UNSW SYDNEY

Dating speleothems and speleothem growth

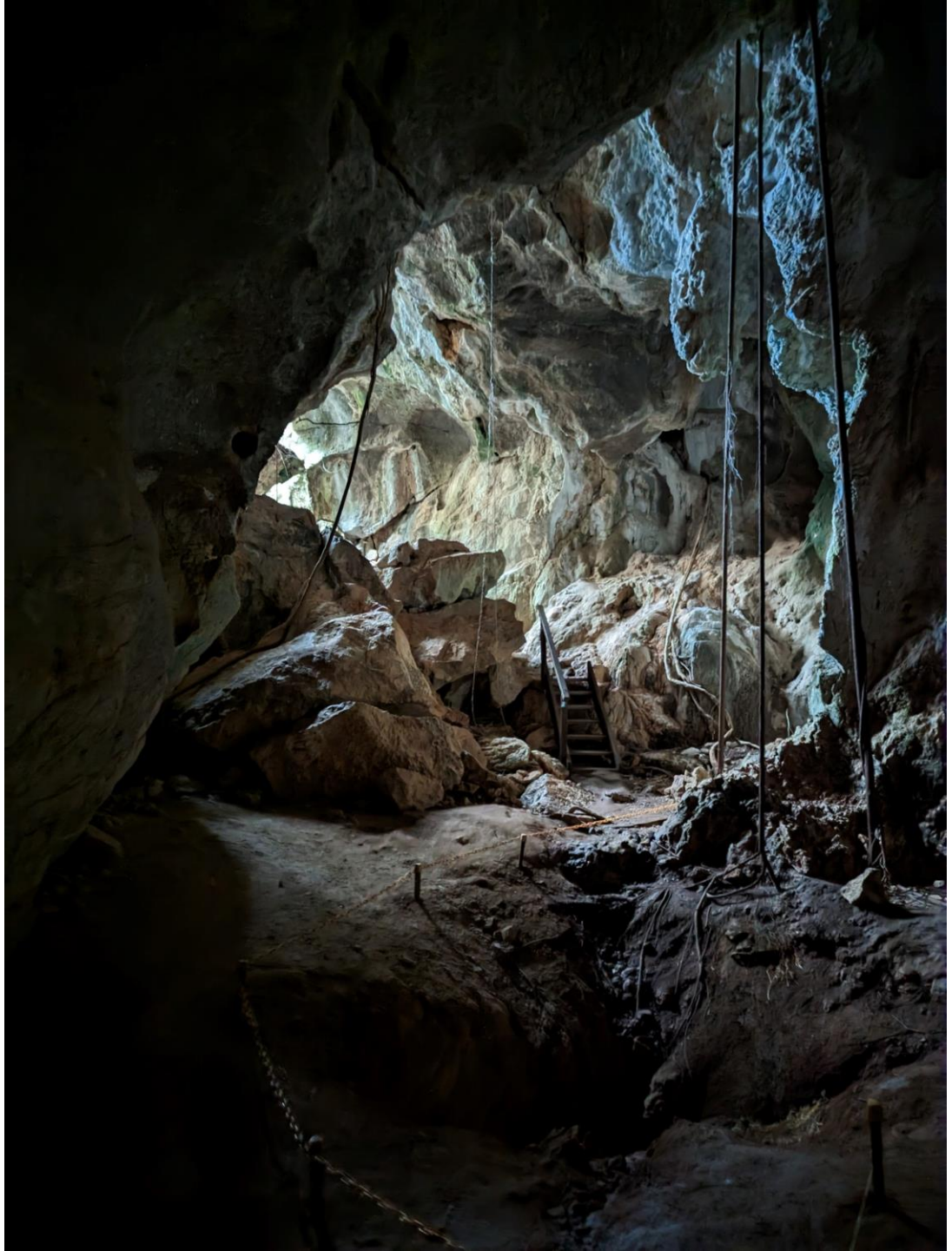
Andy Baker

Some questions?

How old is this cave?

