INNSBRUCK QUATERNARY RESEARCH GROUP

History of Late Pleistocene Permafrost in Southern Ural revealed by studies of speleothems and cave sediments

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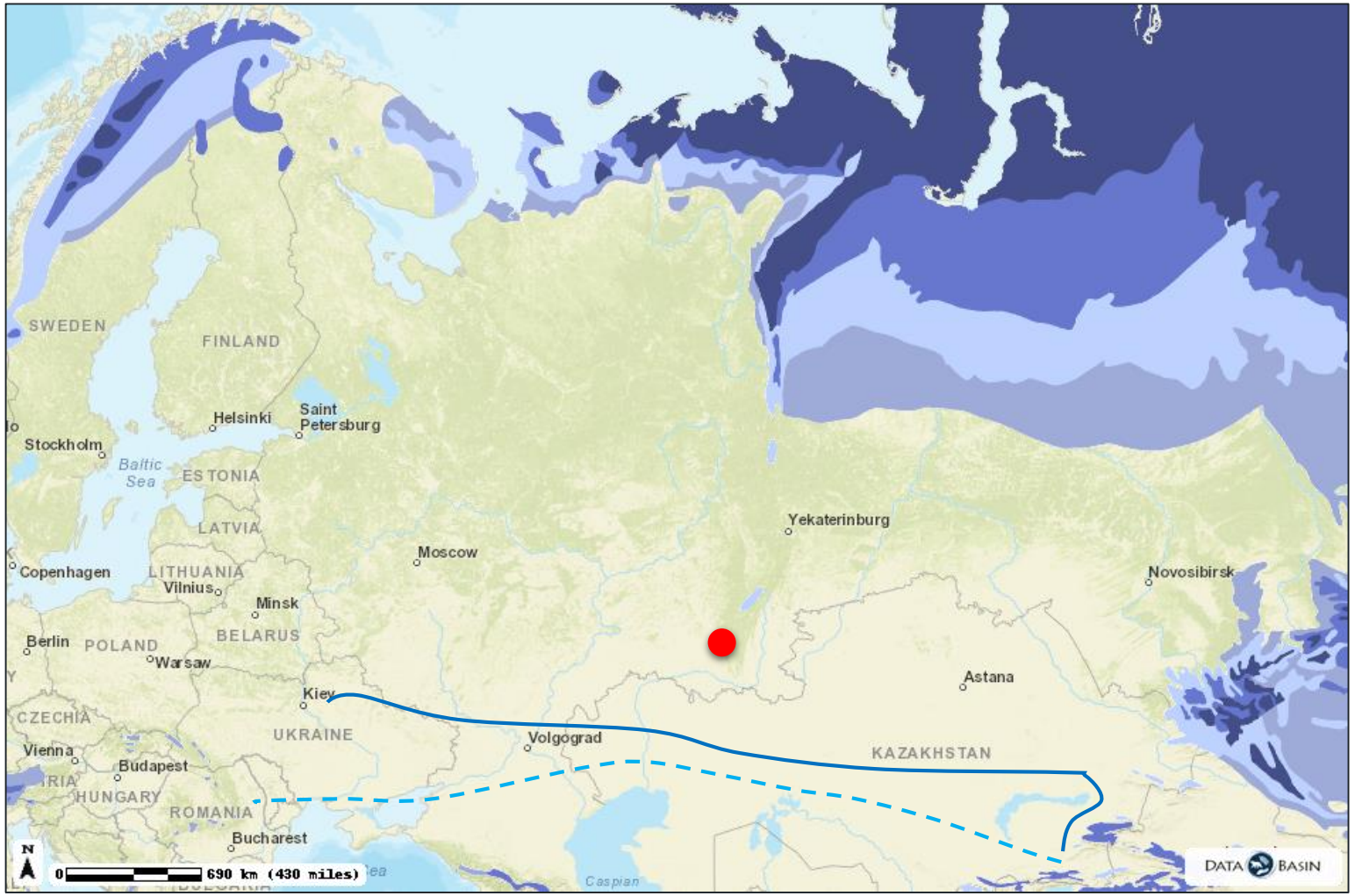


Circum-Arctic Map of Permafrost and Ground Ice Conditions
https://databasin.org/datasets/1f624a31ab224835a78ad4bf11103419

