



ABERRATIONS FROM BACKGROUND CLIMATE: CAUSES AND TIMESCALES

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ABERRATION: a definition

A departure from what is normal, usual, or expected.....typically one that is unwelcome

An irregularity, rarity, anomaly, deviation

What is background climate?

What is background climate?
What counts as an aberration?

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What counts as an aberration?**

TIMESCALES, TIMESCALES, TIMESCALES...

**What is background climate?
What counts as an aberration?**

TIMESCALES, TIMESCALES, TIMESCALES...

(and rates of change)

**Is anthropogenic warming an
aberration?**

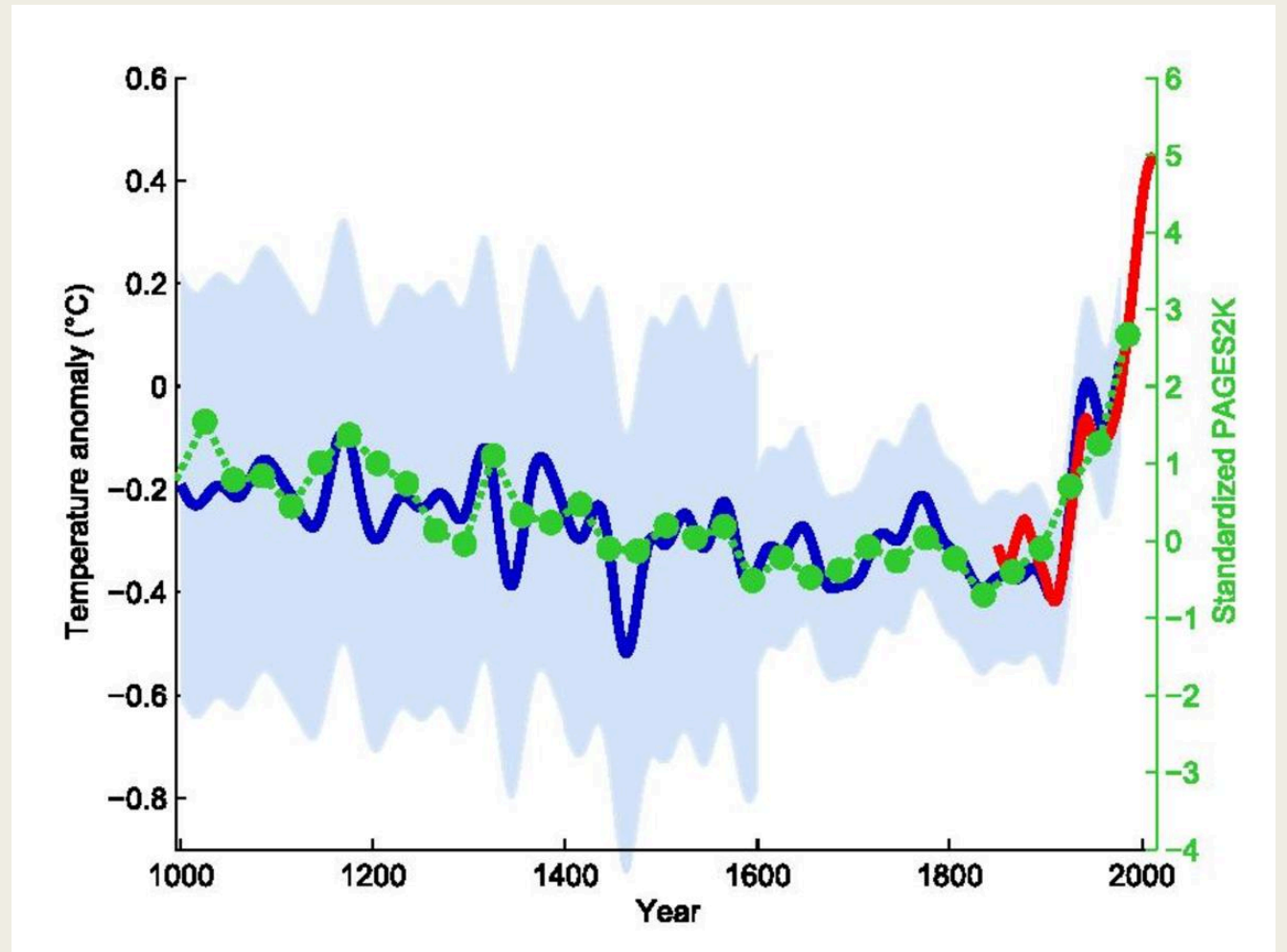
Is anthropogenic warming an aberration?

PAGES2k

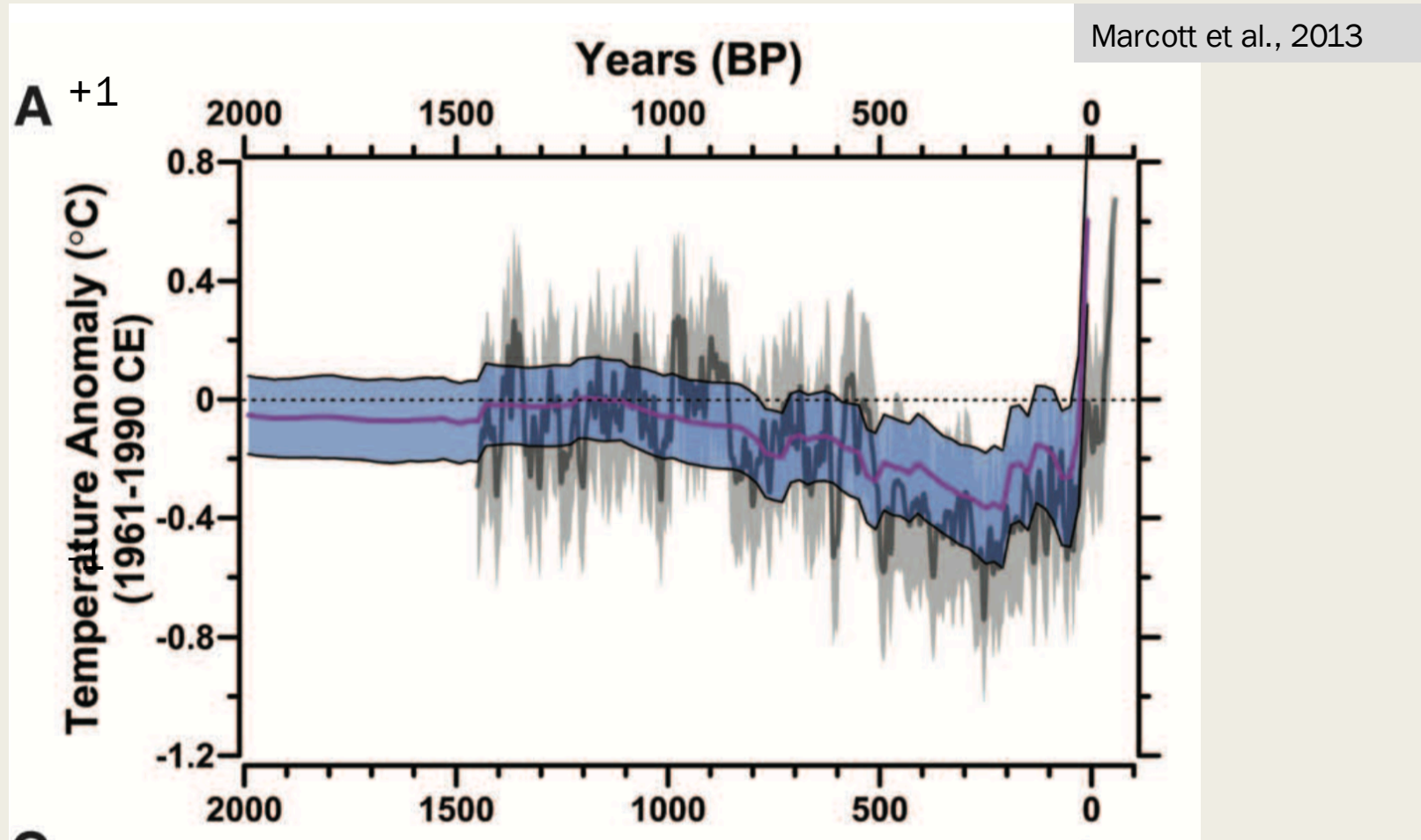
Mann et al. 2008

HadCRUT4 instrumental data

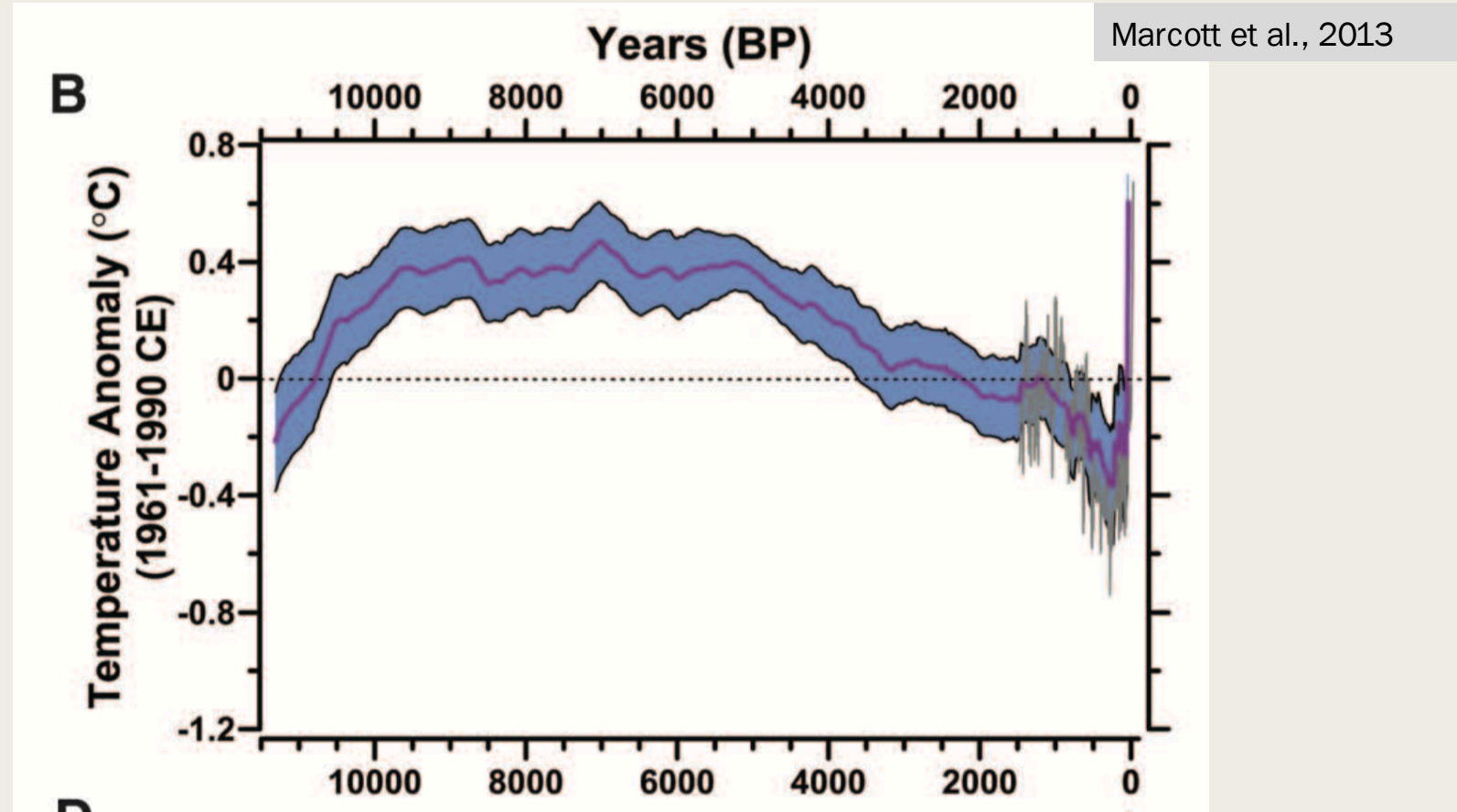
0.5°C over ~100 years
vs.
0.2°C over ~1000 years