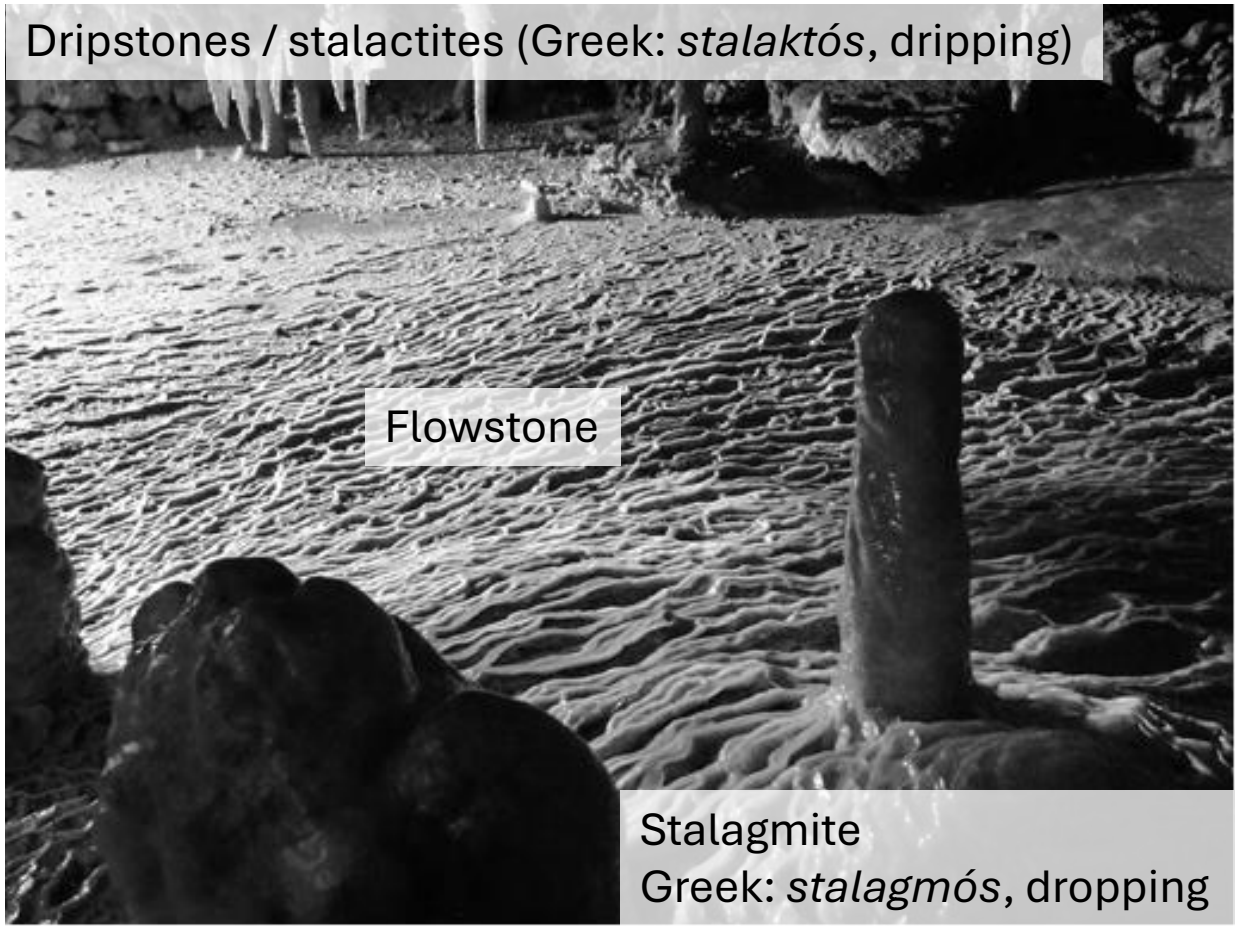
How long does it take that formation to form?

How do scientists date stalagmites?



Speleothems

cave deposits (Greek: *spelaion*, cave; *thema* deposit)
almost all *calcareous* (made largely of calcium carbonate, $CaCO_3$)



