ISOPERM: Understanding environmental controls on permafrost using speleothems

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LEVERHULME TRUST

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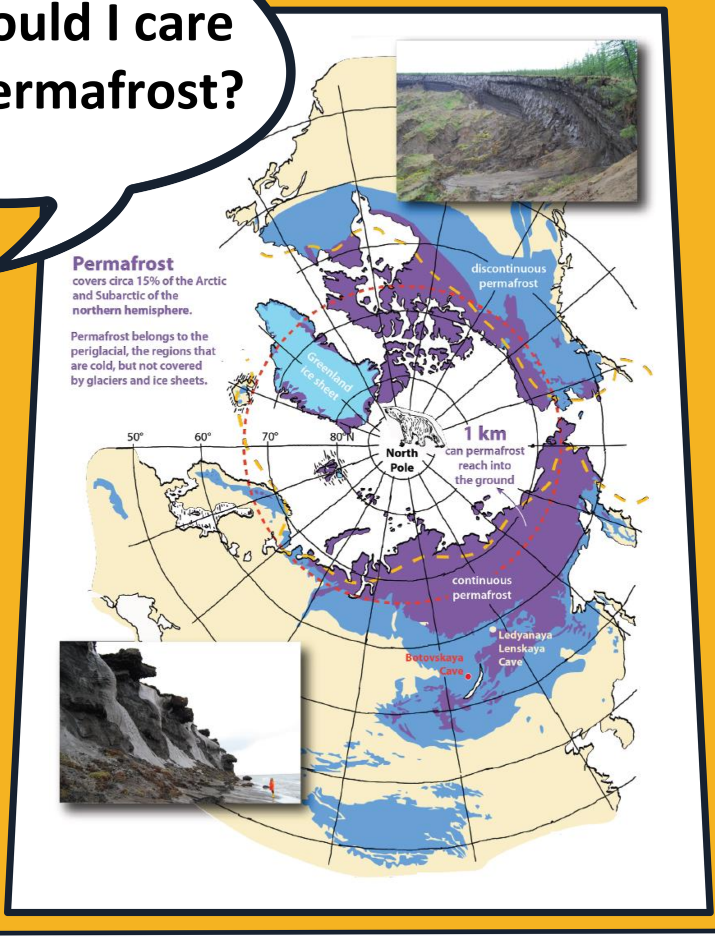
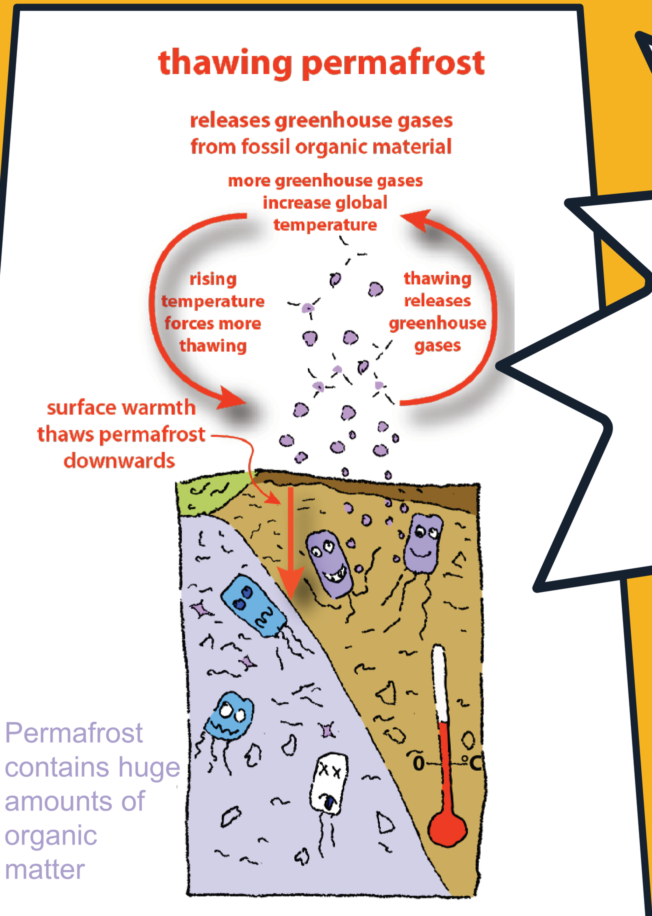
Why should I care about permafrost?