Credits: National Snow and Ice Data Center, USA

Created: April 21, 2020

DATA BASIN

Legend

Circum-Arctic Map of Permafrost and Ground Ice Conditions

Displaying: **EXTENT**

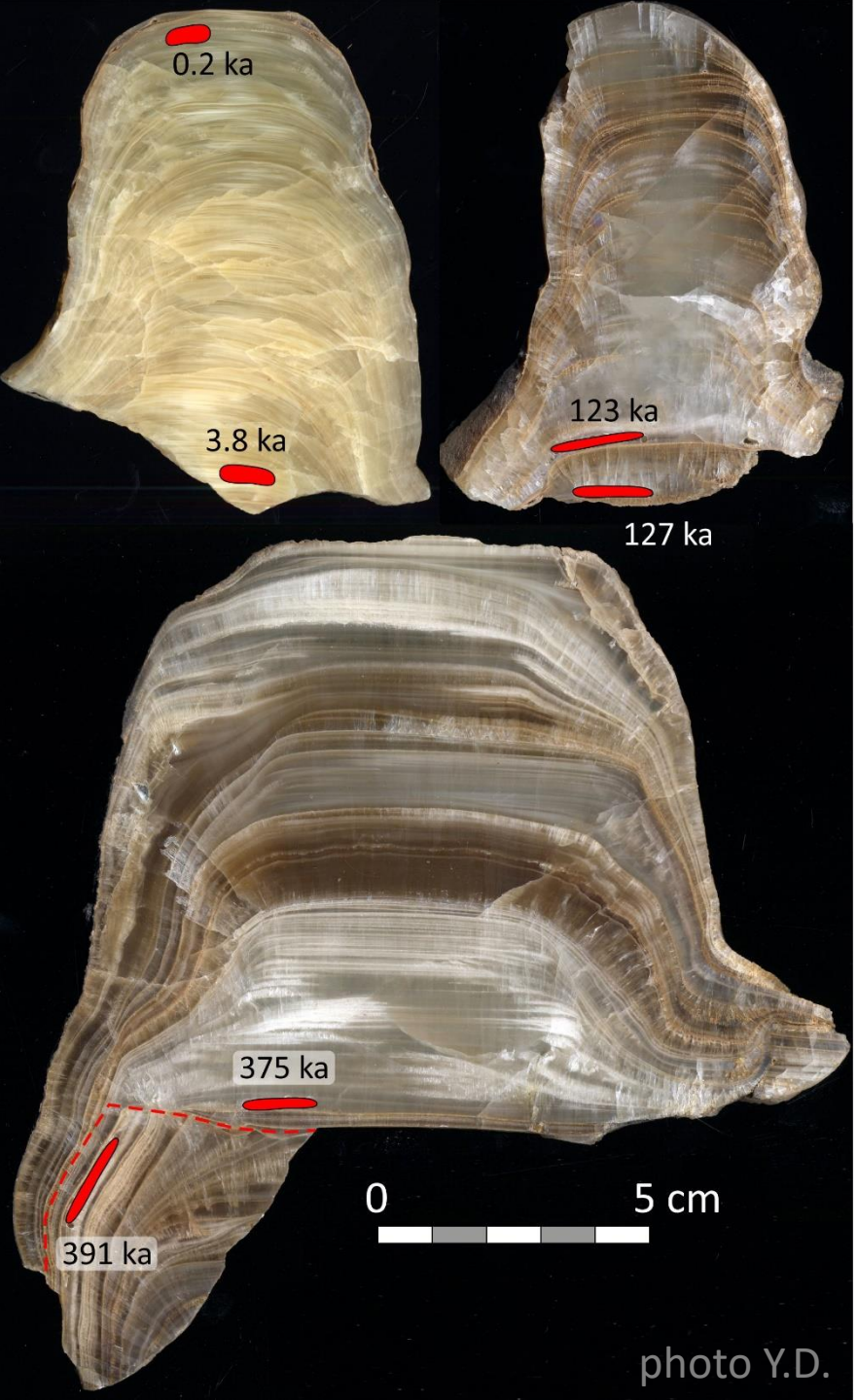
- Glaciers
- Continuous Permafrost (90-100%)
- Discontinuous Permafrost (50-90%)
- Sporadic Permafrost (10-50%)
- Isolated Permafrost (0-10%)
- Study area
- Limit of LGM continuous permafrost (Vandenberghe et al. 2008)
- Limit of LGM permafrost (Vandenberghe et al. 2008)

In the area of the European-Asian border, in the Ural Mountains, the southern boundary of permafrost has moved in meridional direction by more than 1000 km in response to Quaternary climate variations. During cold climate states, permafrost extended as far south as the Southern Ural (53°N).

Study area: Southern Ural (lat. 53°N)

Caves: Shulgan-Tash, Victoria, Grandioznaya

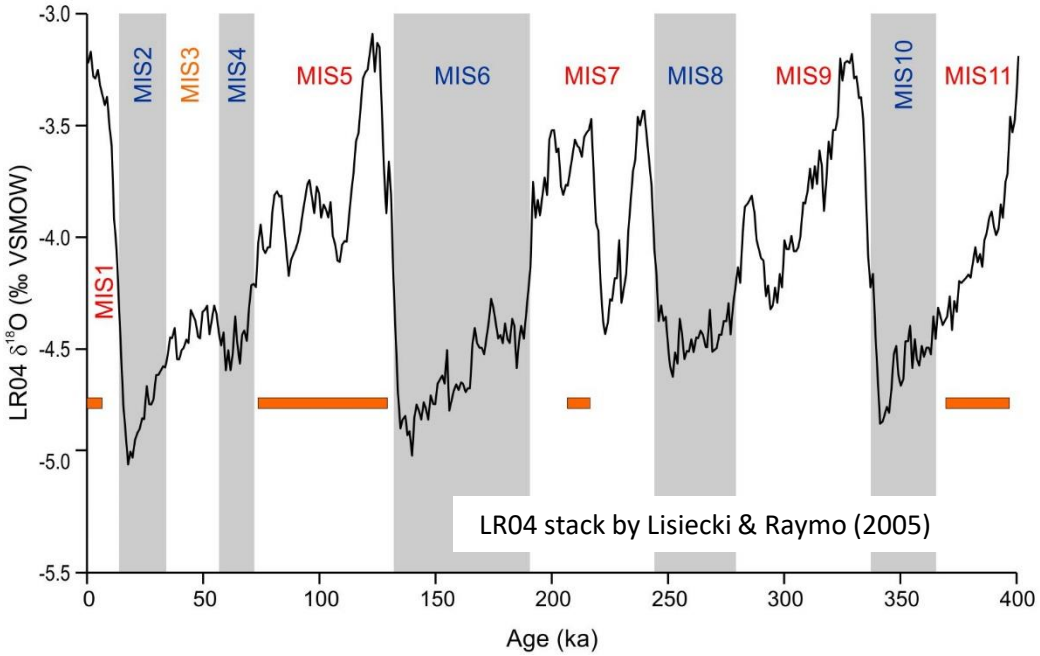
Archives: stalagmites, cryogenic cave calcite (CCC), fluvial cave sediments (silt, sand)

