East Siberian glaciers have contracted over the last two glacial cycles

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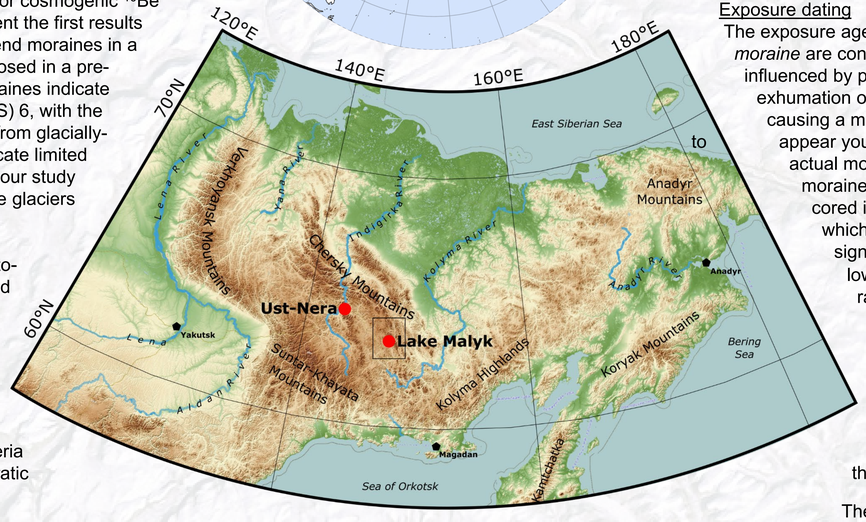
Abstract

Satellite-based maps of glacial landforms reveal that the mountain landscapes of Northeast Eurasia contain over one million km² of glaciated terrain. Previous work has speculated on the existence of large ice masses during the Last Glacial Maximum (LGM) and the preceding cold phases, but the lack of age constraints means that little is known about the timing of past glaciations across this vast region.

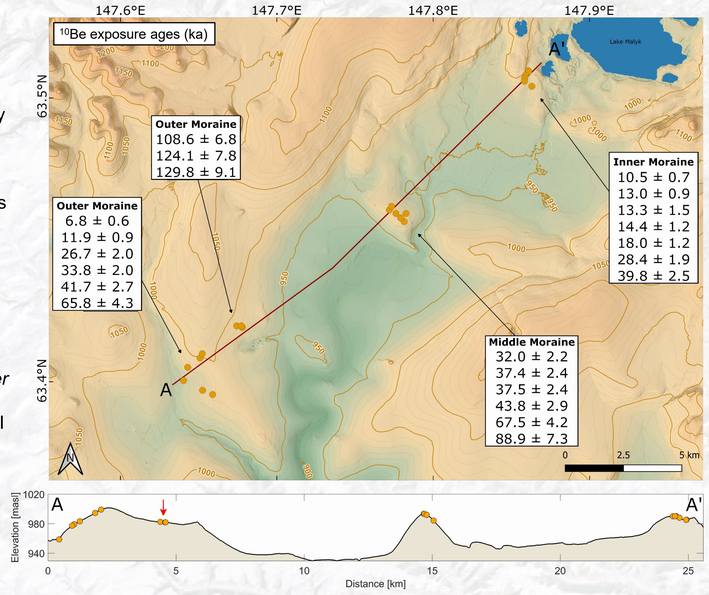
With an aim to gain a better understanding of the glacial history of this region, we collected samples for cosmogenic ^{10}Be exposure dating of boulder erratics and moraines in the mountains of eastern Siberia. Here, we present the first results from two sites, both within the Chersky Range: (1) Malyk Sen, which contains a succession of three end moraines in a foreland setting; and (2) Ust-Nera, which features boulder erratics and glacial bedrock pavement exposed in a previously glaciated valley. At Malyk Sen, the relative positions and corresponding ages of the three moraines indicate progressive contraction of maximum glacier extent since termination of the Marine Isotope Stage (MIS) 6, with the innermost moraine dated to the LGM. Our preliminary results from Ust-Nera suggest exposure ages from glacially-transported boulders and bedrock pavement that are significantly older than the LGM. Both sites indicate limited extents of mountain glaciation during the LGM in eastern Siberia. And while the glacial chronology of our study does not extend beyond MIS 6, mapping of the surrounding areas indicates that even more expansive glaciers existed further back in time.