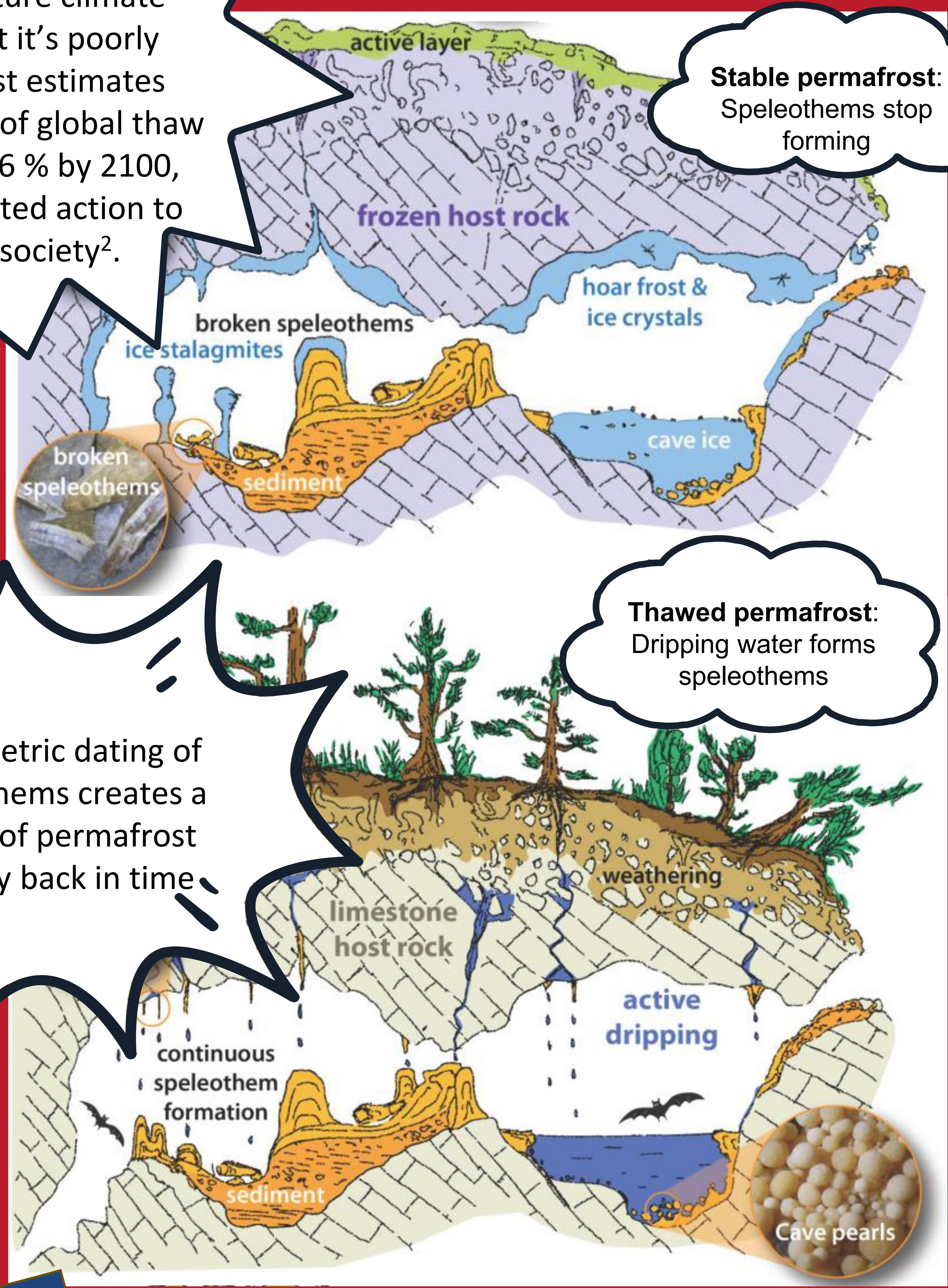
Permafrost is permanently frozen ground. It contains nearly double the carbon in the atmosphere[1].



As the planets warms, permafrost thaws, releasing greenhouse gases to the atmosphere.

Permafrost thaw will play a major role in future climate trajectories. But it's poorly understood. Best estimates project the extent of global thaw between 2 and 66 % by 2100, even with concerted action to decarbonise society[2].