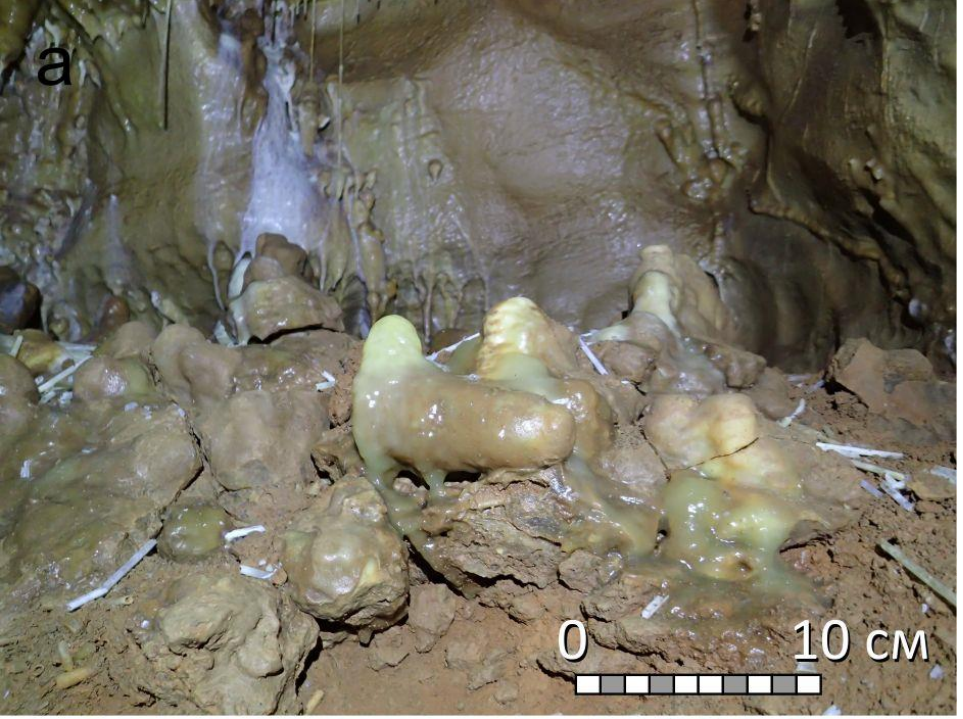


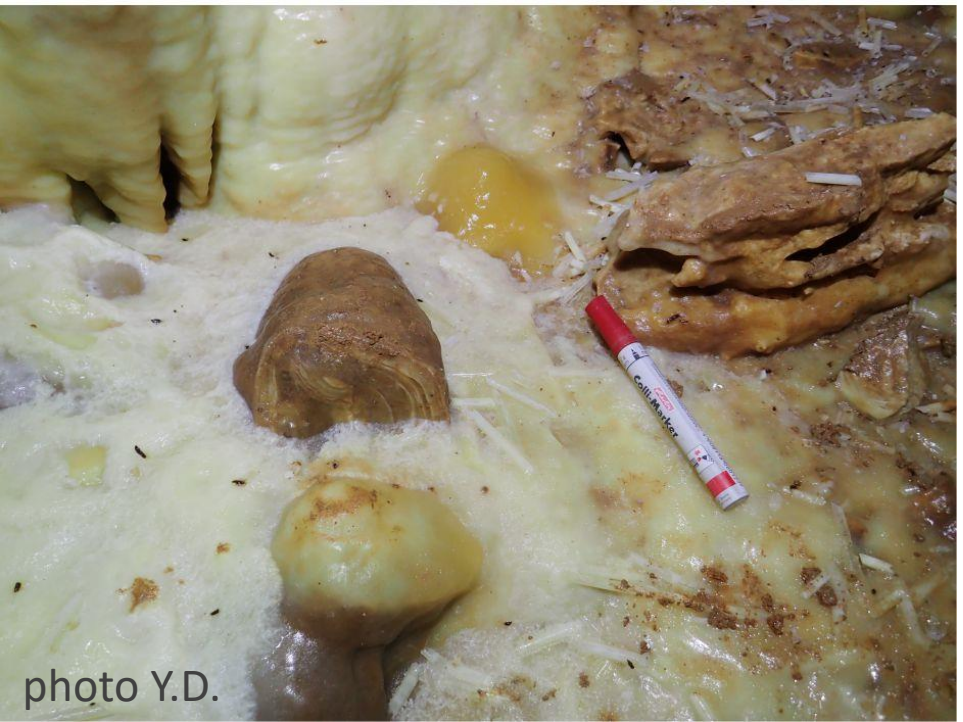
Common speleothems (e.g., stalagmites and flowstone) require liquid water to form, and are therefore restricted to permafrost-free periods.

Stalagmites from S. Ural caves

Several stalagmites from the three S. Ural caves returned ages of MIS11, MIS9/MIS8, MIS7, MIS5 and the Holocene.
No stalagmite growth occurred during glacials.