Zooming out... 2,000 years

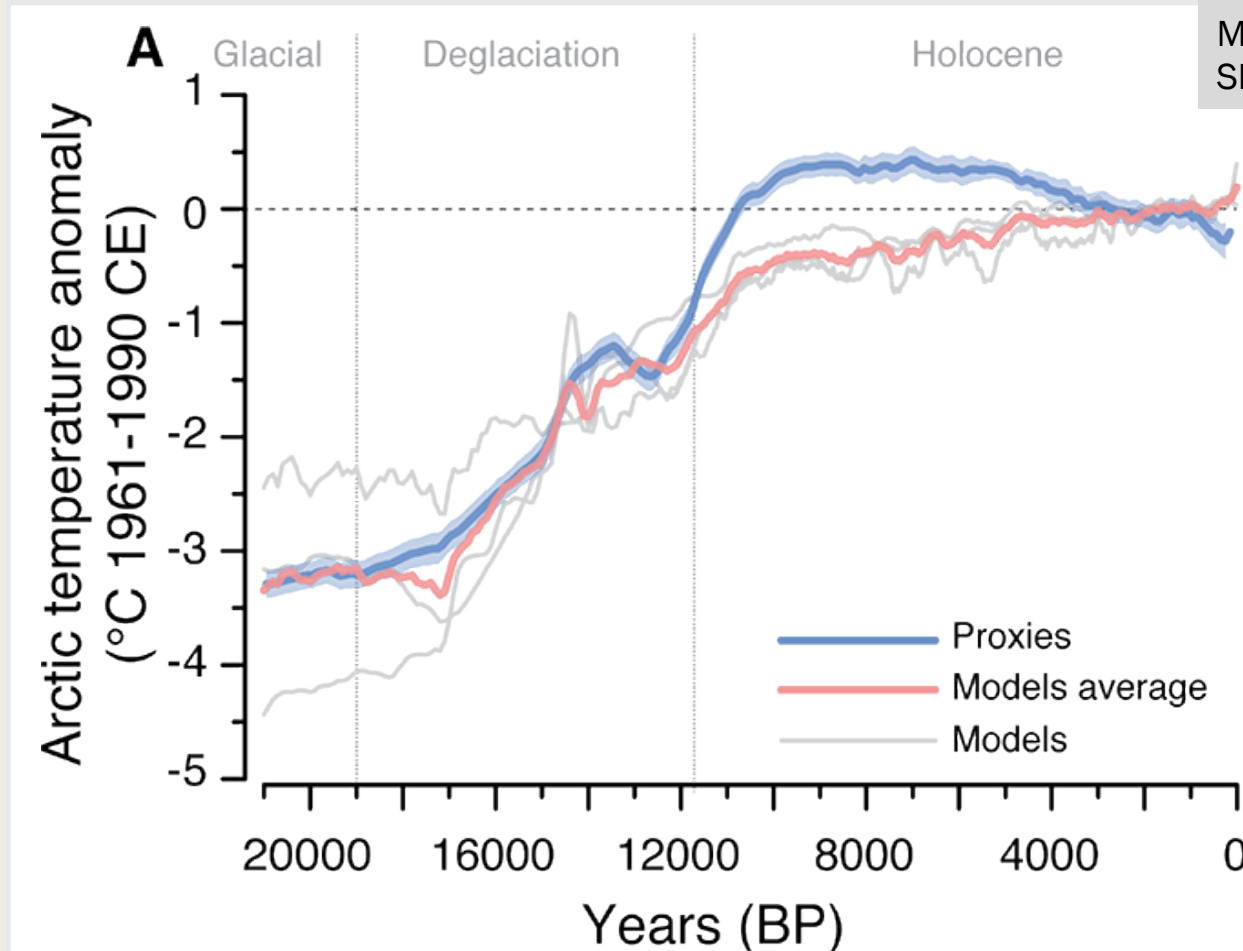


Holocene Climate 10,000 years



Slow change on order 1°C over 1000's of years

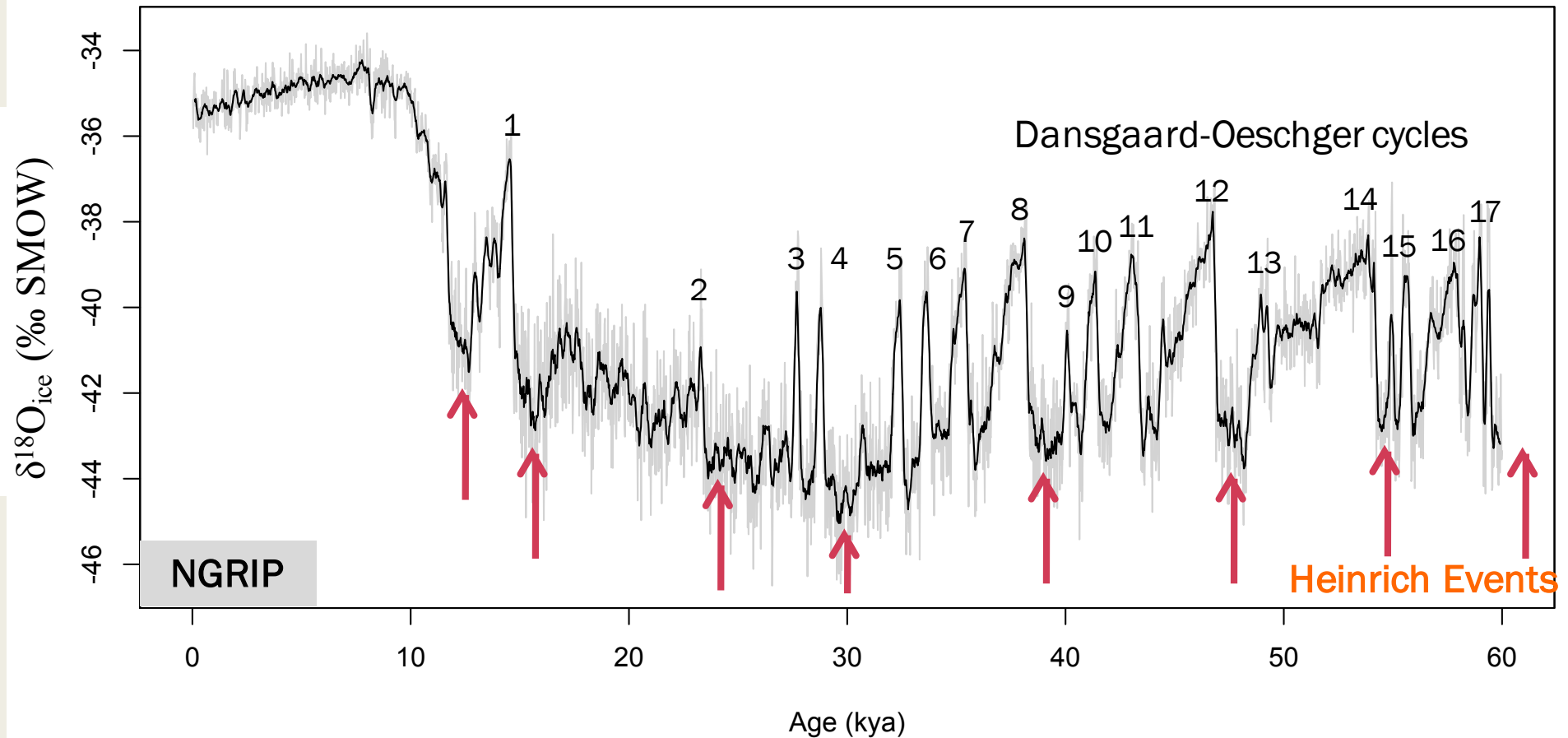
Glacial → Interglacial 20,000 years



Marcott et al., 2013
Shakun et al., 2012

Larger temperature
change, still
relatively “slow”

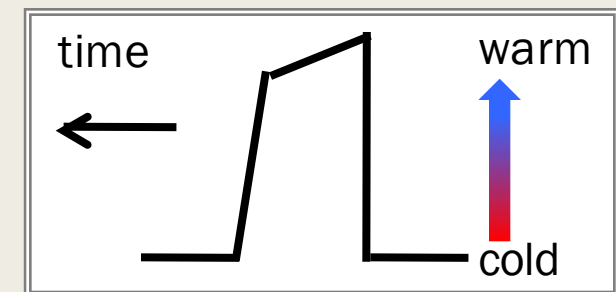
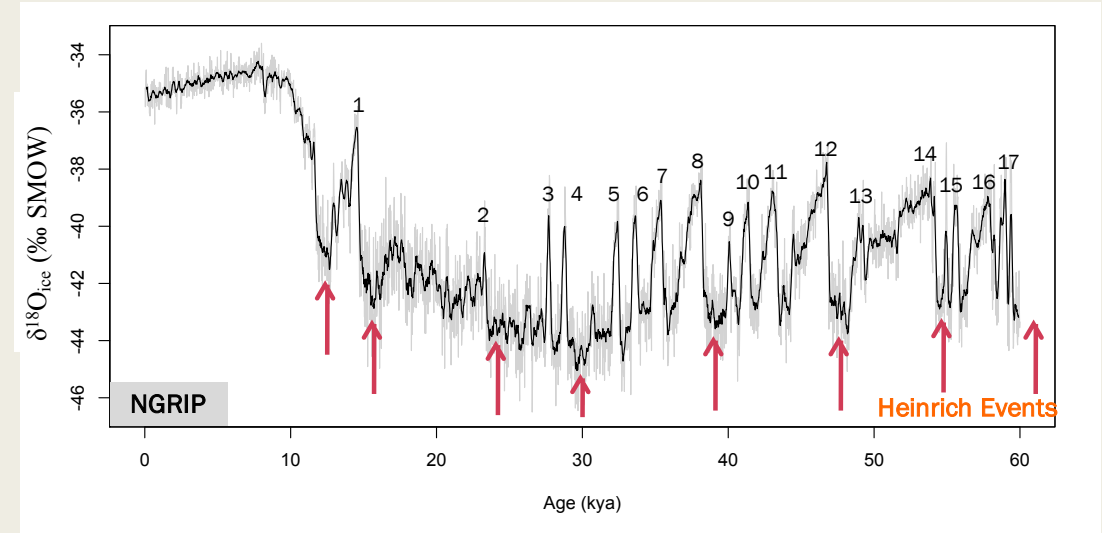
Glacial Climate ~100,000 years



Dansgaard-Oeschger Cycles

~1500 yrs/cycle

- **8-16°C atmospheric warming in years to decades (over Greenland)**
- Rapid warming likely due to abrupt changes in sea ice cover in Nordic Seas
- Some involvement of AMOC