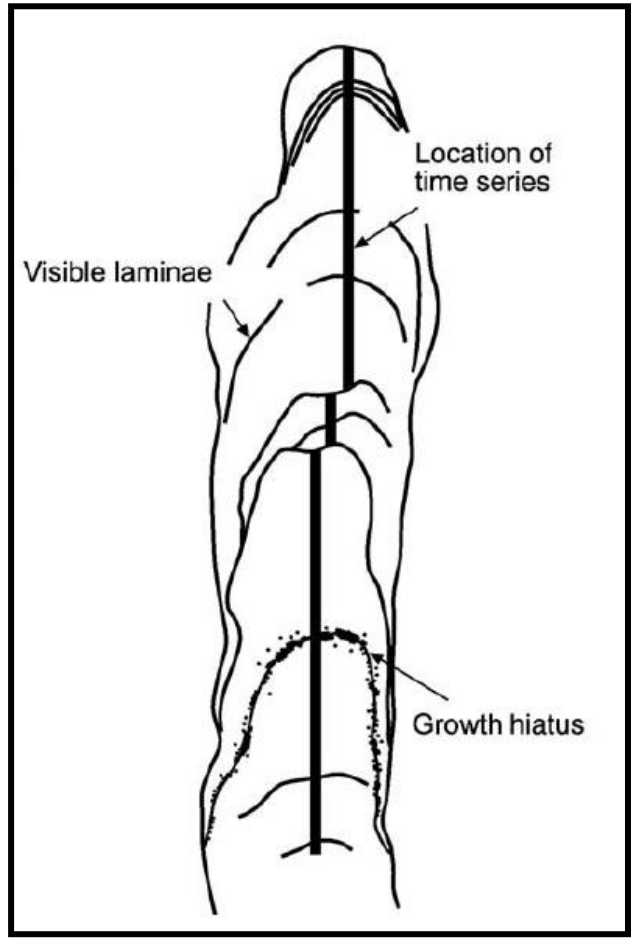


Photo credit: Fairchild and Baker 2012 Speleothem Science

Methods of Dating Speleothems

Uranium-Thorium dating (up to 500,000 years in the past).
Relevant to ice age climate changes, human migration out of Africa, evolution of relatively 'young' landscapes.

Uranium-Lead dating (all of Earth history).
Relevant to long-term landscape evolution, uplift history, relatively ancient environments

Radiocarbon dating (last 50,000 years).
Limited uses

Annual lamina counting
Relevant to questions that require precise timing e.g. how frequent were past wildfires?

Photo credit: Fairchild and Baker 2012 Speleothem Science

Methods of Dating Speleothems

Uranium-Thorium dating (since 1970s)

- Range: up to 500,000 years
- Needs: sufficient uranium for analysis
- Needs: negligible initial thorium when formed

1980s - wait for the radioactive decay, ~100 g samples
1990s – chemically separate and analyse, ~ 1 g samples
2000s – even better instrumentation, < 1g samples
2020s – laser analyses at some labs e.g. Uni Queensland

Uranium-234 in the sample with a half-life of 245,000 years decays to thorium-230. Thorium-230 is also radioactive with a half-life of 75,000 years.

https://environment.uq.edu.au/about/facilities-and-equipment/laboratories/centre-geoanalytical-mass-spectrometry/radiogenic-isotope-facility

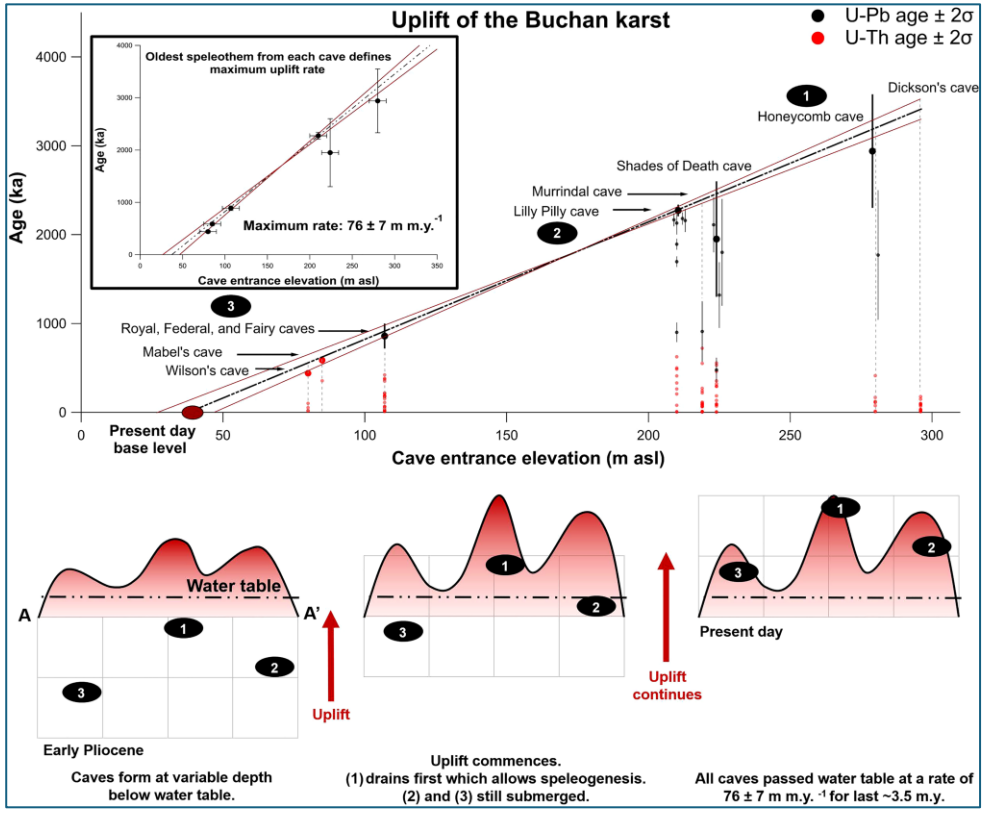
Methods of Dating Speleothems

Uranium-Lead dating (since 1990s)

- Range: whole of Earth history (4.5 billion years)
- Needs: high and variable uranium (not always true!)