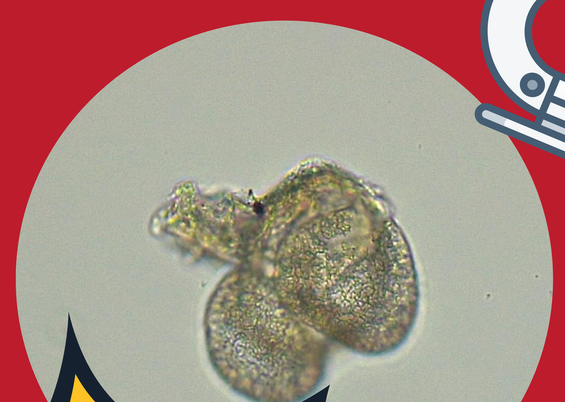
Speleothems (stalagmites and stalactites) precipitate from dripping water. So, they only form when permafrost has thawed above the cave.



Radiometric dating of speleothems creates a record of permafrost stability back in time.

Clumped isotope analysis of speleothem carbonate allows us to directly infer mean multi-annual temperatures during speleothem formation (and permafrost instability).

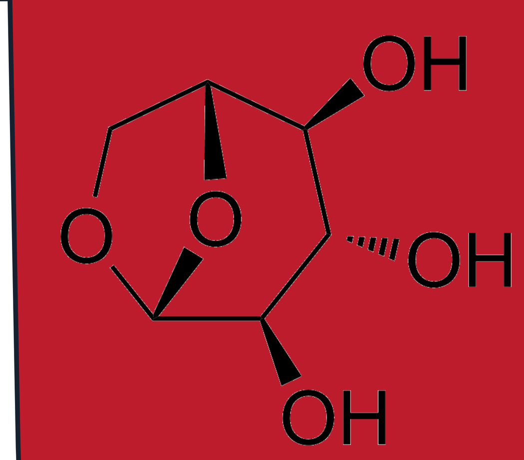
How can we use caves to study permafrost?



That's some 8.7 Ma Pollen!!!

We can find out about vegetation during periods of permafrost thaw by extracting fossil pollen[3] from speleothems and analysing lignins — a biopolymer found in vascular plants that gets trapped in speleothems[4].

Levoglucosan, an organic compound produced only by combustion of cellulose and incorporated into speleothem calcite tells us about forest fires[5].



What have we found out?

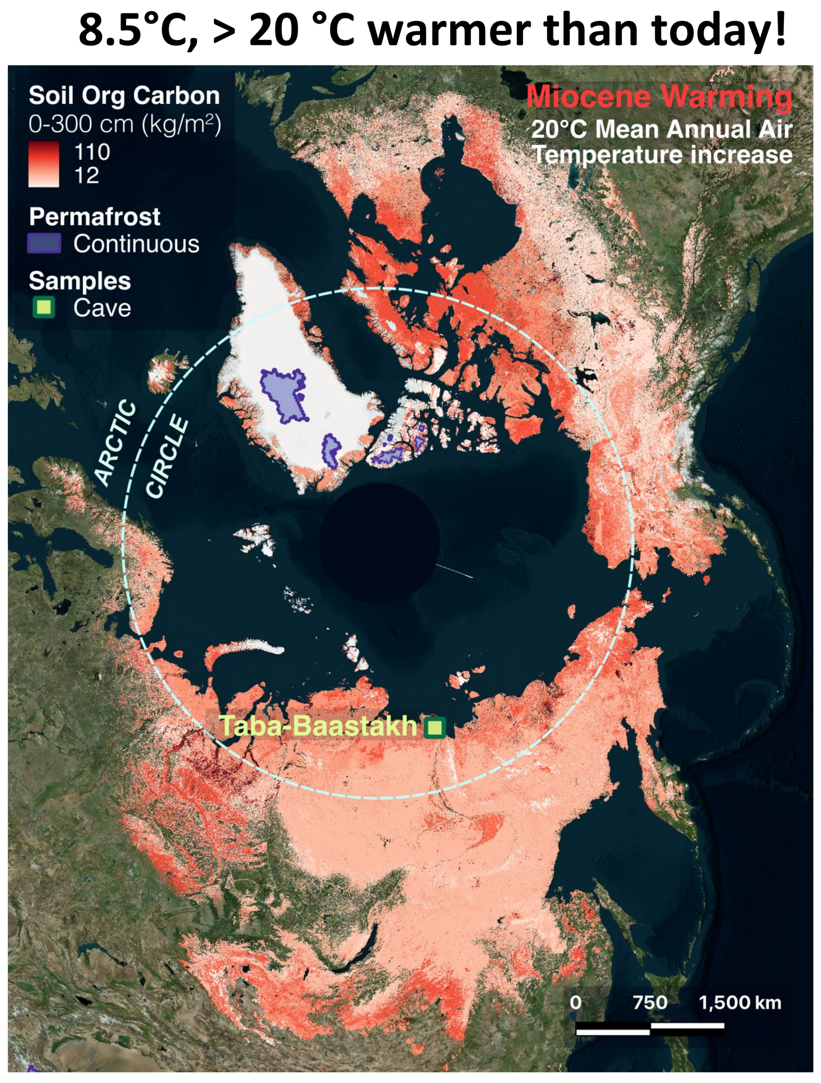
We've analysed multiple speleothems from Taba Bastaakh (72.27 °N, 126.94 °E) in the Siberian Arctic. Today is has a mean annual air temperature of -12.3 °C and sits in deep continuous permafrost[6].