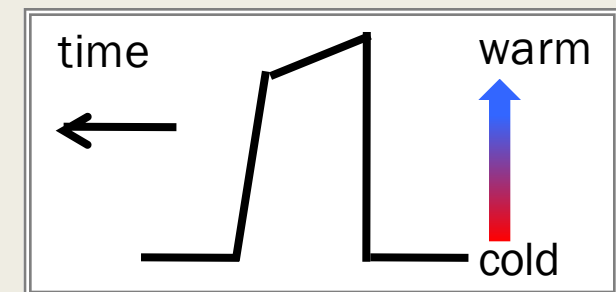
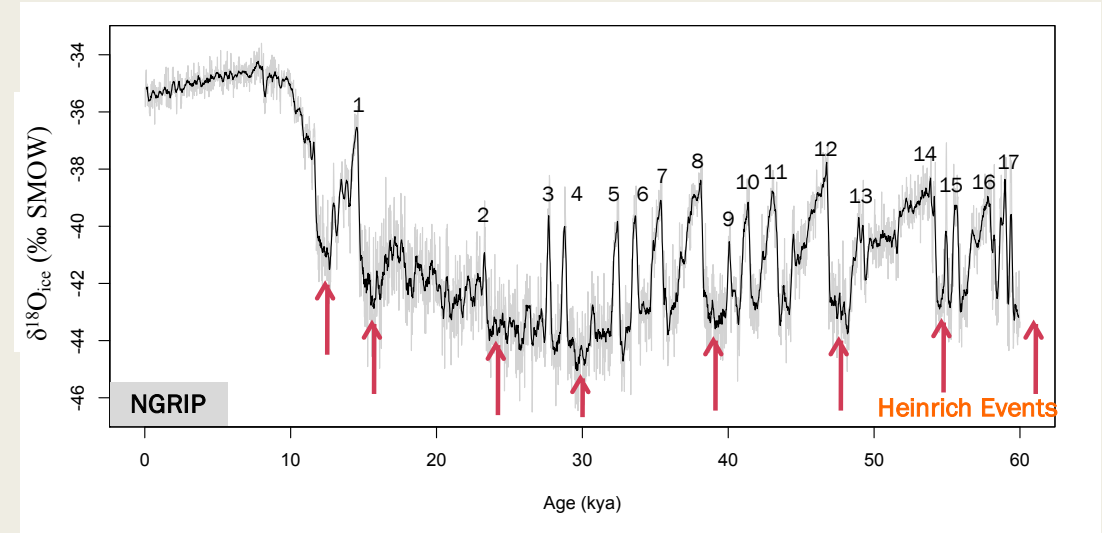


Dansgaard-Oeschger Cycles

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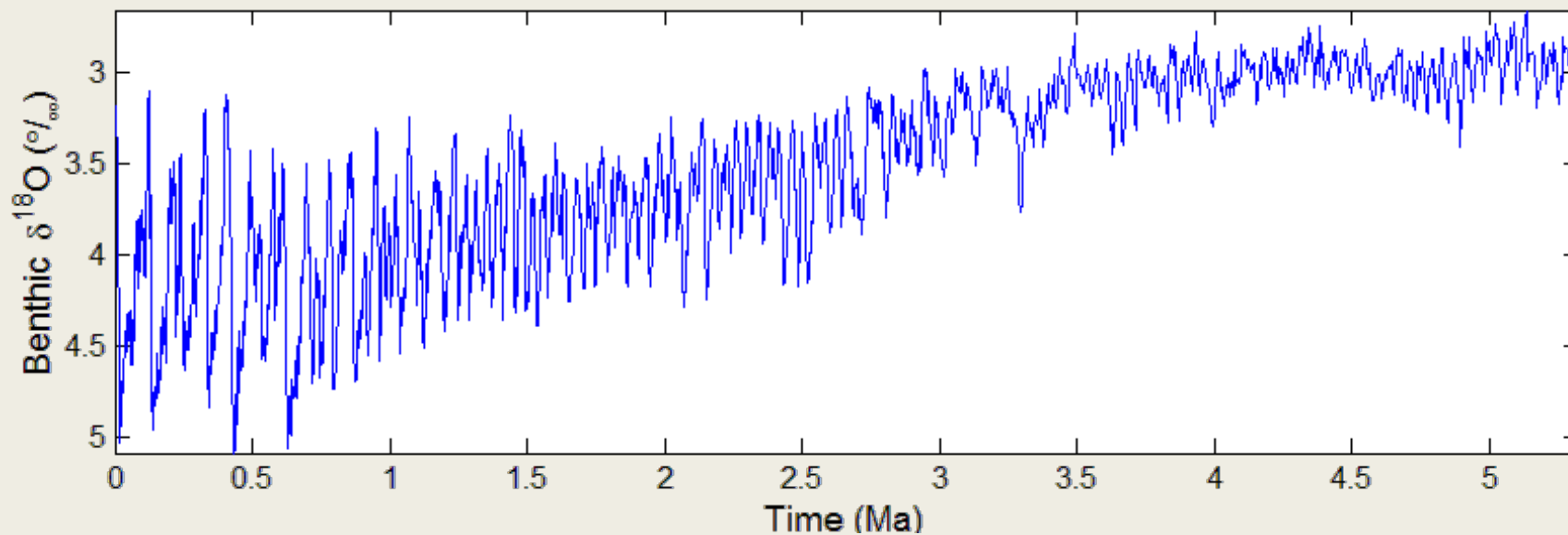
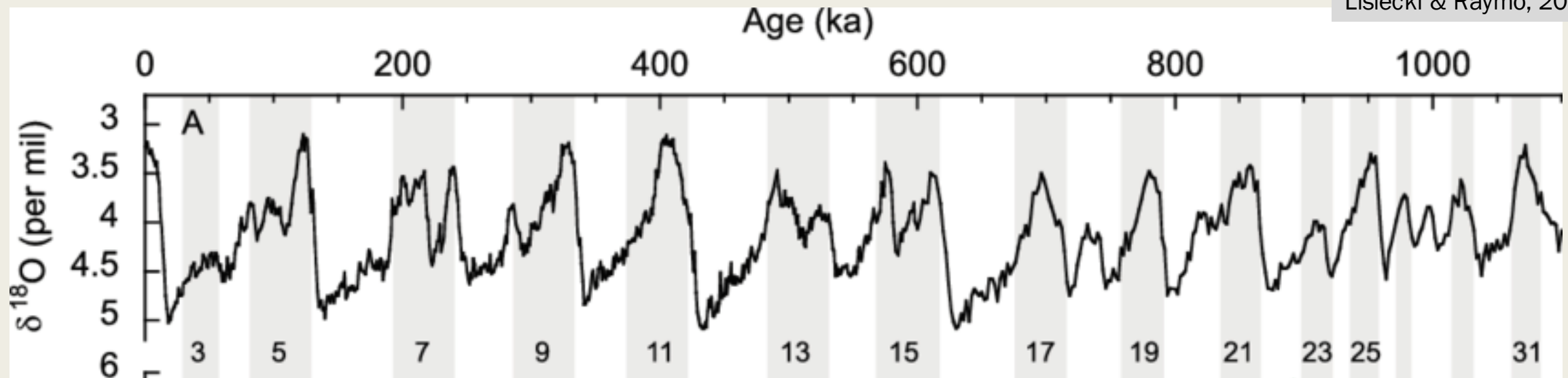
- **8-16°C atmospheric warming in years to decades (over Greenland)**
- Rapid warming likely due to abrupt changes in sea ice cover in Nordic Seas
- Some involvement of AMOC

...but is this unusual behavior?



Plio-Pleistocene Ice Age Cycles

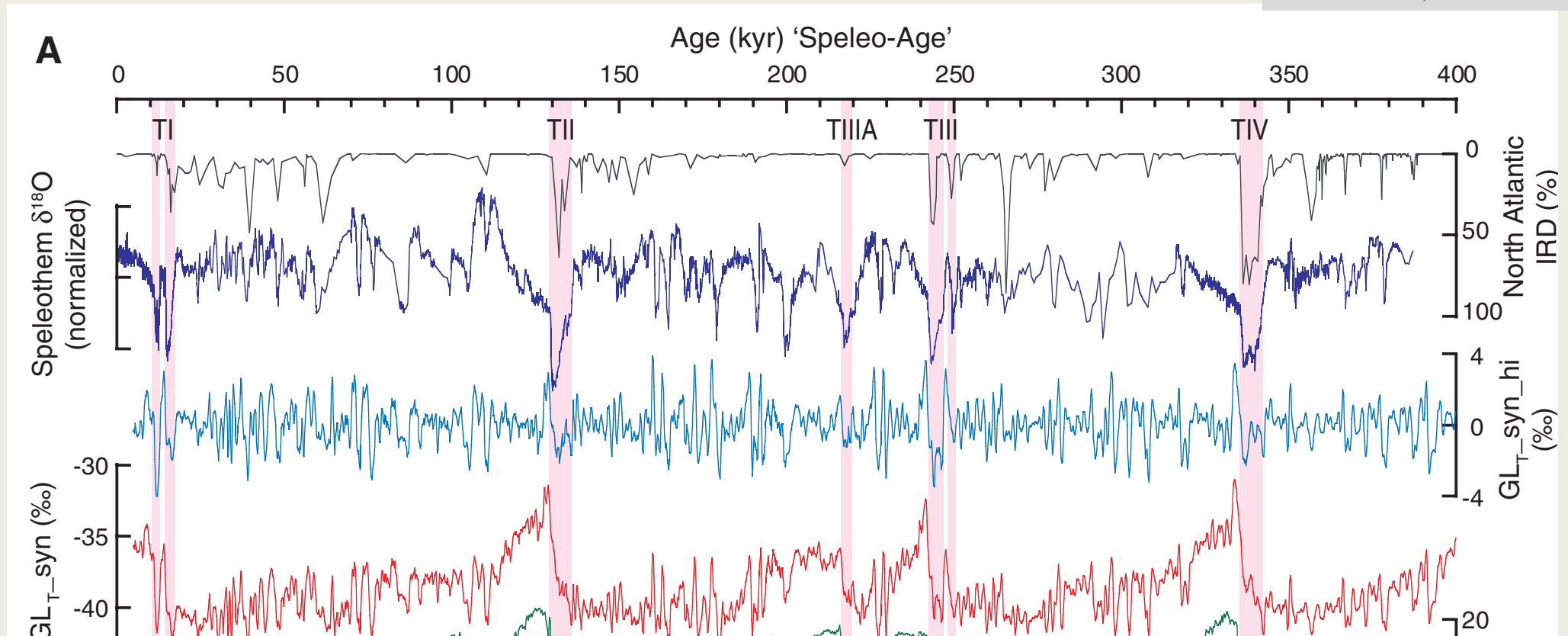
Lisiecki & Raymo, 2004



Dansgaard-Oeschger Cycles In previous ice ages?