1990s – first uranium-lead age of a speleothem
2010s – Uni. Melbourne commence routine analyses
2020s - ?see *read more*?

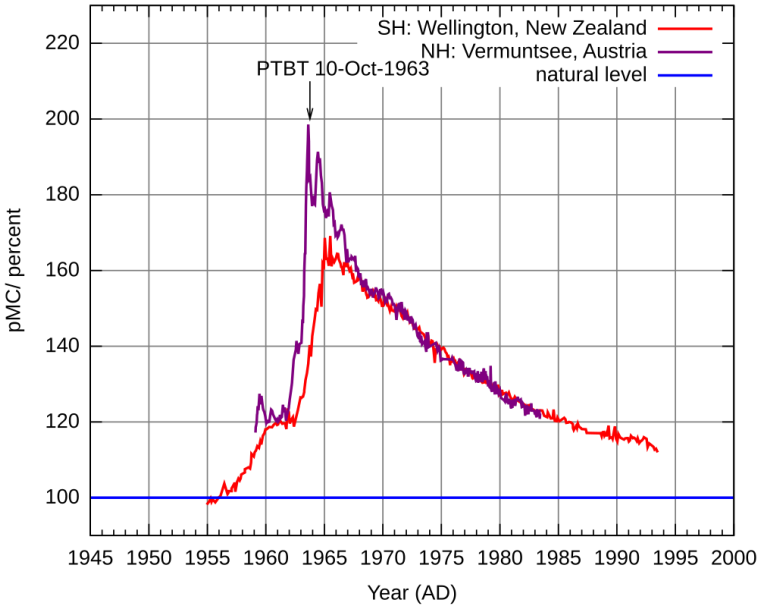
Two separate decay chains. Uranium-238 in the sample with a half-life of 4.47 billion years decays to lead-206. Uranium-235 in the sample with a half-life of 710 million years decays to lead-207



https://pubs.geoscienceworld.org/gsa/geology/article-abstract/48/8/755/584572/Using-speleothems-to-constrain-late-Cenozoic

Read more: John Engel and Robyn Pickering in Quaternary Geochronology: https://www.sciencedirect.com/science/article/pii/S1871101421000935

Methods of Dating Speleothems



Radiocarbon dating (since 1960s)

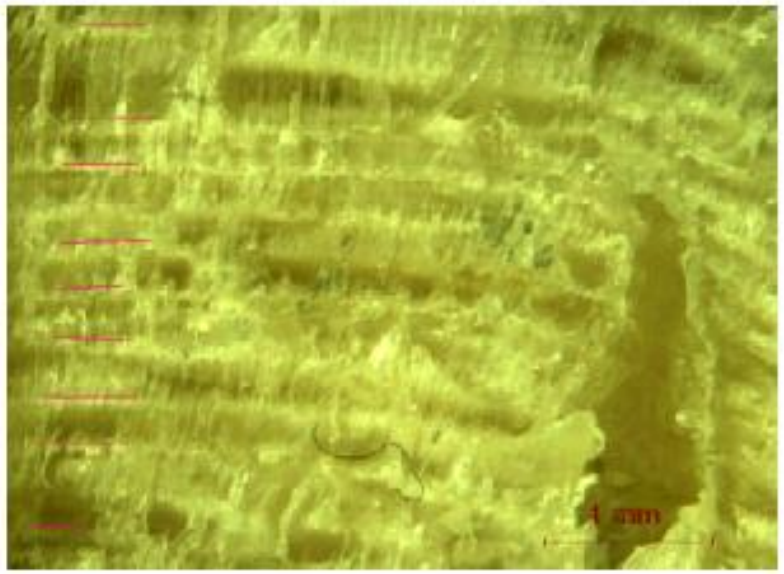
- Range: last ~50,000 years
- But: an unknown amount of speleothem carbon in the calcium carbonate comes from the bedrock.
- Better: good for confirming modern (after 1950s) formation.

