



## 1,100,000 year history of Siberian permafrost based on U-Pb chronology of speleothems

Anton Vaks (1), Andrew J. Mason (1), Sebastian F. M. Breitenbach (2), Alexander M. Kononov (3), Alexander V. Osintcev (4), and Gideon M. Henderson (1)

(1) Department of Earth Sciences, University of Oxford, South Parks Road, Oxford OX1 3AN, United Kingdom (Anton.Vaks@earth.ox.ac.uk), (2) Swiss Federal Institute of Technology Zurich (ETHZ), Sonneggstrasse 5, ch-8092 Zurich, Switzerland, (3) Institute of Earth's Crust, Russian Academy of Science, Siberian Branch, 128 Lermontova Street, Irkutsk 664033, Russia, (4) Arabica Speleological Club, Mamin-Sibiryak Street, Irkutsk 554082, Box 350, Russia

We have used U-Pb dating of the speleothems from Siberian Ledyanaya Lenskaya Cave for tracing of permafrost thawing events during the last 1.1 million years. Rain and snowmelt waters can penetrate into caves only when the soil and subsoil temperatures are above 0°C and permafrost above the cave is discontinuous or absent. Therefore, speleothems in regions currently affected by permafrost provide a tracer of past permafrost thawing events.

Ledyanaya Lenskaya Cave is located at 60°22'N-116°57'E, on the southern boundary of continuous permafrost zone, with no present-day water seepage in the cave. Temperatures in the region range from -32°C (January) to +18°C (July), with mean annual temperature of ~-6°C. U-Th dating of speleothems from this cave in a previous study [1] showed that the youngest speleothem growth period occurred at 427±23 thousand years ago (ka), during the early Marine Isotope Stage (MIS) 11. During this episode global temperature was 1.5°C higher than pre-industrial levels, and ~0.7°C above the present.

In the current study two horizons at the base of a stalagmite were dated using U-Pb chronology [2]. Isochron ages of 1074.1 ± 7.9/-6.9 ka and 951.4 ± 3.6/-4.4 ka were obtained. Timing of these permafrost thawing events correlates with events of exceptionally high Pacific Warm Pool sea surface temperature (~+30°C)[3]. During these warm episodes the average global temperature was 1.2-1.3°C higher than pre-industrial temperatures. These findings put the threshold of thawing of the continuous permafrost near its southern boundary slightly lower than it was found previously. The dating work is still in process and is now focusing on growth periods older than MIS-11 but younger than 950 ka.

The oldest horizon of the stalagmite grew on the bedrock. This layer was probably amongst the first vadose speleothems that formed after the cave was uplifted above the groundwater table (associated with the nearby Lena River). Today the cave is ~50 meters above the river. Therefore, it's likely that the maximum uplift rate of the cave (plus Lena River incision) is slightly less than 50 m/Myr.

### References:

1. Vaks, A., et al., *Speleothems Reveal 500,000-Year History of Siberian Permafrost*. Science, 2013. **340** (6129): p. 183-186.
2. Mason, A.J., G.M. Henderson, and A. Vaks, *An Acetic Acid-Based Extraction Protocol for the Recovery of U, Th and Pb from Calcium Carbonates for U-(Th)-Pb Geochronology*. Geostandards and Geoanalytical Research, 2013. **37**(3): p. 261-275.
3. Hansen, J., et al., *Global temperature change*. Proceedings of the National Academy of Sciences, 2006. **103**(39): p. 14288-14293.