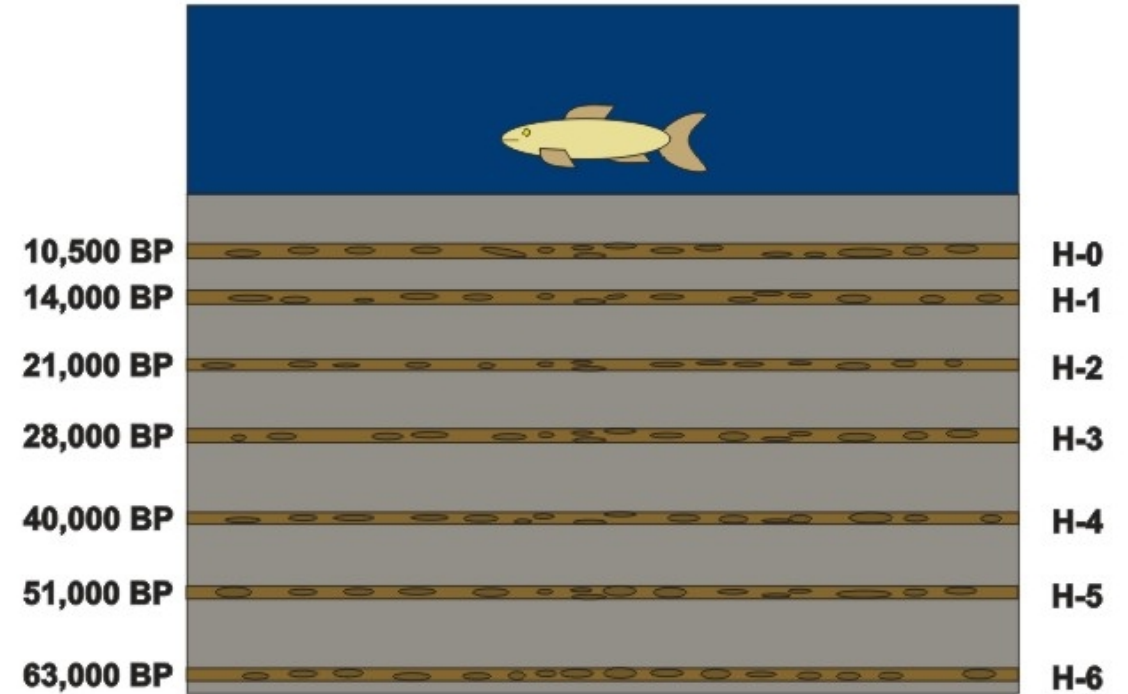
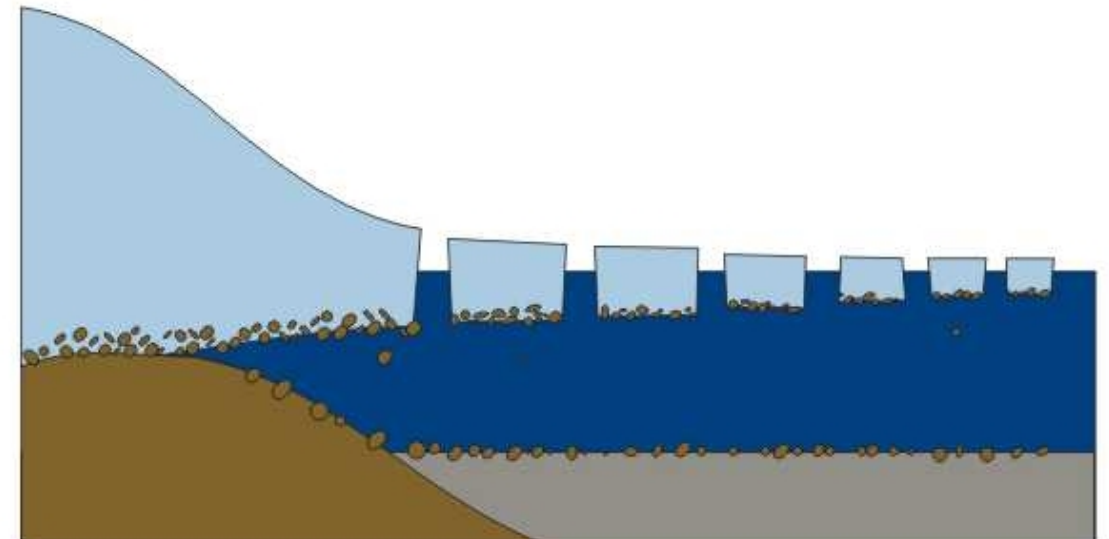
$$d(\text{ANT_d18Oice})/dt \propto 1/\text{GRN_d18Oice}$$

Barker et al., 2011



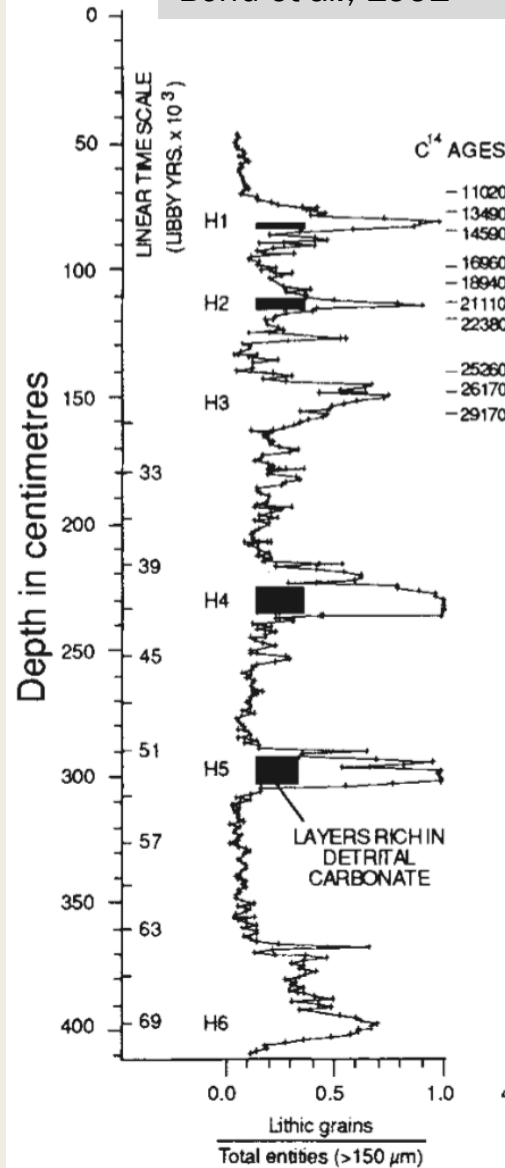
Although abrupt, maybe not that unusual...