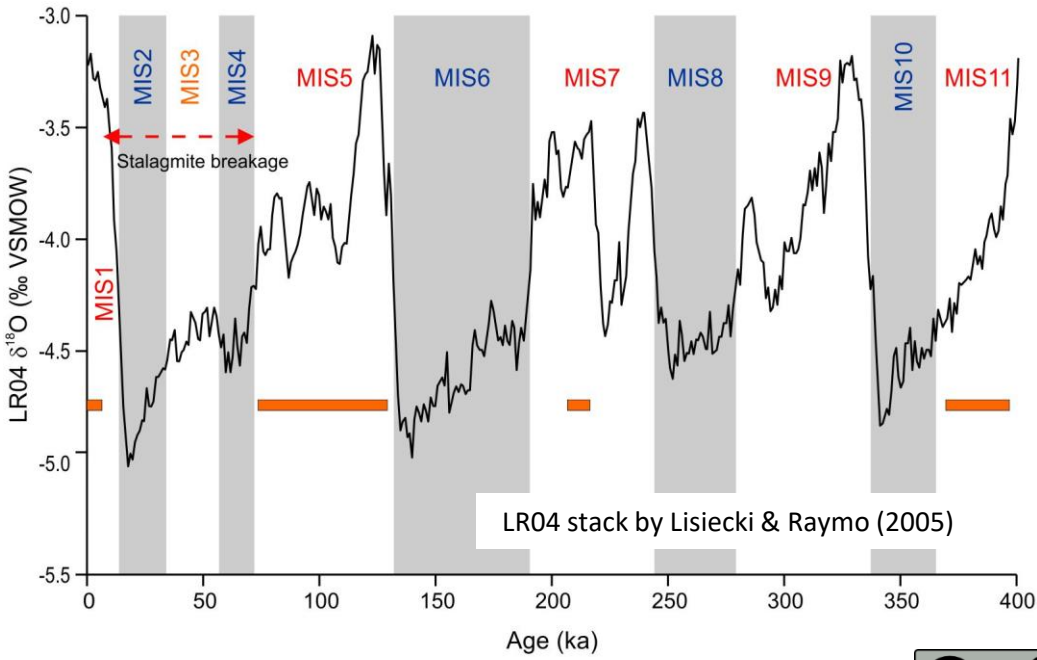




Abundant broken stalagmites, particularly those with not-too-elongated morphology, suggest presence of ice in the cave.

Broken stalagmites in Victoria cave

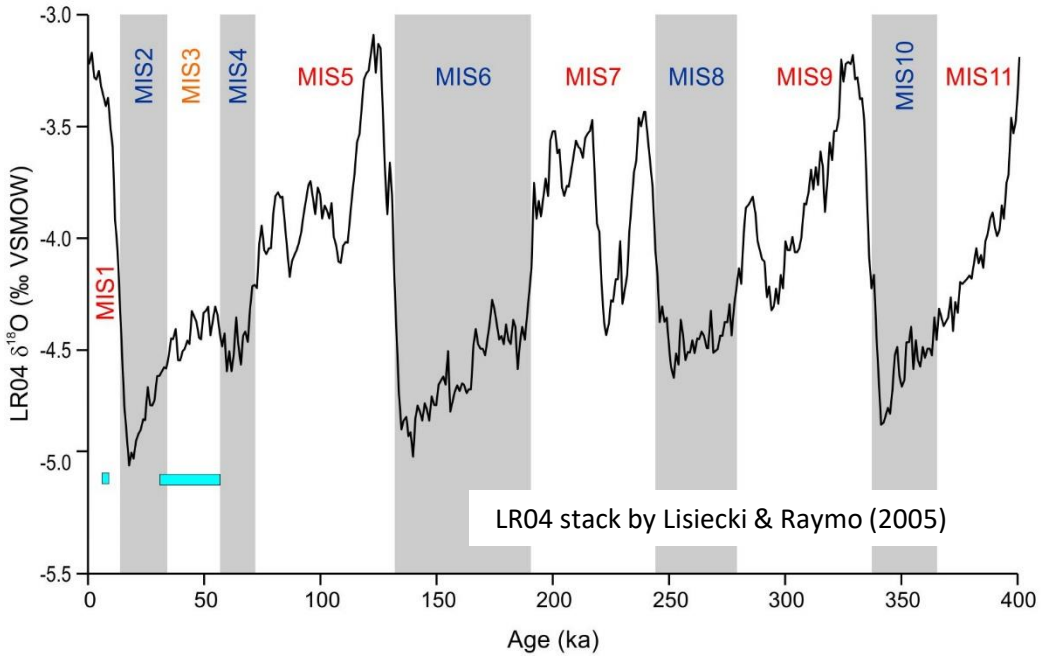
Broken stalagmites in Victoria cave are of MIS5 age. They are cemented/overgrown by the Holocene flowstone and stalagmites.
This is consistent with the presence of permafrost during MIS3 (as indicated by CCC ages; see below).