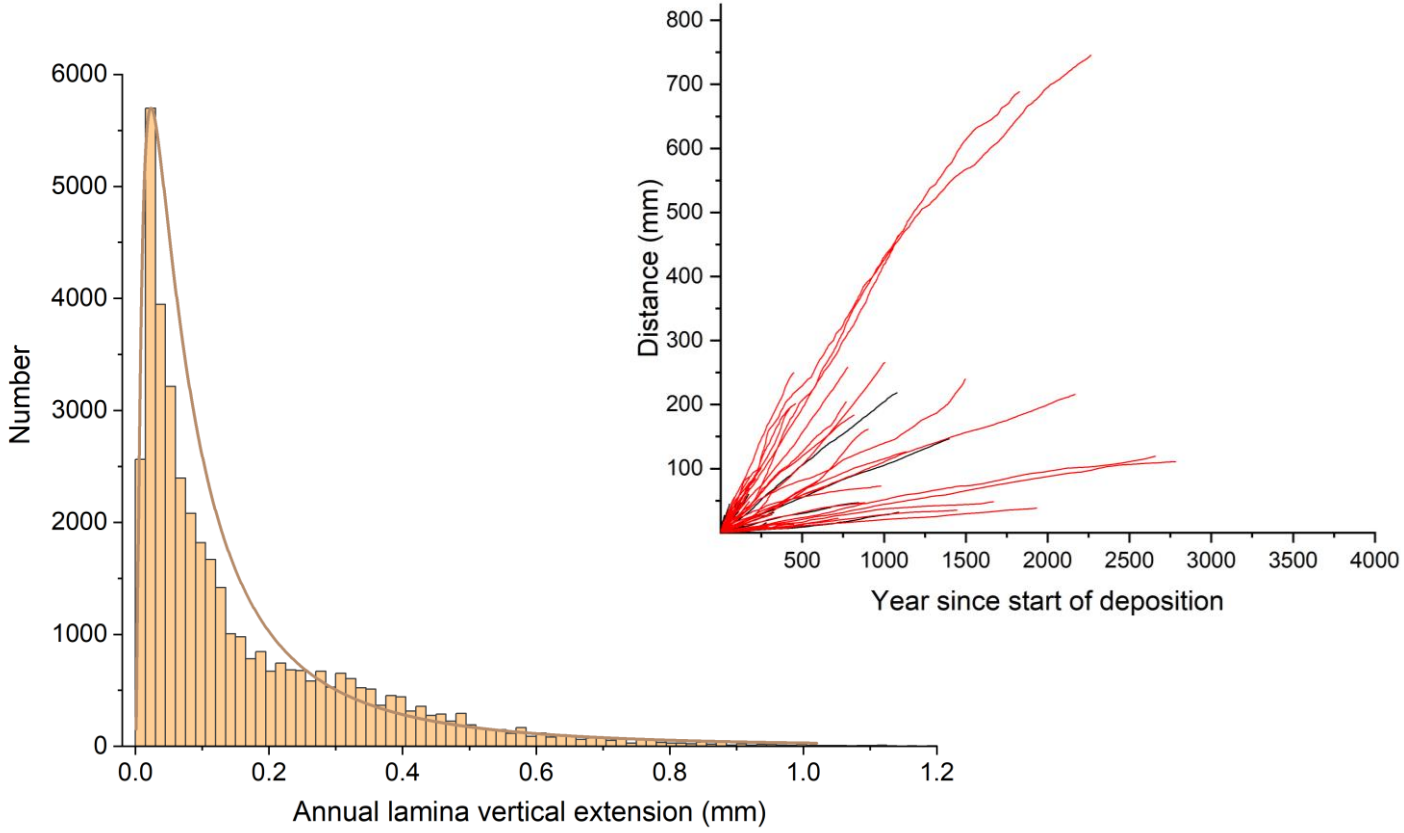
1960s – radiocarbon ages published but too old
1990s – applications in the atomic bomb era (D. Genty, Paris)
2020s - ?more applications to cosmic events?

Carbon-14 decays to carbon-12 with a half-life of 5700 years.

https://www.analytical.unsw.edu.au/facilities/sseau/radiocarbon-laboratory

Annually laminated speleothems





1960s – first paper published, largely forgotten
1990s – rediscovered!
2000s onward – increasing use in geochronology

Requires a regular, seasonal change in water supply or cave climate.