Heinrich Events



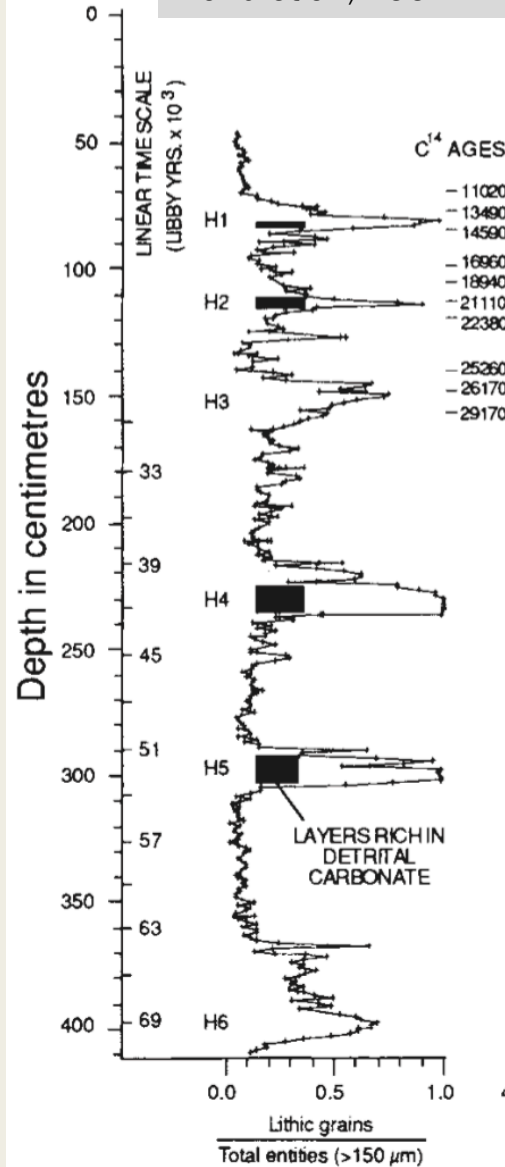
Heinrich Events

Bond et al., 1992

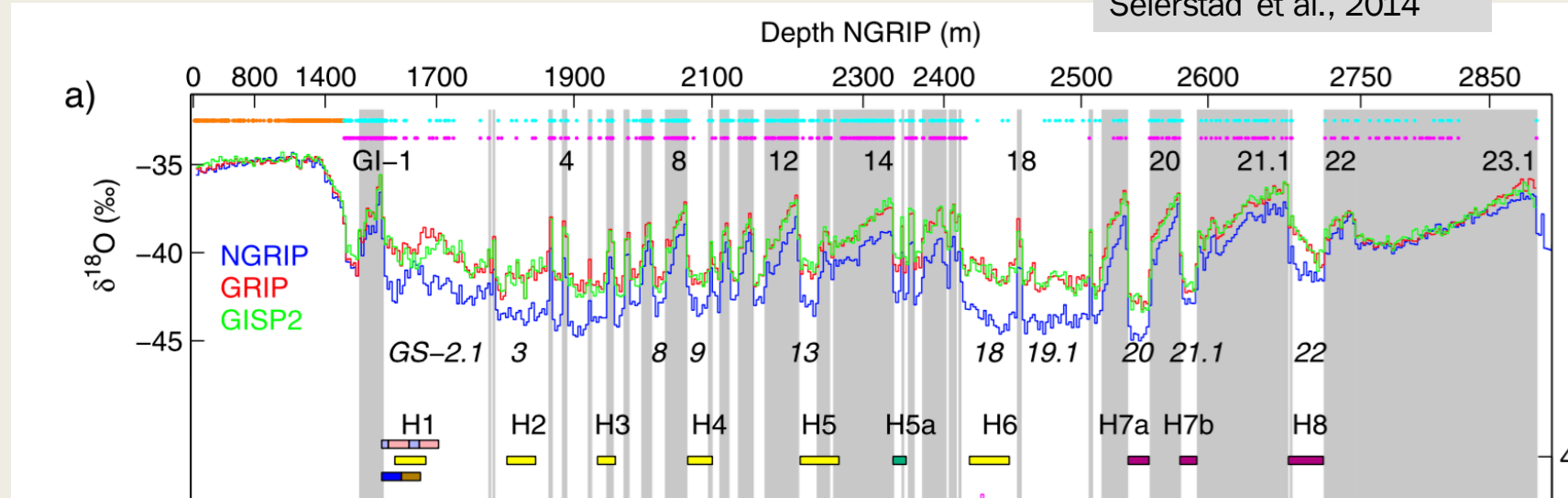


Heinrich Events

Bond et al., 1992

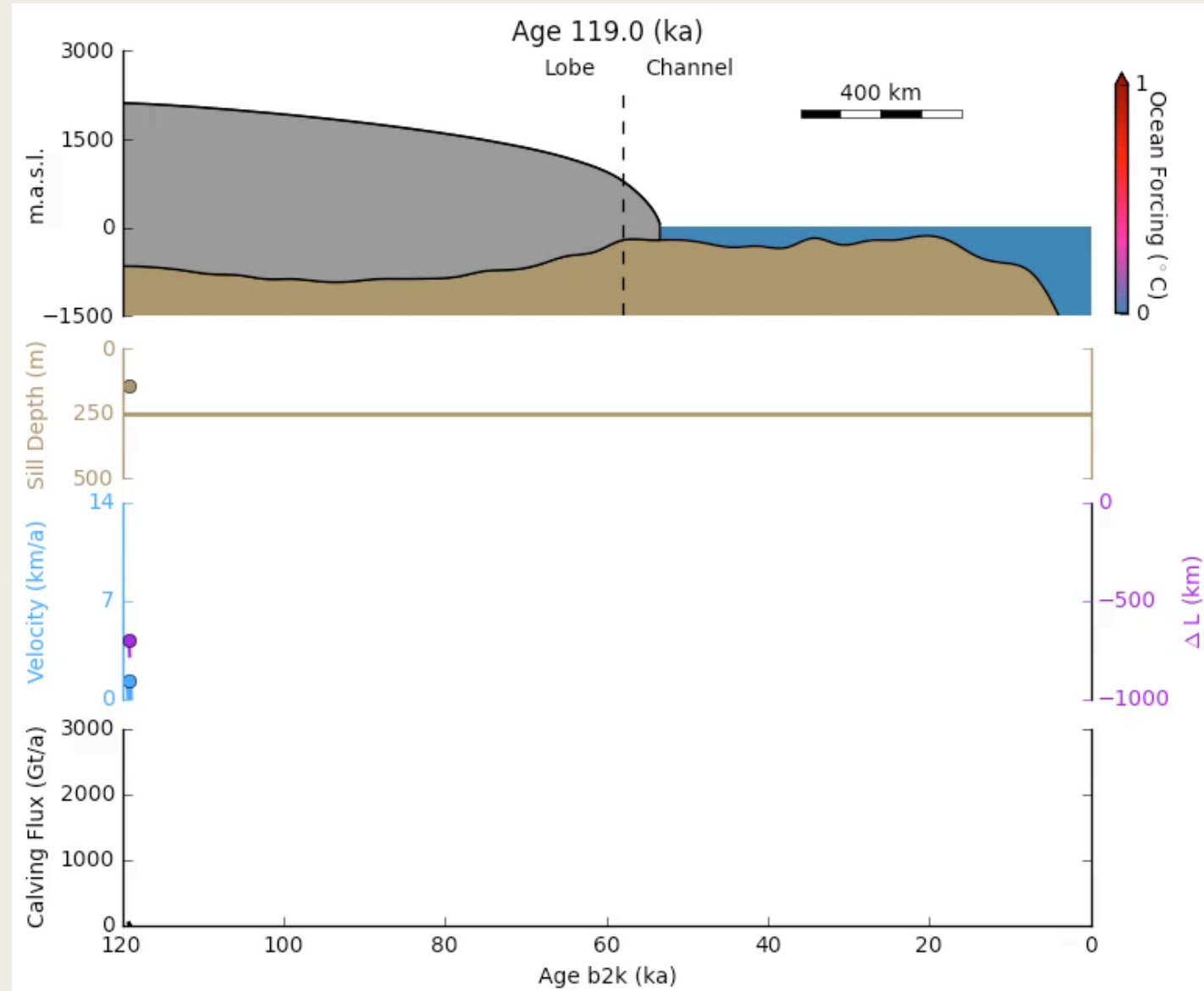


Seierstad et al., 2014



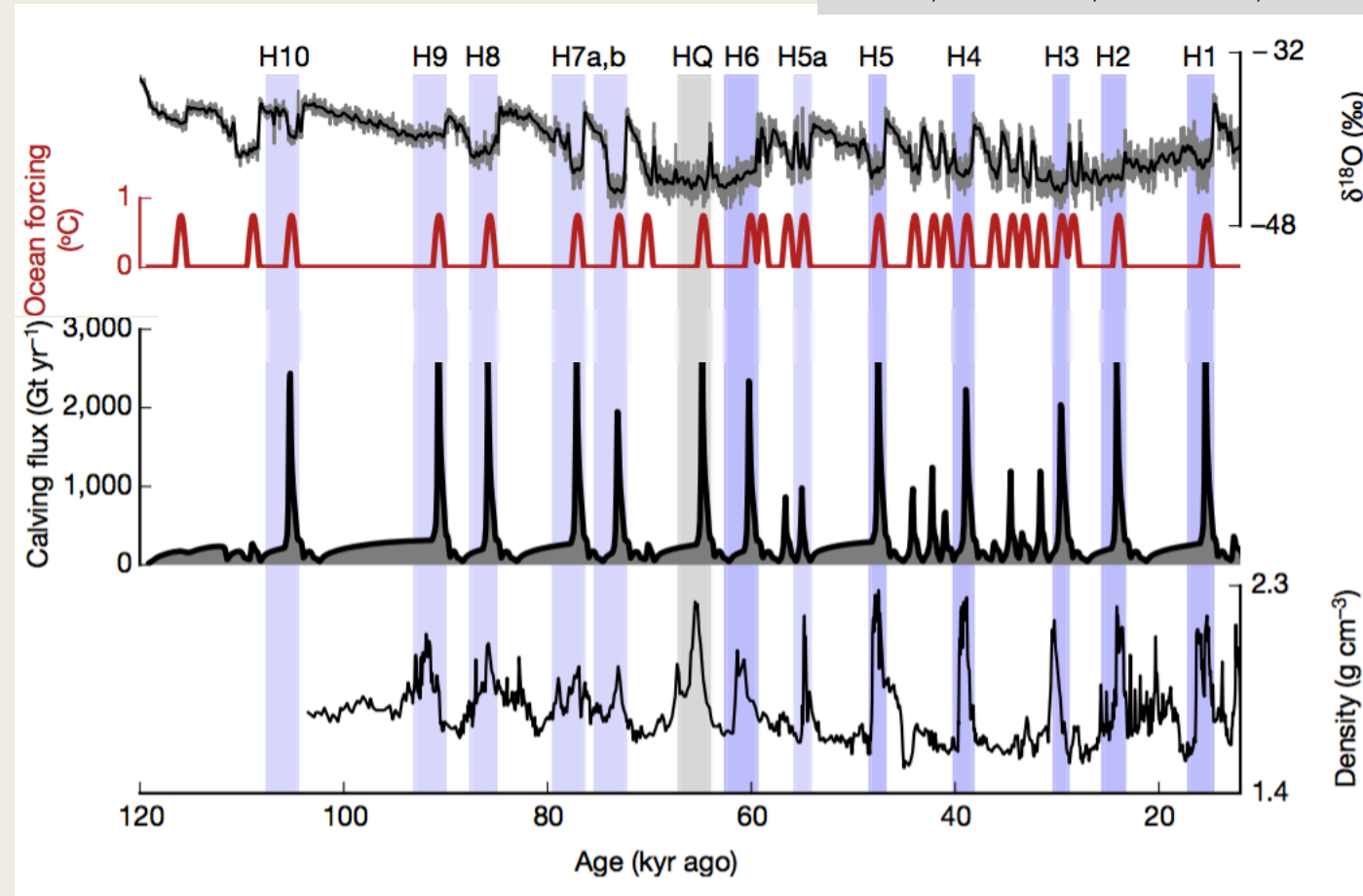
Heinrich Events

Bassis, Petersen, & Cathles, 2017



Heinrich Events

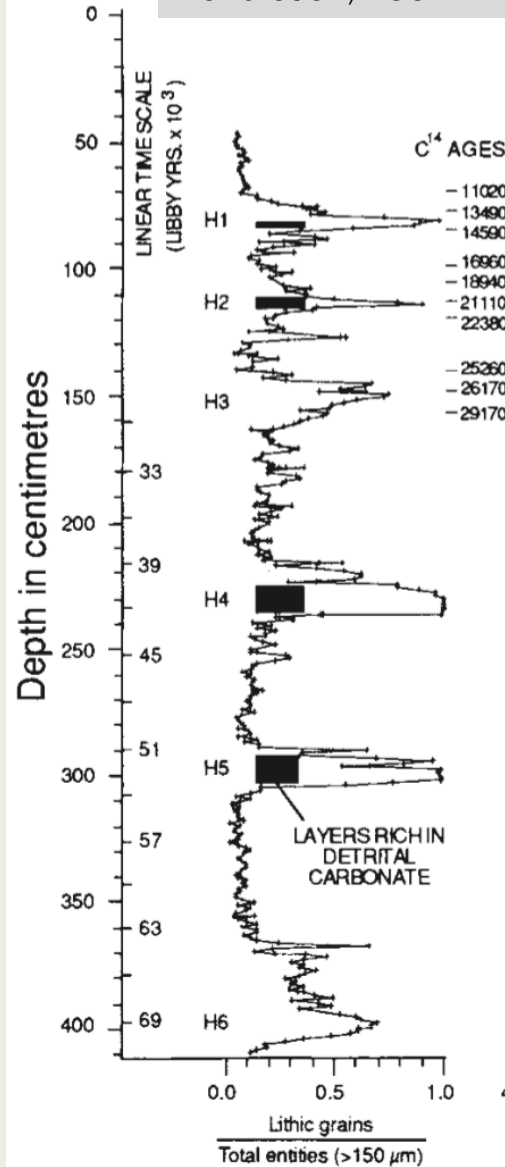
Bassis, Petersen, & Cathles, 2017



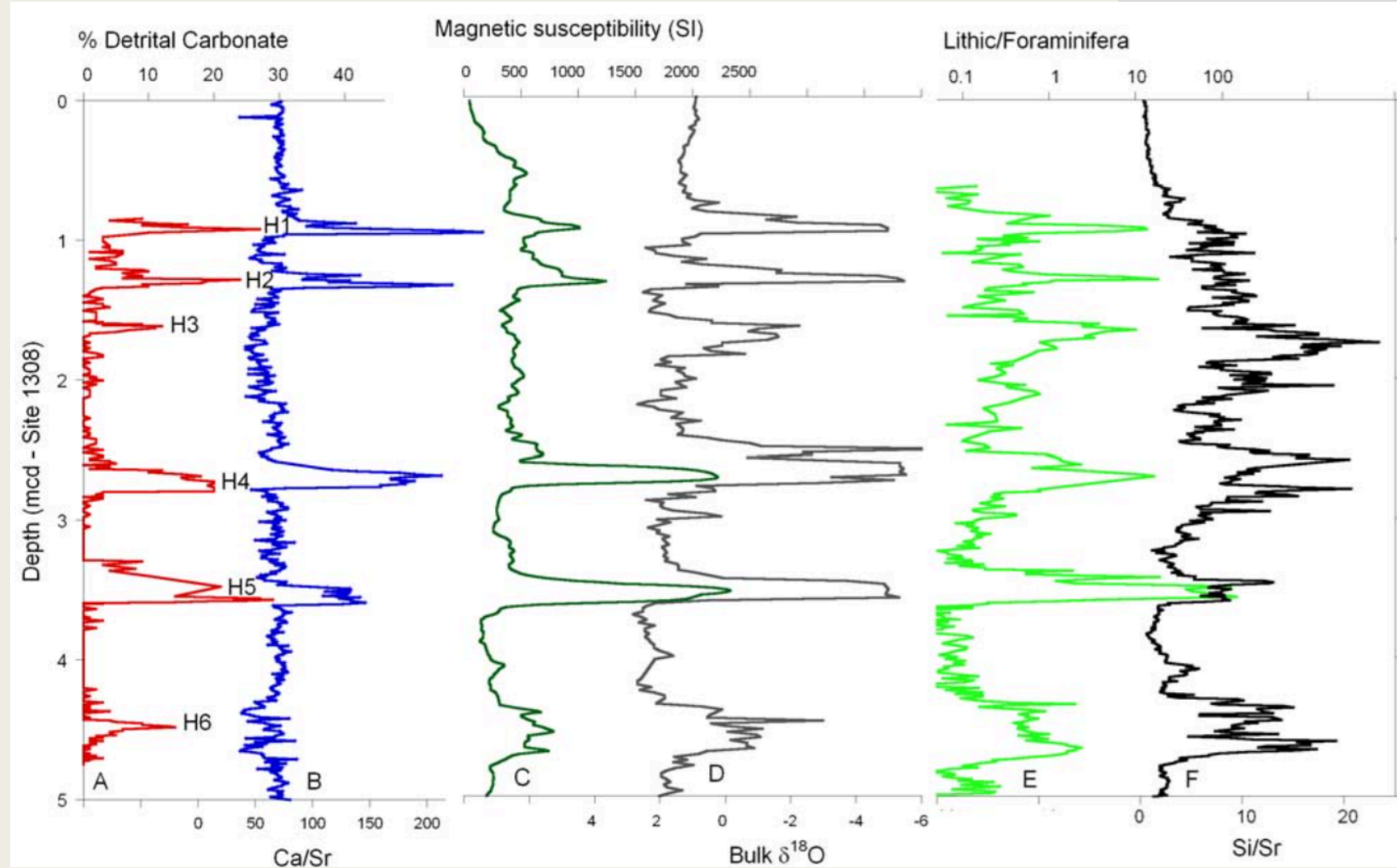
No special physics required to make a Heinrich Event