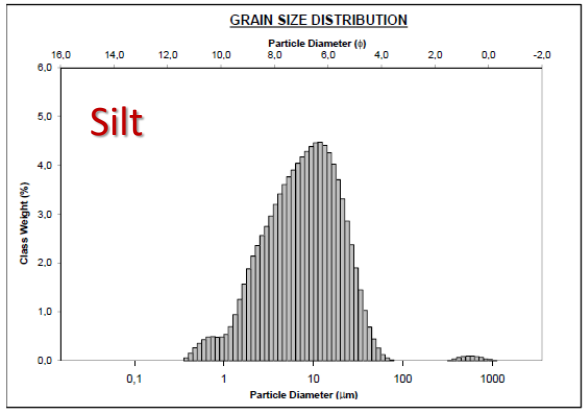


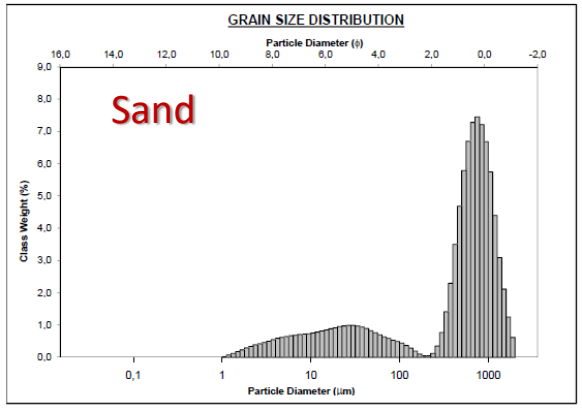
Most of the CCCs found in caves Victoria and Shulgan-Tash formed during MIS3. CCC from Grandioznaya cave showed the Younger Dryas age.

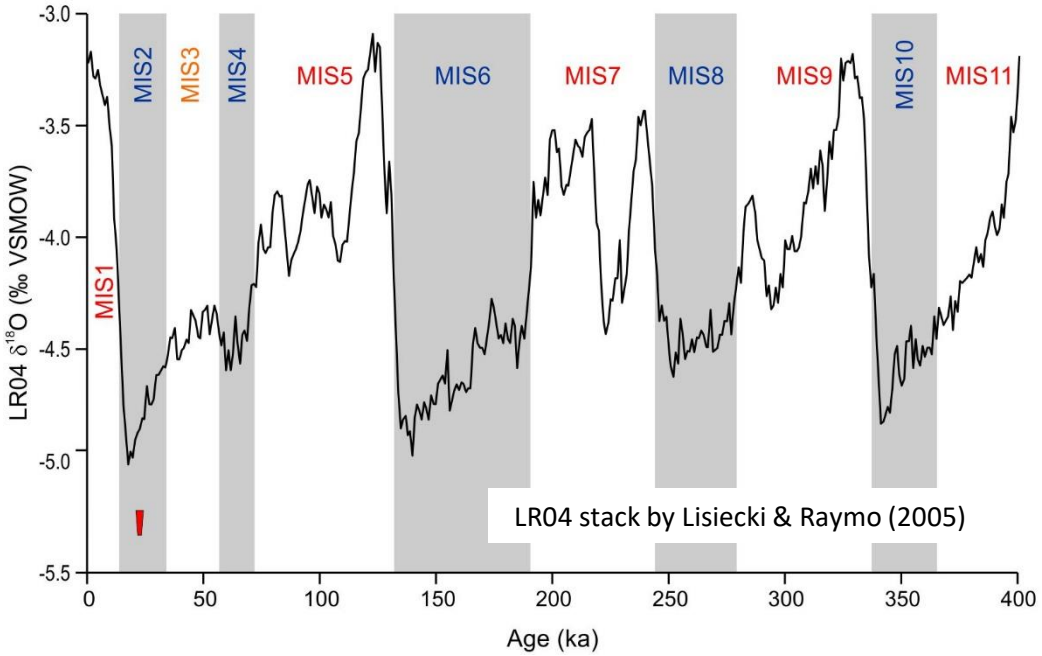
Cryogenic cave carbonates (CCCs) form when the temperature in the cave is close to or slightly below 0°C (permafrost conditions).

Cryogenic calcite and glendonite (pseudomorph of calcite after ikaite) from Victoria cave.



