



Vegetation at the northern pole of cold during the climate extremes of the late Pleistocene Fossil records from the Batagay mega thaw slump, Yakutia

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Beringia - key region for northern ecosystem evolution

the only northern region unaffected by ice sheet formation

uniquely stable cold-continental climate

continuous habitat for northern ecosystems

center of origin, refugium and center of dispersal of many arctic biota

corridor (during sea level lows) or barrier (during sea level highs) for intercontinental migration

too dry for ice sheet formation

cold enough for ice complex formation

The Arctic during the last glacial period

Beringia

North pole

North

America

cold-continental climate

urasia



Photo: F. Kienast

extremely ice-rich permafrost
syngenetically frozen sediments
organic matter is preserved frozen
perfect palaeontological archive
susceptible to warming

instead of ice sheets, there formed

Yedoma Ice Compex



The Batagay mega thaw slump

73

0.8 km

formed within 40 years triggered by changes of the radiation budget as result of timber cutting and other anthropogenic disturbances of the isolating vegetation cover

Journey to the past

Late Pleistocene

Middle Pleistocene

not accessible at the time of sampling

PHOTOGRAPHY

Science on camera

Announcing the winners of the inaugural Scientist at Work photo competition.

BY JACK LEEMING

Palacobotanist Kseniia Ashastina took this collecting samples of ancient plants from a permafrost exposure in northeast Siberia, in June 2014. Ashastina, who is a PhD student at the Senckenberg Research Station of Quaternary Palacontology in Weimar, Germany, says it was a velcome 20°C at the time; this region of the world endures temperatures below freezing for 7 months a year. Over hundreds of thousands of years, the water in the soil has forzen and thawed over and over, carving deep

cuts into the ground and creating steep, icy formations like the one pictured above. It's a remote area: Ashastina and Kienast were the only people there, and there was no hone signal. It doewn't look it, but it's noisy, says Ashastina. "There are tons of mosquitoes there trying to bite you. There is cracking ice and creaking trees. It's dangerous. You'd need to be crazy to enjoy it, but in a good way." The permafrost under the exposed surface makes this area perfect for Ashastina's research, because it's too cold for her samples to be digested by bacteria. The same goes for

this area, around 20,000 years ago, when a green, energy-rich land bridge joined Asia and North America. Femurs, skulls, fibulas and tibias are churned up every summer as the ice melts along the formation, and the cut retreats further into the forest.

GUNS AND IVORY

Shortly after this photo was taken, as Ashastina and Kienast camped near the formation, two locals — drunk and carrying guns — emerged from the forest and demanded to know what the scientists were doing. Every summer, the pair had made money by pulling the tusks »

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the bones of the mammals that once roamed



Photo: Northeast Federal University Yakutsk-

bison, horse, mammoth and wooly rhino

above the cirque bottom



Aim:

to reconstruct the vegetation in the refugial area of arctic megafauna during key intervals of the Late Pleistocene:

- The last cold stage
- The last warm stage (in comparison to the current warm stage)

- to understand: the impact of Quaternary climate changes
- causes and consequences of megafauna demise
- herbivore vegetation interaction

Tundra steppe in the Khangai Mountains, Mongolia. Photo: F. Kienast



Yedoma ice complex of the last cold stage

Organic accumulation of the last interglacial (LIG)

Last glacial assemblage

from the onset of the Last Glacial Maximum

winter storage of an Arctic ground squirrel (*Urocitellus parryii*)



AMS ¹⁴C-dating of herb remains (*Plantago* sp., *Artemisia* sp.) and ground squirrel droppings

26.180 ± 0.22 ka BP 25.620 ± 0.22 ka BP calibrated 30.915 - 29.828 cal ka BP calibrated 30.483 - 29.217 cal ka BP

The nest was built during a time of massive global ice sheet formation equivalent to 40m sea level drop within less than 2000 years – the coldest period of the late Pleistocene



Last glacial assemblage

plant remains in the ground squirrel nest indicate steppe grassland vegetation



A huge continuous steppe belt as a corridor for migration of grasslands plants and animals into the North

echwarzes Meer

Vittelmeer

modern zonal steppes

1000 km

KAUKASU



- In small well-drained, dry habitats, steppe vegetation still occurs in Central Yakutia, the Yana Highlands around Batagay and at other places in Northeast Siberia outside of the steppe zone (extrazonal).
 - The LGM assemblage from Batagay is almost exclusively composed of plants diagnostic for steppe vegetation suggesting that steppe was the zonal vegetation at this time, i.e. there was a continuous steppe belt extending from Central Asia to Yakutia

Last interglacial assemblage

bottom of a woody organic fill of a former



depression

plant remains after sieving

directly below the (last cold stage) Yedoma Ice Complex

indefinite AMS ¹⁴C age of >44 ka BP

OSL date of 142.8 ± 25.3 ka from sediments underlying the sampled deposits

Last interglacial assemblage

plant remains in the organic accumulation indicate open woodland vegetation



Modern vegetation at the site

open woodland vegetation as well but with crucial differences

Pinus pumila as indicator of thick snow cover is widespread today but was absent during the LIG

Larches are the only tree species today. Birches are absent but were present during the LIG

there is no herb layer

but, instead, a thick cover of mosses and lichens, which are sensitive in terms of mechanical disturbances shrub birch and shrub alder are present today and during the LIG but wild roses and raspberries are absent today

Modern vegetation at the edge of the Batagay outcrop in 2014. Note the cut tree stumps. Photo: F. Kienast

Last interglacial assemblage: the herb layer



Conclusions

the study area was covered with grasslands during cold stages and with woodlands during warm stages

grasslands occurred in the Yana Highlands during the entire investigated timespan of the Quaternary, as zonal steppes during cold stages or as small extrazonal patches in during warm stages

nitrophytic ruderal plants, especially the abundant *Urtica dioica*, suggest that the area was a refugium for large herbivores during the last interglacial

the absence of stone pine suggests thin snow cover; the presence of raspberry and wild rose suggests well drained ground during the LIG, thus, conditions drier than today at the site

modern steppe occurrences in the Yana Highlands are relicts of a formerly continuous steppe belt extending from Central Asia to Northeast Yakutia during Pleistocene cold stages