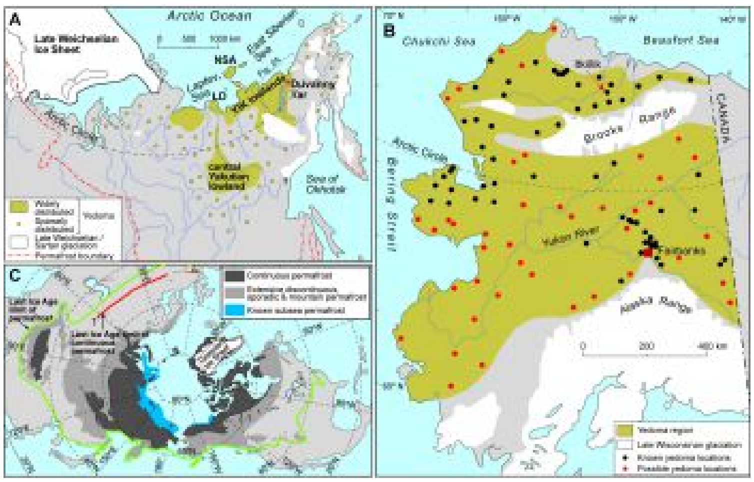

Maps showing yedoma distribution

Research into 50,000 years of arctic vegetation has identified the plant life that sustained giant Ice Age animals such as the woolly mammoth.

University of Sussex Professor of Permafrost Science Julian Murton is one of the authors of an international research paper published in the journal *Nature* today (6 February 2014).

The study presents a 50,000-year record of arctic vegetation history based on the first circumpolar ancient environmental DNA study of plant diversity from permafrost sediments.

Professor Murton says: "Permafrost acts like a giant freezer, preserving countless plant and animal remains from which we can build a record that covers millennia."

The study challenges the prevailing view that the Ice Age "mammoth steppe" (which fed the Ice Age megafauna – giant mammals including woolly mammoths, woolly rhinoceros, bison and horse) was grass-dominated.

Instead, the DNA analysis reveals that the dry steppe tundra on which the animals lived and fed was dominated by forbs (herbaceous vascular plants that are not grasses, sedges and rushes), which provided more nutrients to the grazing animals than grasses.

One such forb whose Ice Age DNA remains occur in Siberian permafrost is Plantago canescens (Northern Plantain).

After the Ice Age ended about 10,000 years ago and many of the megafauna became extinct the forb-rich vegetation was replaced with moist tundra vegetation dominated by woody plants, grasses, sedges and mosses.

Permafrost sediments were collected by drilling into geological exposures at 21 field sites, mostly in Siberia, Alaska and Canada.

Professor Murton's role was to evaluate the geology and permafrost history of the eastern Siberian site of Duvanny Yar in order to provide a geological context for interpreting the DNA results. Exceptional exposures of permafrost here provided 81 the of 242 permafrost samples in the study, as well as mammoth tusk and even the buried larders of Ice Age ground squirrels.

Here, Professor Murton discusses the significance of permafrost sediments to Ice Age history and greenhouse gas emissions, while study co-author Professor Mary Edwards (Professor of Physical Geography at the University of Southampton) describes the nature of the ice-age ecosystem that was the home of mammoths and woolly rhino.

A field worker holds part of a mammoth tusk

Q What and where is permafrost?

Permafrost is ground that remains at or below 0°C for two years or more. The permafrost region in the Northern Hemisphere occupies about 23 million square kilometres (24 per cent of the exposed land area), underlying vast areas of Siberia, Canada and Alaska. The thickness of permafrost reaches 1.5 km in central Siberia.

Q What are permafrost sediments?

The permafrost sediments being studied consist of silt and sand rich in organic carbon and ice. These sediments are known by the Russian term yedoma and occupy a region of about 1 million square kilometres (four times the UK's area) in central and eastern Siberia, as well as large parts of central and northern Alaska and the Klondike region of Yukon, Canada. Collectively, these areas represent the Ice Age subcontinent of Beringia, which included a wide land bridge linking Siberia to Alaska.

Q In what environmental conditions did yedoma form?

Yedoma formed during the last Ice Age (about 80,000–13,000 years ago) by year-on-year accumulation of silt accompanied by upward growth of permafrost. Silt accumulation at the key yedoma site of Duvanny Yar in eastern Siberia resulted mainly from wind action. Ice Age Earth was windier than at present, with massive dust clouds generated in cold permafrost regions of the Northern Hemisphere. The dust settled on and was trapped by vegetation.

The yedoma at Duvanny Yar formed part of a huge belt of windblown silt that stretched across much of the permafrost zone in the Northern Hemisphere, from eastern England in the west across northern Europe to Siberia and North America. Permafrost still occurs within the Siberian yedoma, but has long since thawed in the windblown silts of England and NW and central Europe.

Q What does permafrost tell us about Ice Age history?

Yedoma preserves an exceptional record of Ice Age history. Permafrost acts like a giant freezer, preserving countless plant and animal remains of the past ecosystem of Beringia.

Thawing permafrost sediments at Duvanny Yar, eastern Siberia

Such remains include carcasses and bones of the woolly mammoth, woolly rhinoceros and many other mammals as well as fossil rodent burrows.

More abundant still are tiny pollen grains, insect remains and microbial communities immobilised on the surface of ancient seeds.

Regeneration of whole fertile plants from 30,000-year-old fruit tissue preserved in Siberian yedoma demonstrates the important role for such permafrost as a depository for an ancient gene pool.

Additionally, the ancient environmental DNA preserved in the permafrost provides a record of past vegetation communities, as described in the Nature paper. Such environment DNA derives mainly from plant remains above and below ground and from animal skin cells and excrement, and is thought to be local in origin.

In permafrost environments the DNA is not leached out of the sediments by percolating water, but remains in place, making the permafrost sediments ideal for ancient DNA studies.

Q Why is permafrost important to understanding climate warming?

Permafrost sediments and soils contain more than twice the amount of the carbon that is present in the atmosphere. With high latitudes warming faster than other regions of the planet, the frozen carbon pool is vulnerable to permafrost thaw and release of the greenhouse gases carbon dioxide and methane.

Such release may increase the concentration of greenhouse gases in the atmosphere and amplify climate warming and permafrost thaw – an example of positive feedback. To investigate these processes, the University of Sussex is studying the impact of permafrost thaw on carbon cycling and greenhouse gas emissions from arctic and boreal regions (Carbon Cycling Linkages of Permafrost Systems, CYCLOPS) as part of the NERC Artic Research Programme.

More information: "Fifty thousand years of Arctic vegetation and megafaunal diet." Eske Willerslev, John Davison, Mari Moora, et al. *Nature* 506, 47–51 (06 February 2014) DOI: 10.1038/nature12921 . Received 24 July 2013 Accepted 28 November 2013 Published online 05 February 2014.

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