Our findings confirm the trend of successively smaller glacial extent maxima's in continental Eurasia towards the LGM, with at least one ice advance during MIS 5-3 larger than the LGM advance. This trend could to be linked to extreme continental settings such as in Eurasia and westernmost America, as it contrasts with larger parts of the Northern Hemisphere glaciations where Late Pleistocene maxima were reached during LGM.



Lake Malyk

Lake Malyk (956 m asl) is located at the mouth of an old glacier valley in the southeastern parts of the Chersky Range, the tallest mountain range in Northeast Siberia. In front of the valley is a glacial moraine sequence consisting of three well-defined ridges formed by an outlet glacier that emanated from a mountain icefield. We have conducted ^{10}Be exposure dating on 22 boulders distributed across the three moraines.



Exposure dating

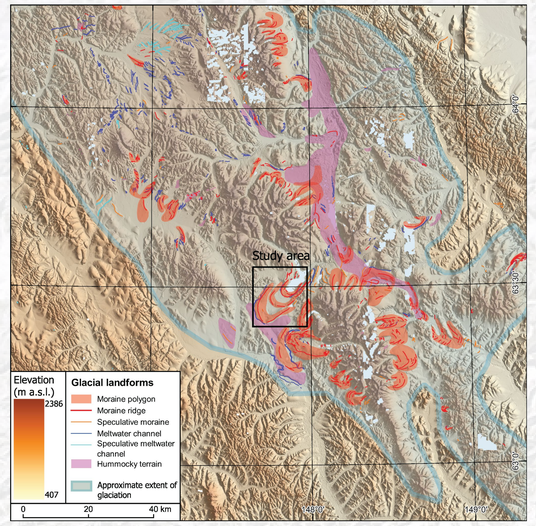
The exposure ages from the *outer moraine* are considerably influenced by post-depositional exhumation of the boulders, causing a majority of them appear younger than the actual moraine. The moraine was likely ice-cored in the past, which have led to significant surface lowering and denudation of the ridge since deposition, gradually exhuming the boulders, resulting in a range of different exposure ages across the moraine. Three large boulders from the more stable proximal side of the moraine (red arrow) were more protected from the post-depositional processes, and they therefore provide an age representative of the true depositional age. This cluster of boulders suggests the moraine was deposited around the end of MIS 6.

The *middle moraine* exhibits a great scatter of exposure ages likely due to similar processes of surface lowering. It is also possible that some of the boulders were subjected to significant exposure prior to deposition making them appear older. However, the moraine must be younger than the outer moraine and older than the inner moraine suggesting it was deposited around MIS 4 or 5.

The *inner moraine* is the youngest, as reflected by the exposure ages. The two oldest samples have likely been subjected to prior cosmic exposure making them appear older than the rest. However, the remaining five samples provide a weighted mean of approximately 14.2 ± 1.1 ka, close to the end of MIS 2.