Baker, A et al. 2021 The properties of annually laminated stalagmites - a global synthesis. Reviews of Geophysics, 59, e2020RG000722 https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2020RG000722

Read more: https://www.australiangeographic.com.au/topics/science-environment/2021/11/microscopic-layers-of-stalagmites-provide-clues-to-earlier-climate-changes/

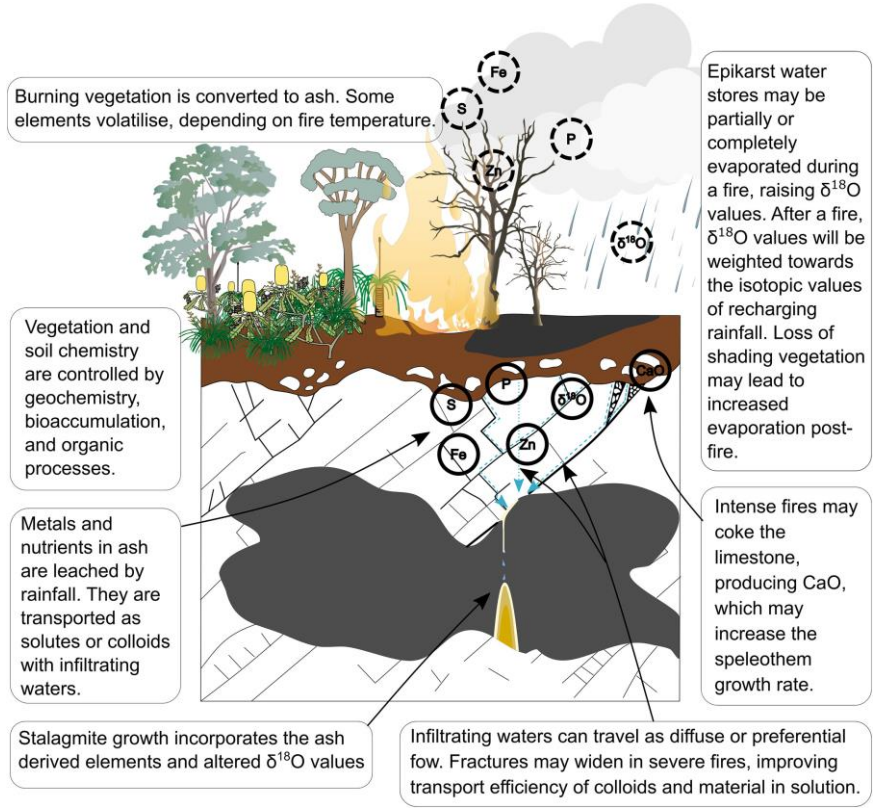
Case Studies in the media!

- Rieneke Weij et al in 2022 used uranium-lead dating of speleothems to show that Naracoorte Caves formed at least 1.34 million years ago (older than previously thought!) https://www.nature.com/articles/s43247-022-00538-y

- https://theconversation.com/study-finds-famous-australian-caves-are-up-to-500-000-years-older-than-we-thought-and-it-could-help-explain-a-megafauna-mystery-190688

Case Studies in the media!

- Micheline Campbell et al in 2023 review the use of uranium thorium dated and annually laminated stalagmites to obtain records of fire frequency in Western Australia (stalagmites record fire history!) https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2022RG000790
- https://eos.org/editors-vox/using-cave-formations-to-investigate-ancient-wildfires



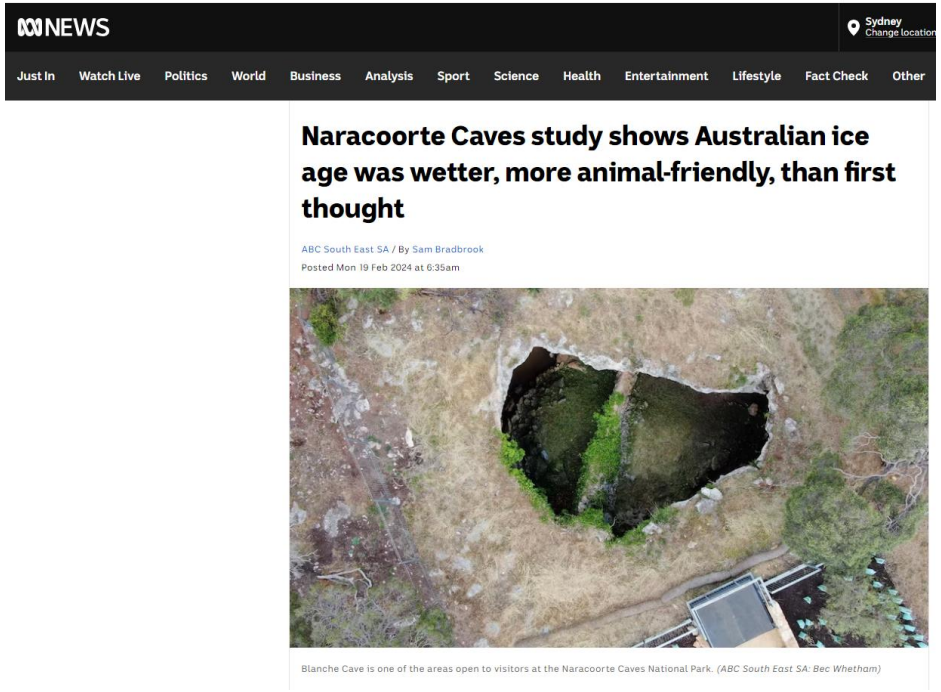
Using Cave Formations to Investigate Ancient Wildfires