Heinrich Events

Bond et al., 1992



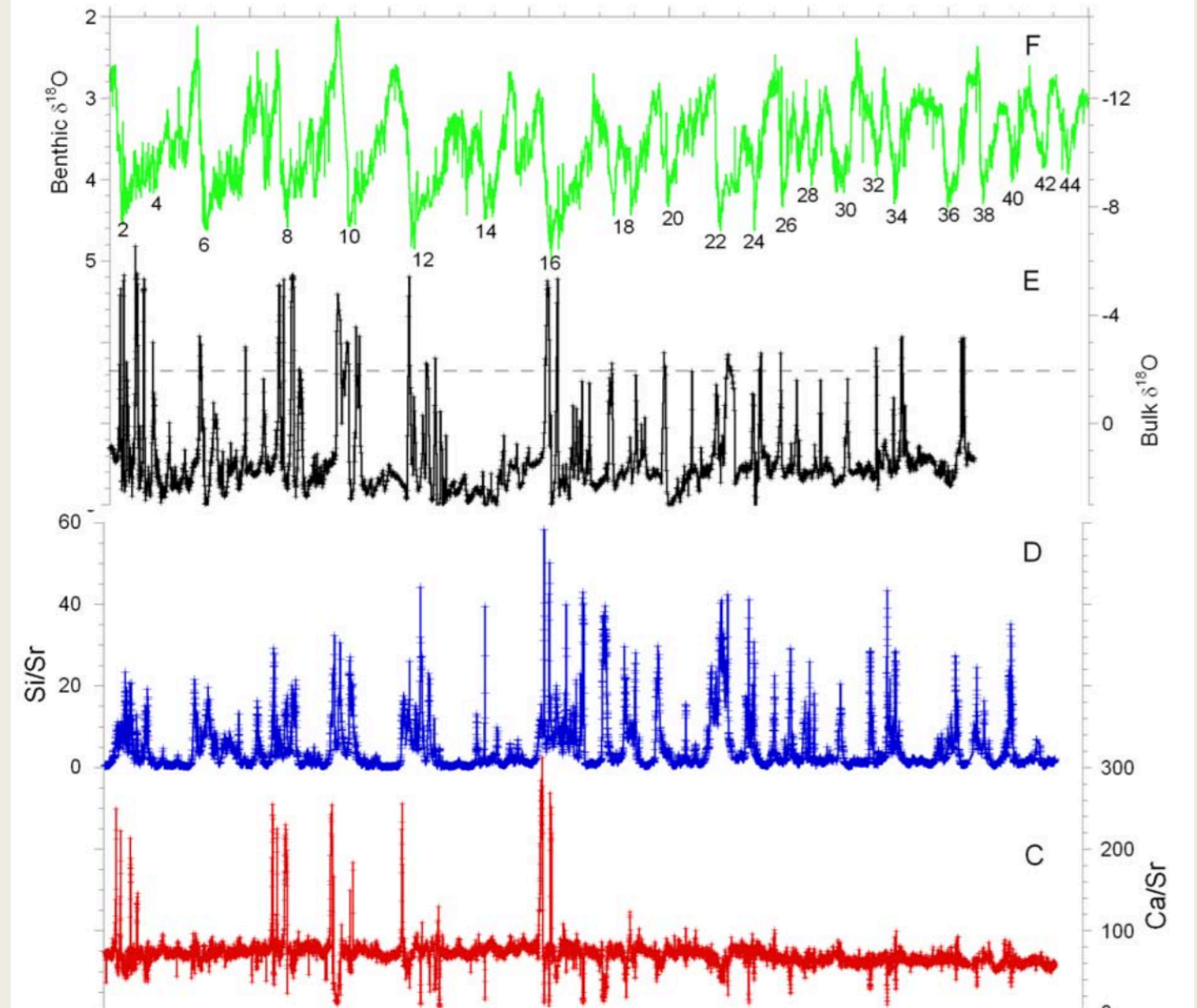
Hodell et al., 2008



Heinrich Events

Hodell et al., 2008

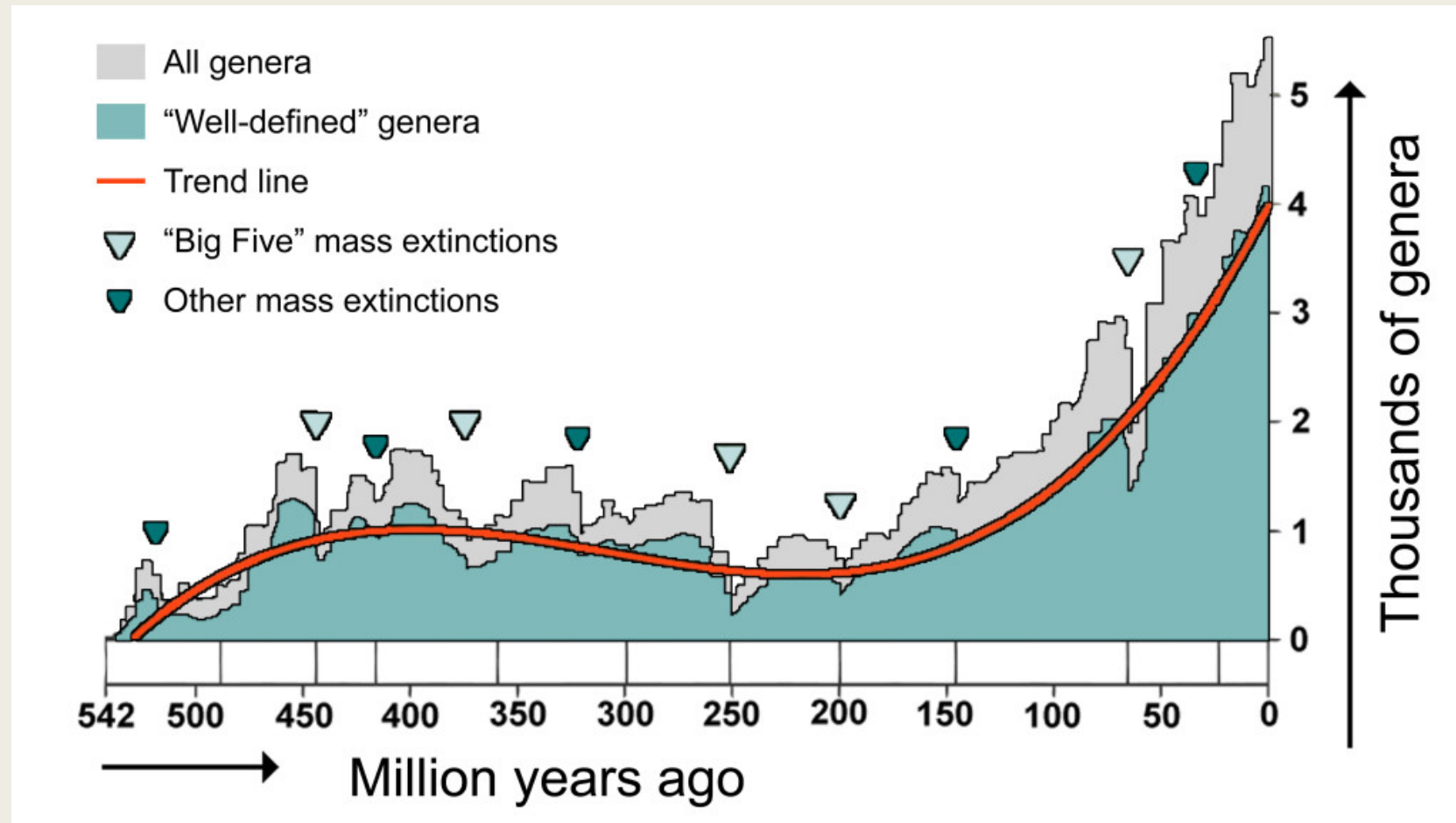
**Again, occurring
over multiple
glacial cycles**



Classes of aberrations

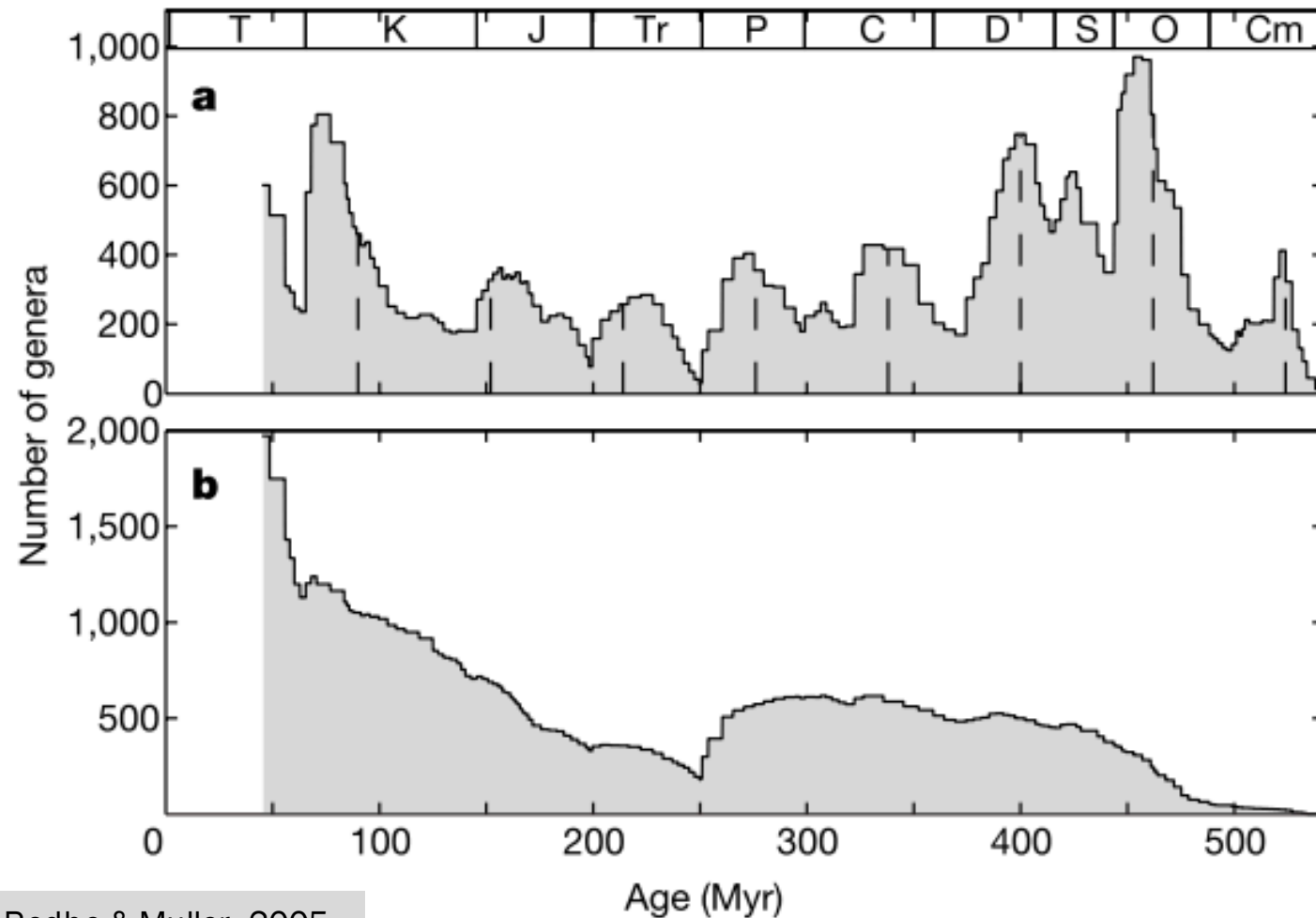
- Temperature changes e.g. D-O's, PETM
- Ice Sheet changes e.g. HE's, EOT
- Ocean Anoxic Events
- Mass Extinctions
- Global Shifts e.g. Rise of pO_2 , Evolution