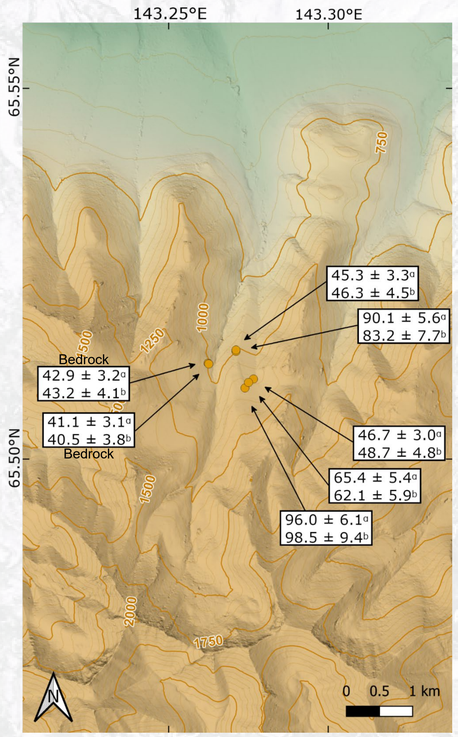
Remote sensing

Our dated moraine sequence suggests that the maximum glacier extent progressively contracted from Marine Isotope Stage 6 to the Last Glacial Maximum. However, our mapping based on the high-resolution digital elevation model ArcticDEM suggests an even older and more expansive glaciation in the region that is yet to be dated.



Ust-Nera

The valley (~1000 m asl) is located in a mountain field in the central Chersky Range of Northeast Siberia close to the settlement Ust-Nera. A total of 7 samples were collected for exposure dating, five from erratic boulders on a lateral-end moraine and two from bedrock outcrops within the valley.



Exposure dating

It is likely that the three older erratics have been subjected to prior exposure. Tors standing up on both sides of the valley make it easy to envisage a scenario where the glacier plucked and eroded material from the valley sides, incorporating material that was once standing above the glacier surface into the ice to be deposited with significant nuclide inheritance. The remaining four samples suggest that deglaciation of the valley happened approximately 45 ka ago. This indicates that the valley was not covered by a glacier during the LGM, and infers that ice extent must have been very limited during both the LGM and MIS 4 in this area.

The ^{10}Be and ^{26}Al exposure dates are in excellent agreement across all samples which inspires confidence in the boulder and outcrop ages. However, it was not possible to identify any additional glacial features further down the valley or on the foreland, and we are therefore not able to speculate on the MIS 6 ice extent at this site.

[a] denotes ^{10}Be exposure age (ka)
[b] denotes ^{26}Al exposure age (ka)

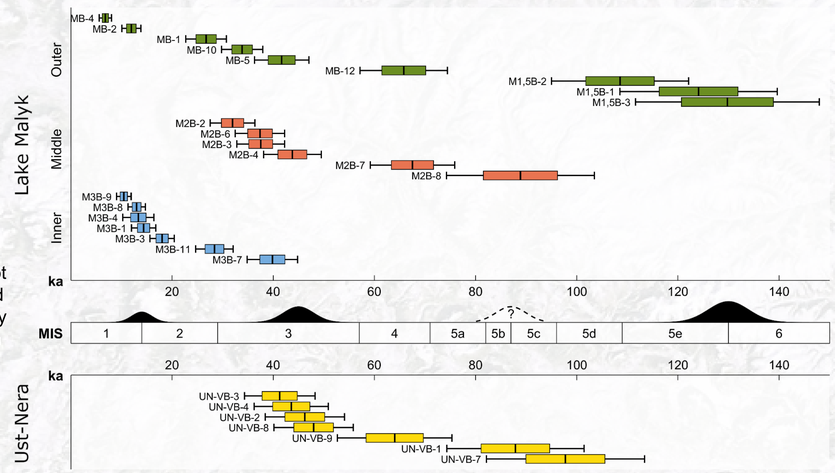


Figure Exposure ages shown with 1-σ (box) and 2-σ (whisker) uncertainties. Top panel shows the sorted exposure ages of the outer, middle and inner moraines with green, orange and blue respectively. The middle panel displays the Marine Isotope Stages together with a visualization of our interpretation of glacial extents in the Chersky Range. The bottom panel shows the sorted exposure dates at Ust-Nera.

Key points

- Glacial landforms from MIS 2 and 6 are present in Northeast Siberia together with glacial landforms tentatively linked to MIS 4.
- Exposure ages from moraines in the Chersky Range show that glaciers in central Northeast Siberia contracted over the last two glacial cycles.
- Northeast Siberia hosted mountain-centered icefields during the Late Pleistocene, but no large-scale continental ice masses.
- Largest ice extent in the Chersky Range predates the penultimate glacial cycle and likely occurred during one of the Mid-Pleistocene super-glacials.

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