From sediment cores to speleothems, environmental archives are helping us to understand the history of wildfires.

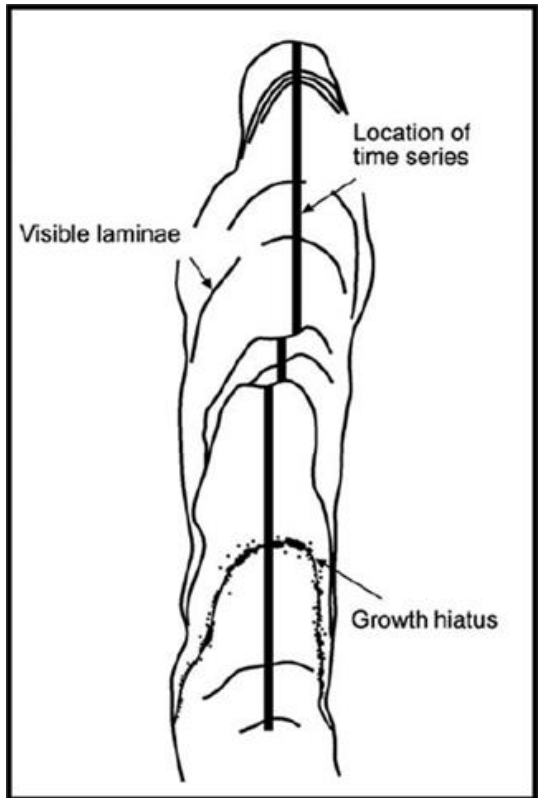
By **Micheline Campbell, Liza McDonough, Pauline C. Treble,** and **Andy Baker** 2 May 2023

Case Studies in the media!

- Rieneke Wiej et al in 2024 used uranium-thorium dating of speleothem rubble (n=153) at Naracoorte to show that glacial periods were relatively wet and interglacial relatively dry (opposite of previous thought!) https://www.nature.com/articles/s41586-023-06989-3
- https://www.abc.net.au/news/2024-02-19/australia-climate-history-study-naracoorte-caves-ice-ages/103455378



Some questions?