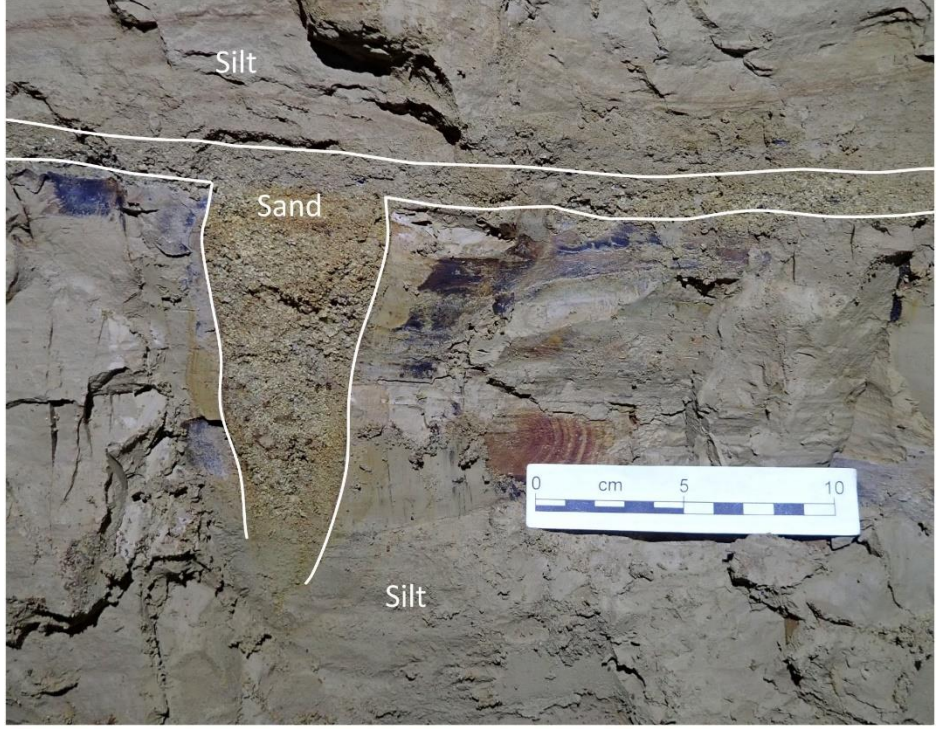


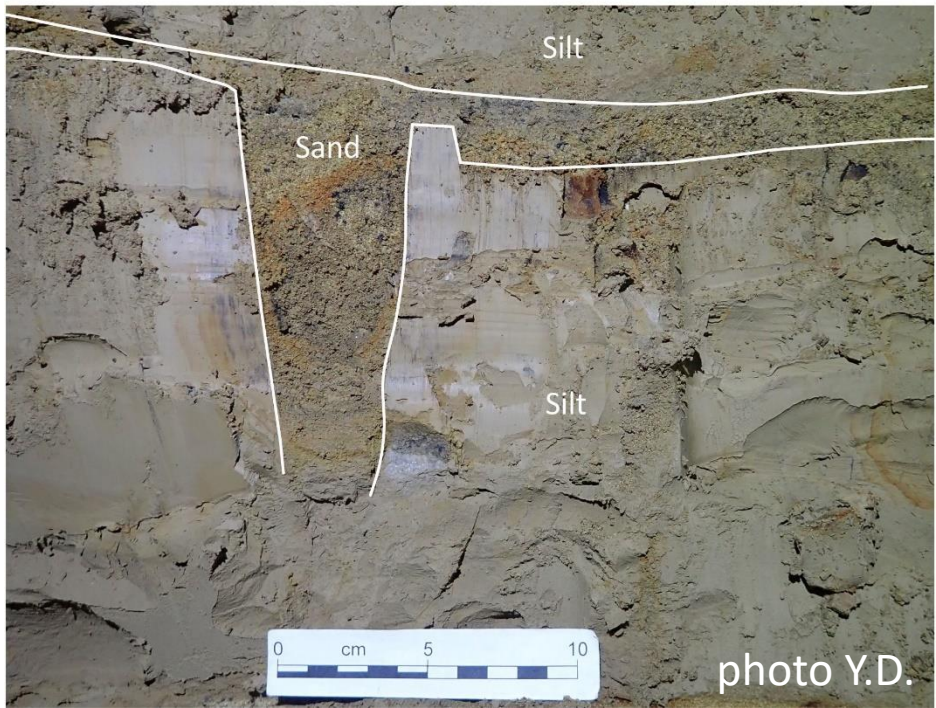




Sand from three discrete layers yielded the LGM dates (22.5 ka; OSL)

Sand wedges in fluvial silt sediments, found in far-from-entrance part of Victoria cave, may reflect permafrost-related flow dynamic and freezing-thawing in the underground stream.





Grain size analysis

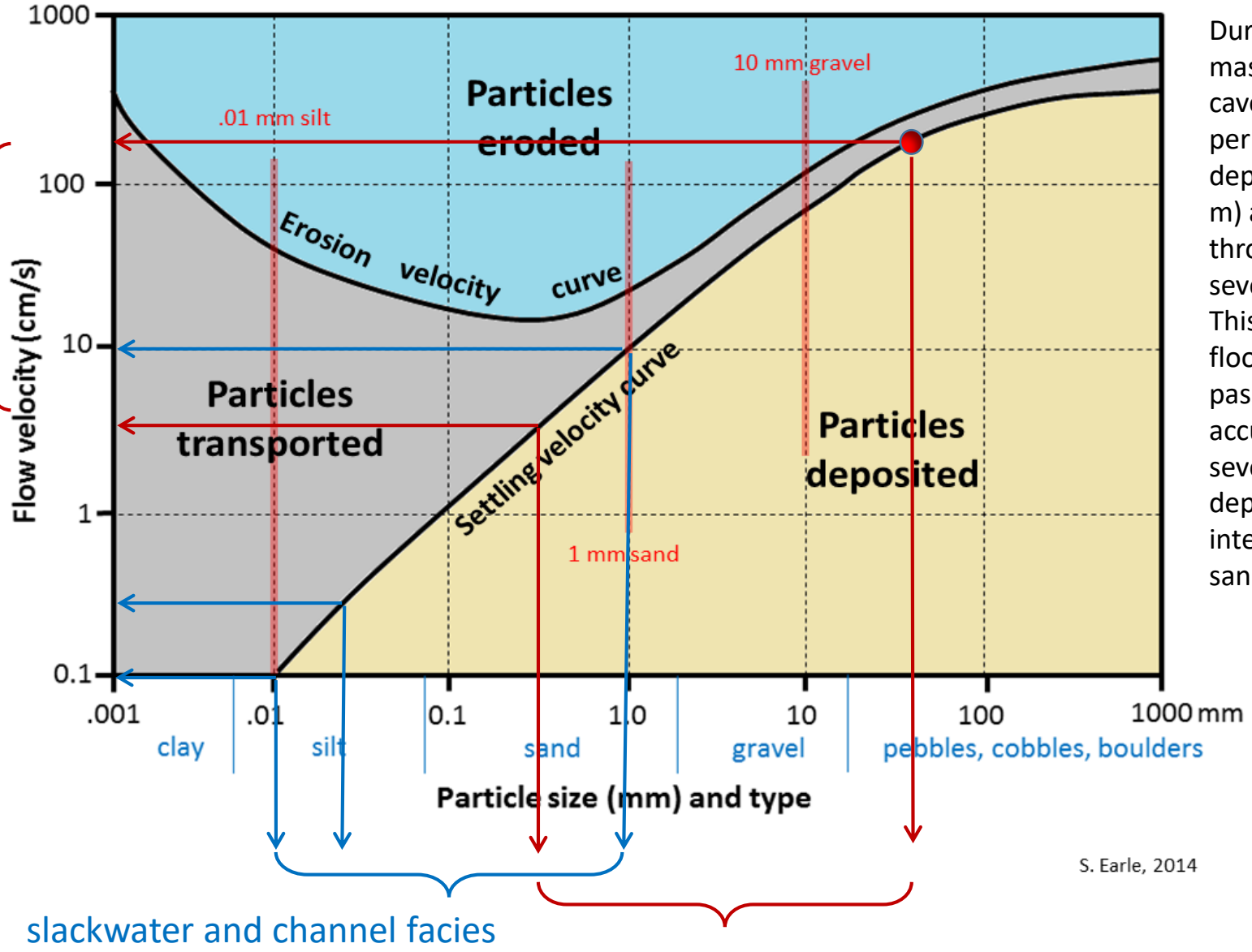
Drastically different flow dynamics during LGM and in Holocene