MASS Extinction throughout Earth History



Rodhe & Muller, 2005 via Andersen at INESAD

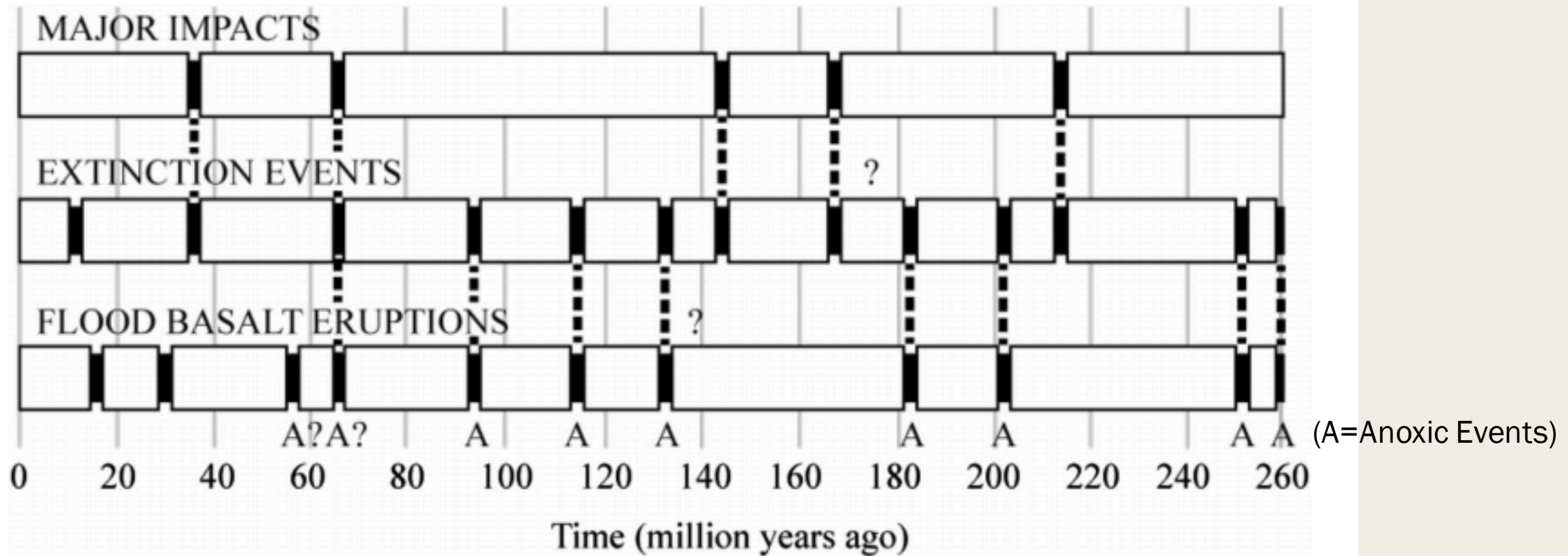
Extinction throughout Earth History



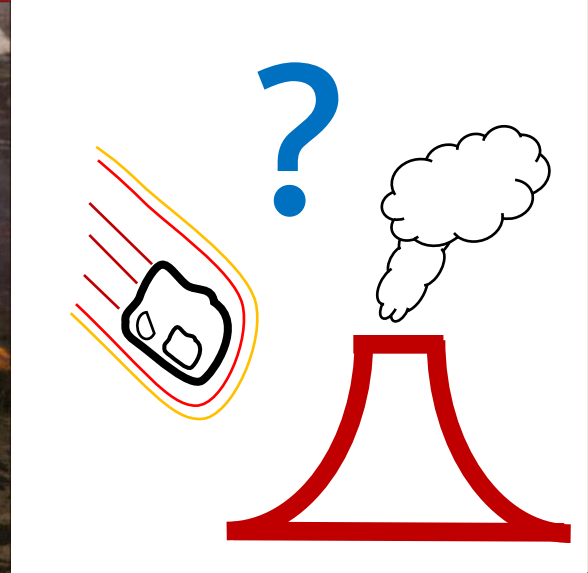
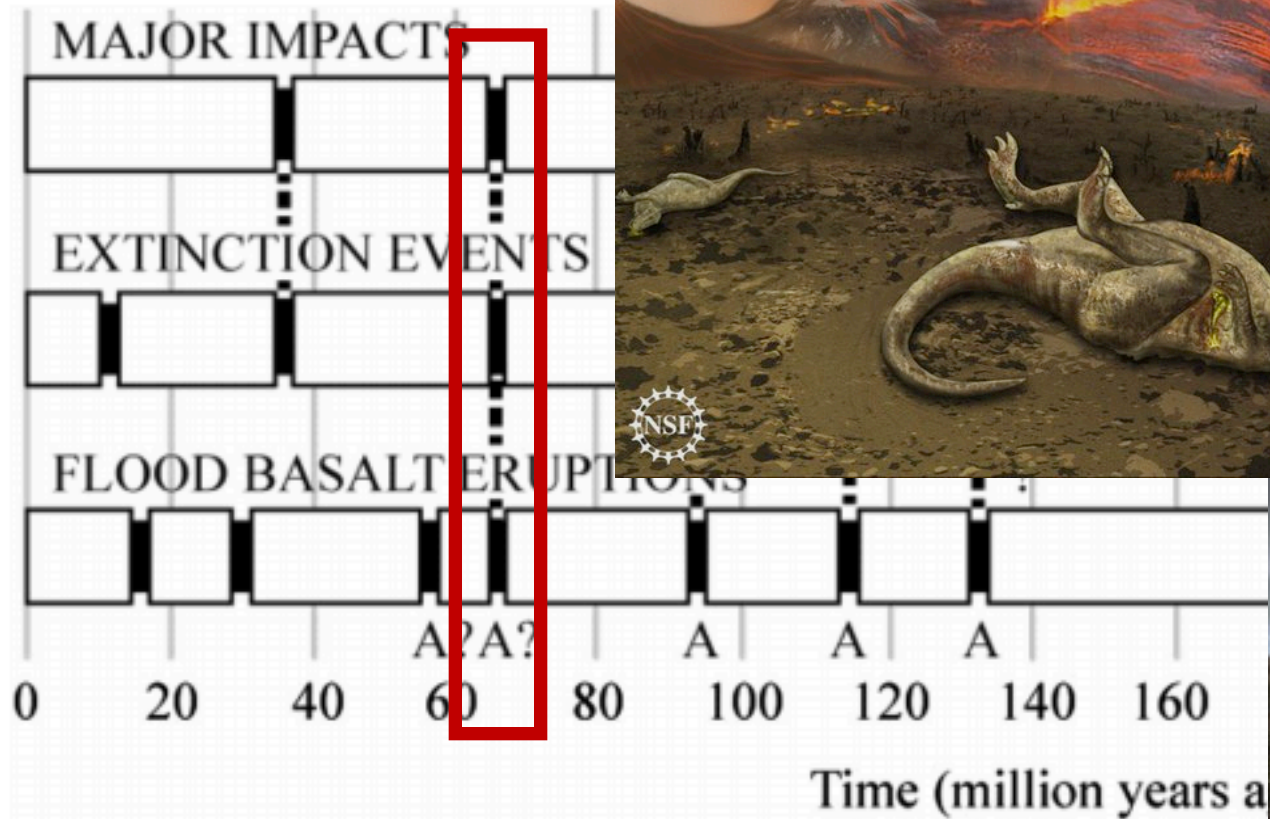
“Short-lived” genera
(living < 45 Myr)

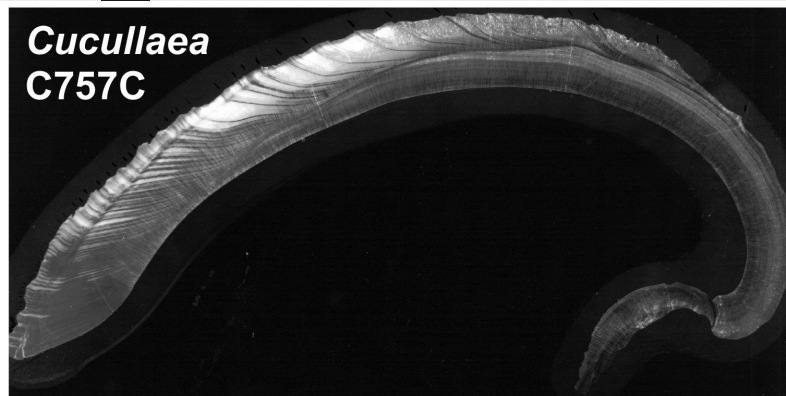
“Long-lived” genera
(living > 45 Myr)