Radiometric dating puts the samples at 8.702 ± 0.536 Ma[7], during the Late Miocene.

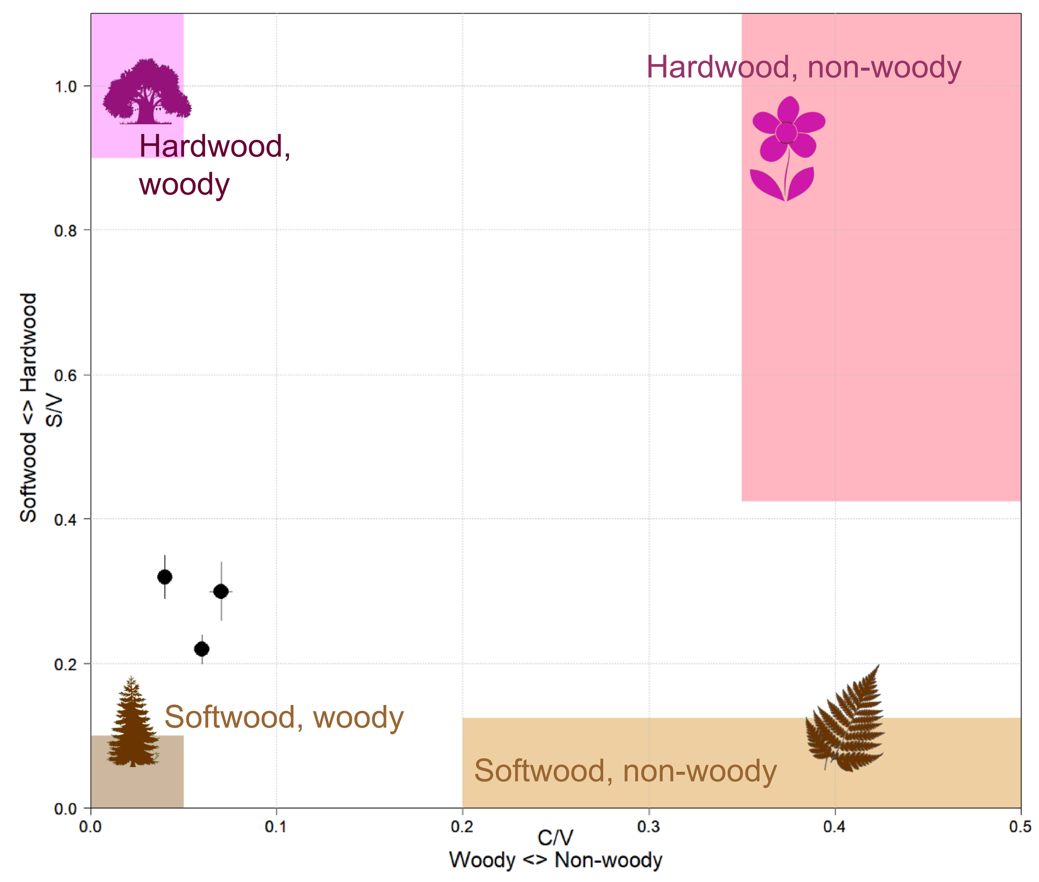
The late Miocene makes a great analogue for near-future climate change. Global average temperatures were ca. 4°C warmer than present[8], with atmospheric CO_2 up to 600 ppmV[9,10].

Understanding environmental controls on permafrost during the Miocene can inform projections of permafrost thaw in the near future.

Clumped isotopes suggest mean annual air temperatures between 4.5 – 8.5°C, > 20 °C warmer than today!



Areas of modern permafrost vulnerable to +20°C of warming[11,12]. Only a few patches in Greenland and northern Canada remain.



The types of lignin extracted from the speleothems suggest the presence of softwood (pine, fir) forest. This is supported by fossil pollen evidence. Today, Taba Bastaakh sits north of the treeline.

References

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