flood

Holocene/modern flow conditions

base flow

LGM flow conditions

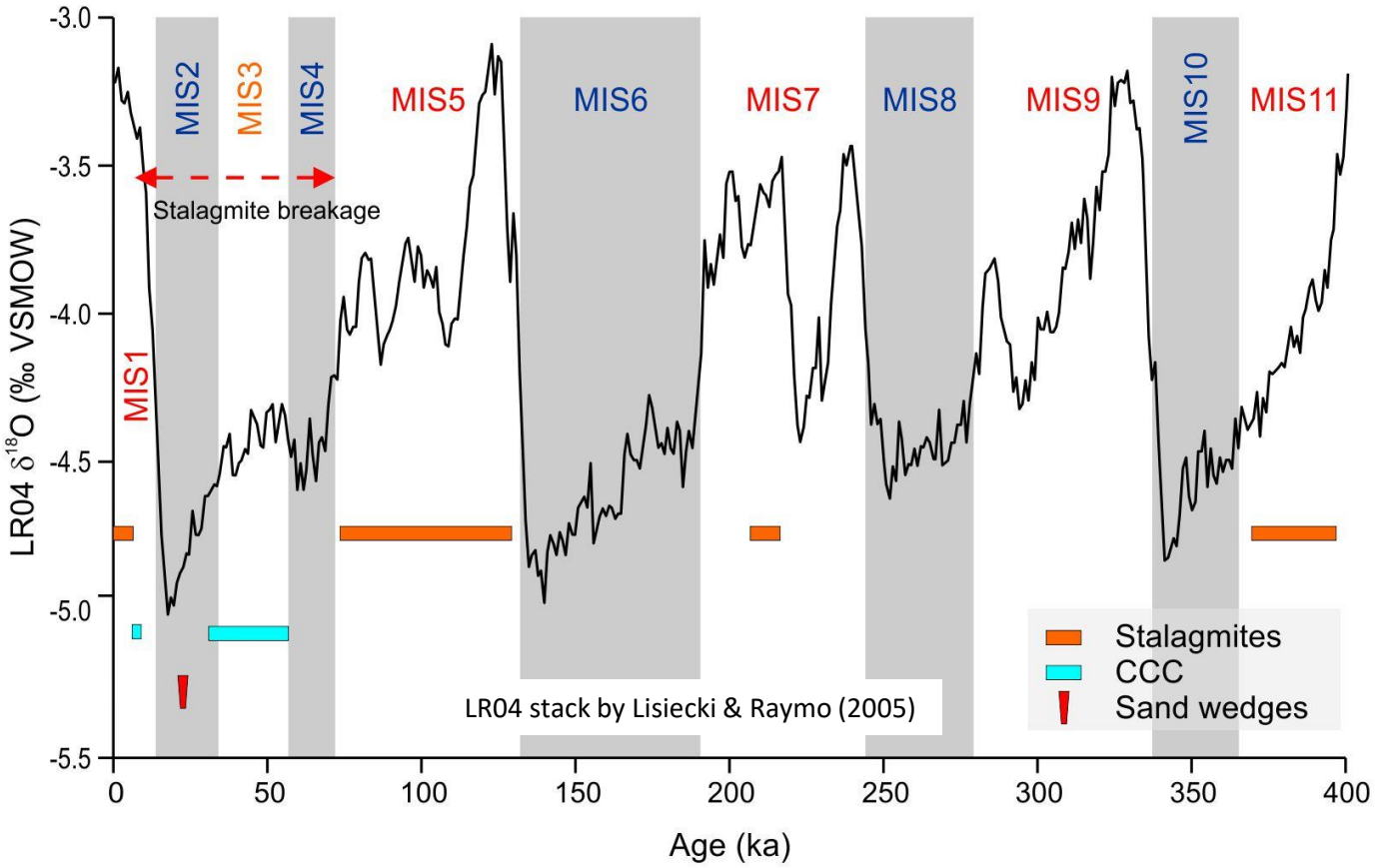


During LGM the karst massif hosting the cave was engulfed by permafrost (to a depth of at least 90 m) and flow of water through the cave was severely restricted. This led to back-flooding of the cave passage and the accumulation of several m-thick silt deposits, interspersed with thin sand layers.