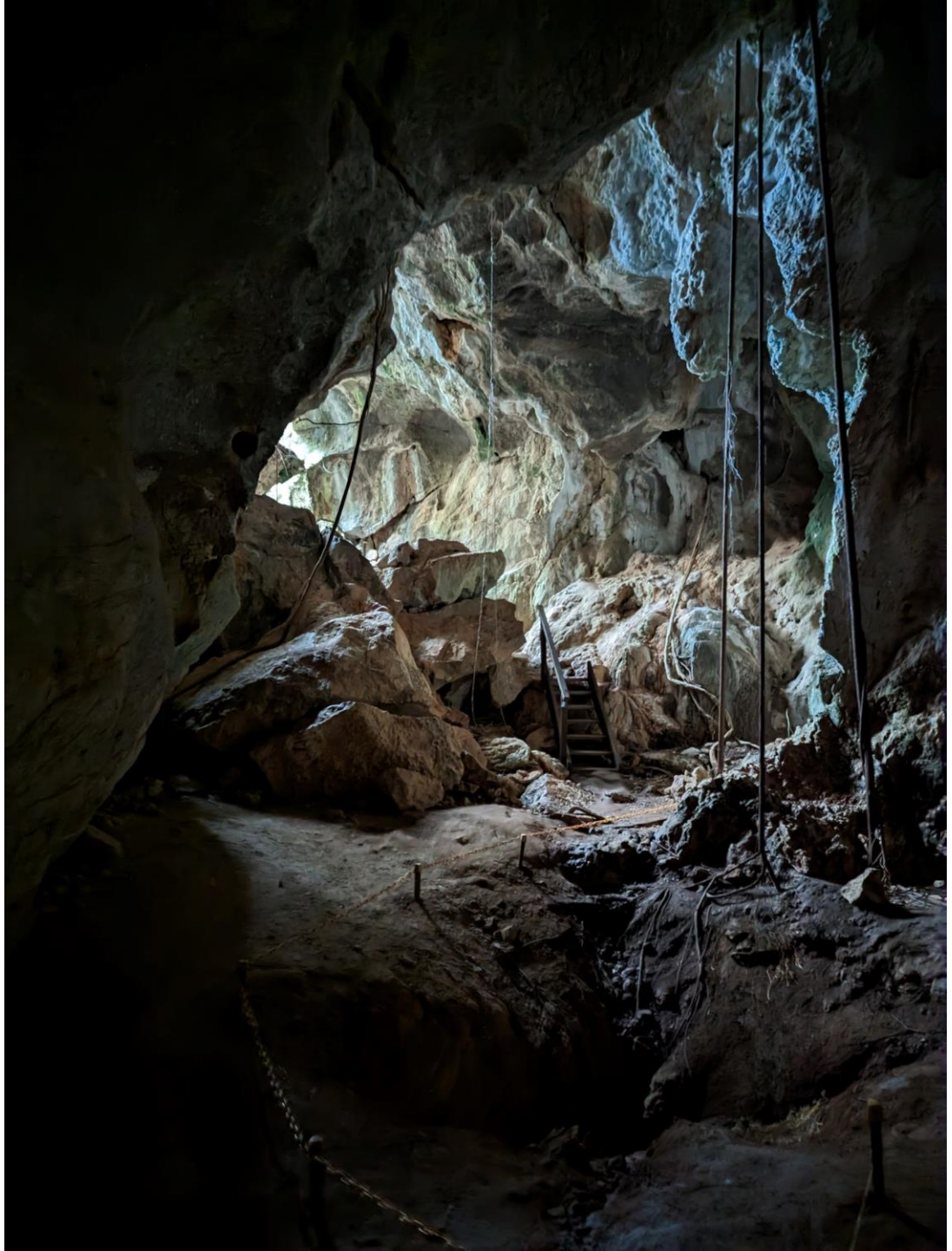
How old is this cave? How do you know?

How long does it take that formation to form?

How fast do stalagmites grow?

How do scientists date speleothems?

Why don’t you use radiocarbon dating?



Concluding thoughts

Sampling, archiving and cave conservation

"We compiled 1,237 speleothem U-Th dates with finite uncertainties from 108 sites across Britain and Ireland from the literature" https://cp.copernicus.org/preprints/cp-2024-48/

The pioneers have retired or are retiring, where are the speleothems?

As technology improves, impact decreases.

International Journal of Speleology	51 (1)	1-11	Tampa, FL (USA)	January 2022

Available online at scholarcommons.usf.edu/ijs

International Journal of Speleology

Official Journal of Union Internationale de Spéléologie

Low impact sampling of speleothems – reconciling scientific study with cave conservation

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[2]Natural and Cultural Heritage Division, Department of Primary Industries, Parks, Water & Environment, GPO Box 44 Hobart TAS, 7001, Australia

Abstract: Speleothems are increasingly valued as important paleoclimate archives and yet the removal of samples from caves can come at a cost to natural heritage, impacting delicate environments with limited mechanisms for repair. Conservation of cave environments is a key responsibility

https://doi.org/10.5038/1827-806X.51.1.2406

APPENDIX 1

Archiving speleothems and speleothem data

Even a rudimentary understanding of speleothem-forming systems leads one to understand that they are vulnerable and that many speleothem samples, particularly stalagmites, are irreplaceable. Hence, at the present time, there is an urgent need for the community of scholars who study speleothems to adopt appropriate protocols for archiving speleothem samples and data, so that previous work is captured and future researchers can build on this work. This concern is part of the wider issue of minimizing destructive activity in caves and hence balancing scientific research with conservation (Frappier, 2008). Although archaeological investi-

original visual appearance. Even in cases where the cave aesthetic damage is limited or temporary, the collected speleothems are scientifically a non-renewable resource. Most geologists have regarded speleothems simply as a type of rock sample and have been slow to grasp the necessity for conservation through archiving. If instead, one regards them as an archaeological resource, then the necessity for thorough documentation of the context and properties of the material is more obvious.

In the UK, good practice in archaeological archiving is summarized in Brown (2007) and has at its core the creation of a stable, ordered, accessible

https://onlinelibrary.wiley.com/doi/epdf/10.1002/9781444361094.app1

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Any Questions?

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