slackwater and channel facies

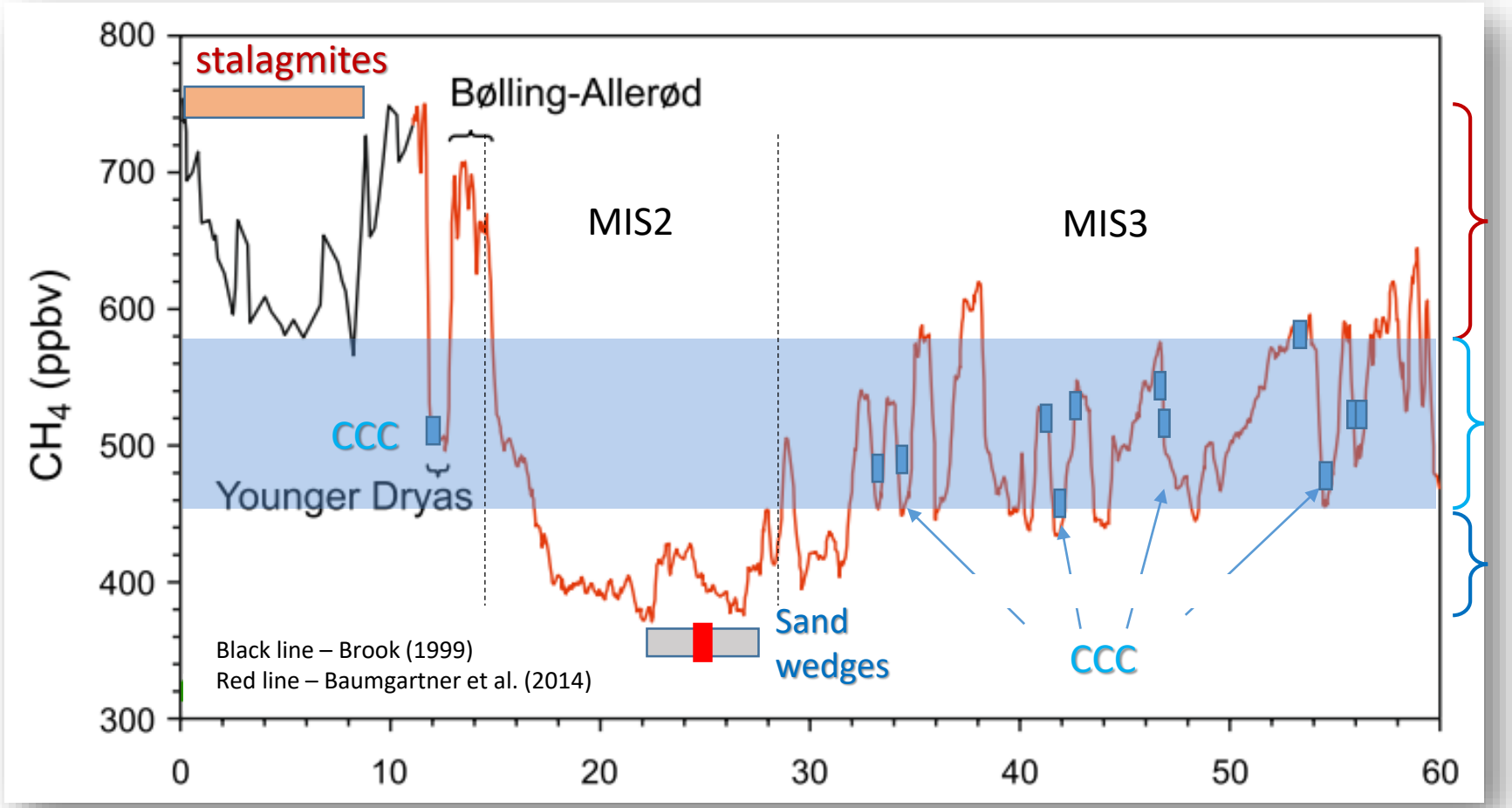
thalweg and channel facies (+ erosion of silt and sand)

Summary of permafrost-related cave archives in Southern Ural



Permafrost in Southern Ural over the last 60 ka

CCCs in Shulgan-Tash and Victora caves yielded MIS3 ages, typically lagging cooling events (Greenland stadials) GS-16.1, GS-15.1, GS-13, GS-12, GS-10, and GS-7 by several hundred years up to 1 ka. CCC from Grandioznaya cave formed during a single episode following GS-1 (Younger Dryas).



No permafrost – stalagmites form

Thermally unstable permafrost – CCCs form

Stable permafrost – neither stalagmites nor CCCs form (too cold)

References

Baumgartner M., et al. (2014): NGRIP CH_4 concentration from 120 to 10 kyr before present and its relation to a $\delta^{15}N$ temperature reconstruction from the same ice core. Climate of the Past 10: 903-920. doi:10.5194/cp-10-903-2014

Brook E.J. (1999): GISP2 Methane Concentrations. PANGAEA. doi: 10.1594/PANGAEA.56093

Circum-Arctic Map of Permafrost and Ground Ice Conditions. National Snow and Ice Data Center, USA. https://databasin.org/datasets/1f624a31ab224835a78ad4bf11103419

Earle S. (2015). *Physical Geology*. Victoria, B.C.: BCcampus. Retrieved from https://opentextbc.ca/geology/

Lisiecki L.E., Raymo M.E. (2005): A Pliocene-Pleistocene stack of 57 globally distributed benthic $\delta^{18}O$ records, Paleoceanography, 20, PA1003, doi:10.1029/2004PA001071.