Impacts, Volcanism & Mass Extinction



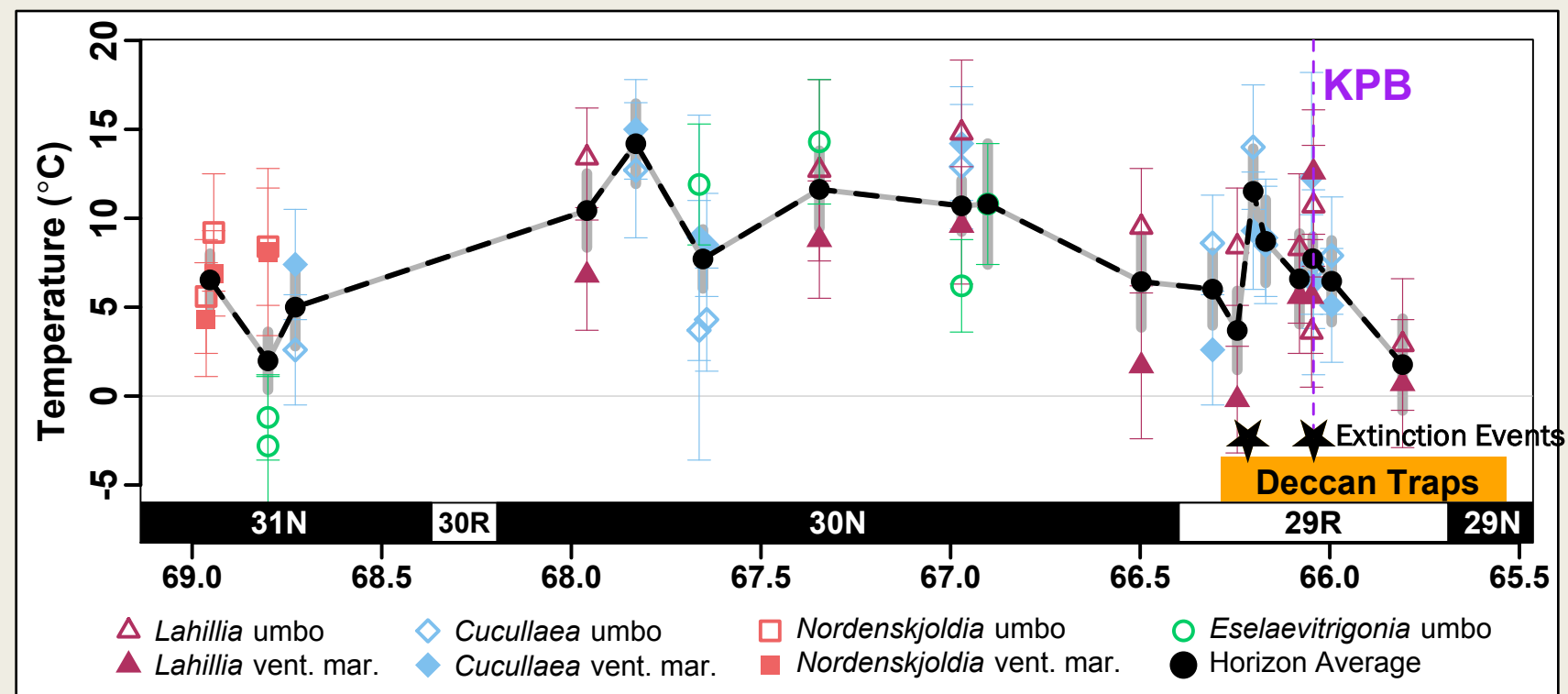
Cretaceous-Paleogene Mass Extinction





Cretaceous-Paleogene Boundary

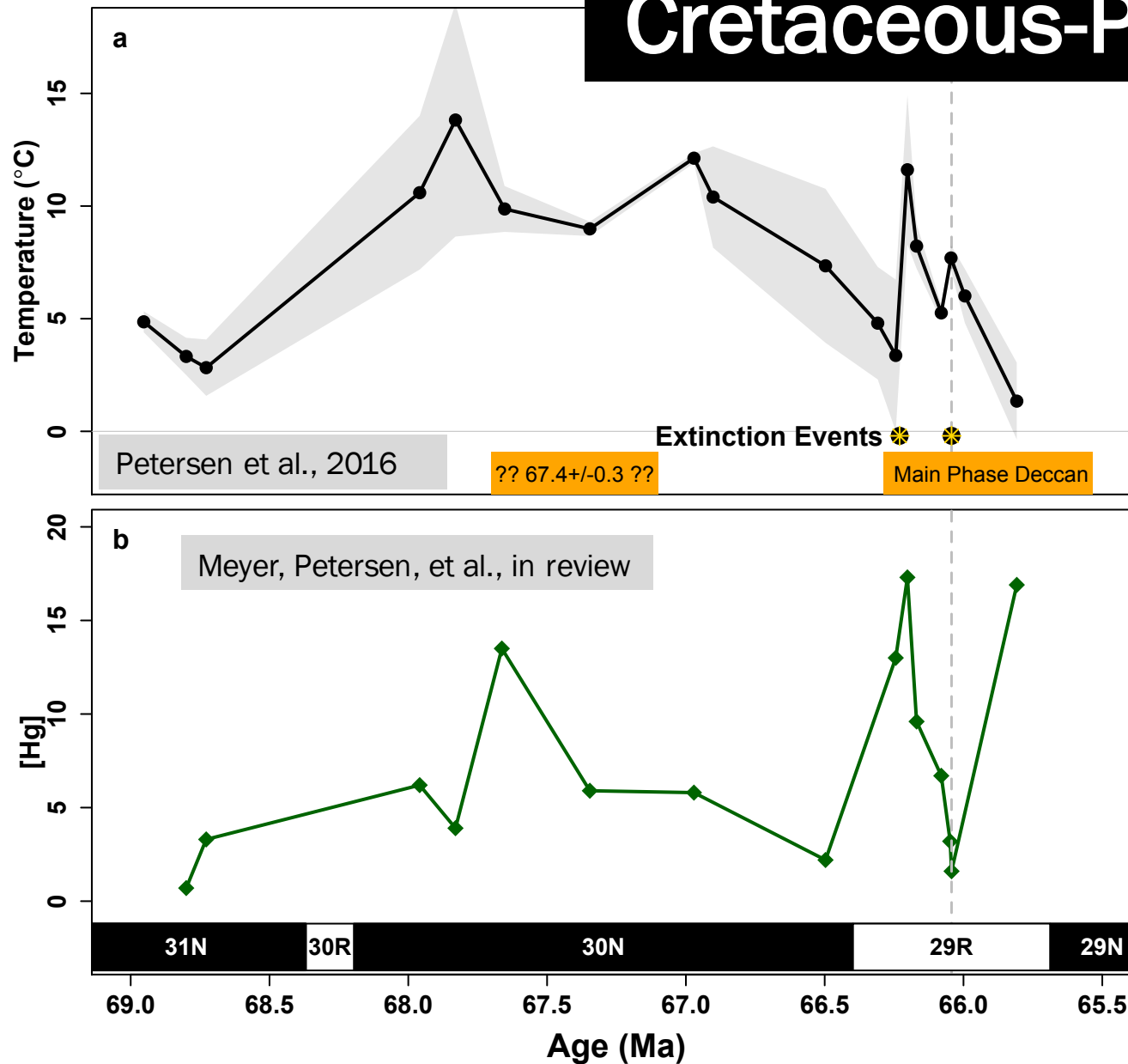
Petersen et al., 2016



Seymour Island, Antarctica

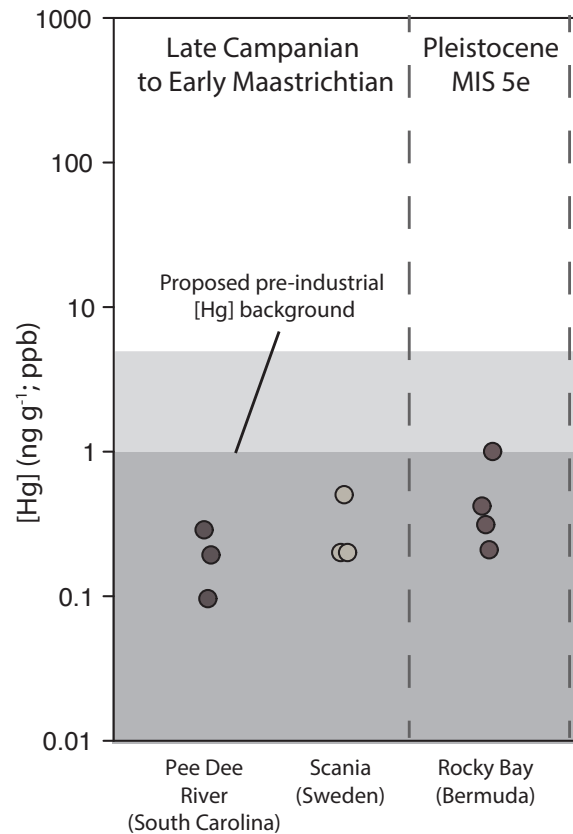


Cretaceous-Paleogene Boundary



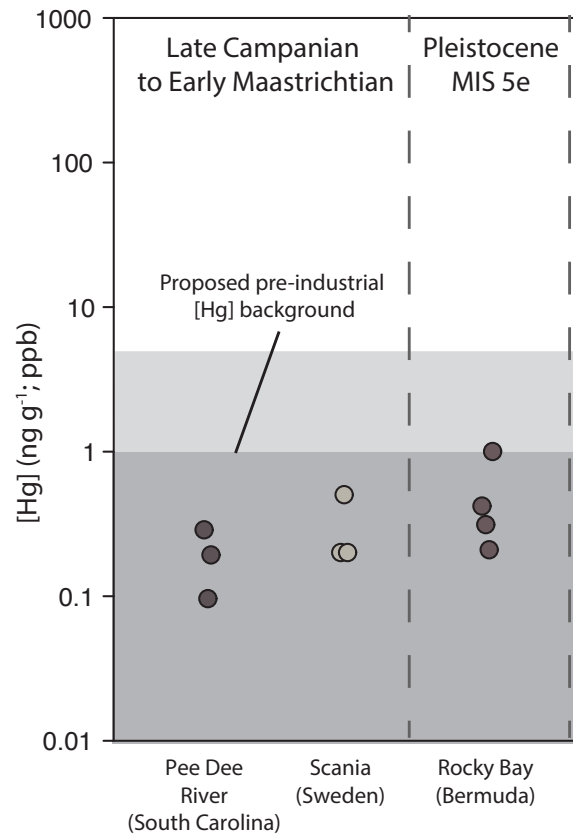
Cretaceous-Paleogene Boundary

Non-Deccan

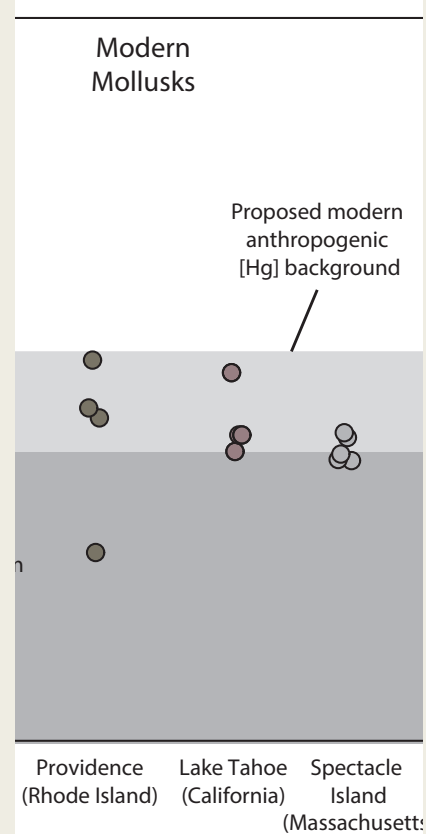


Cretaceous-Paleogene Boundary

Non-Deccan

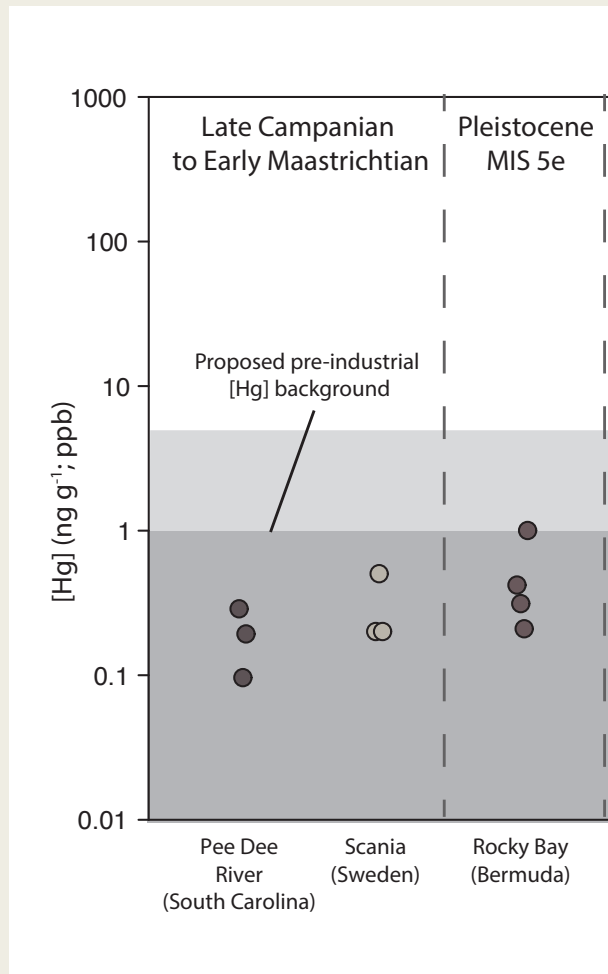


Modern

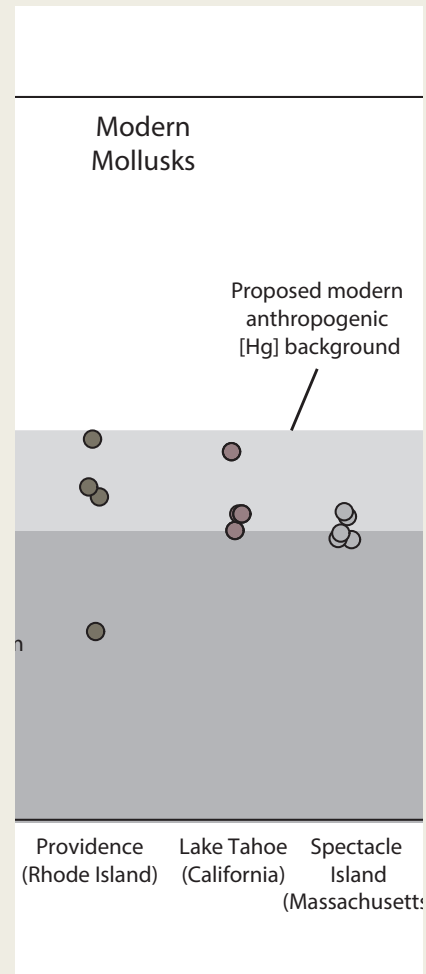


Cretaceous-Paleogene Boundary

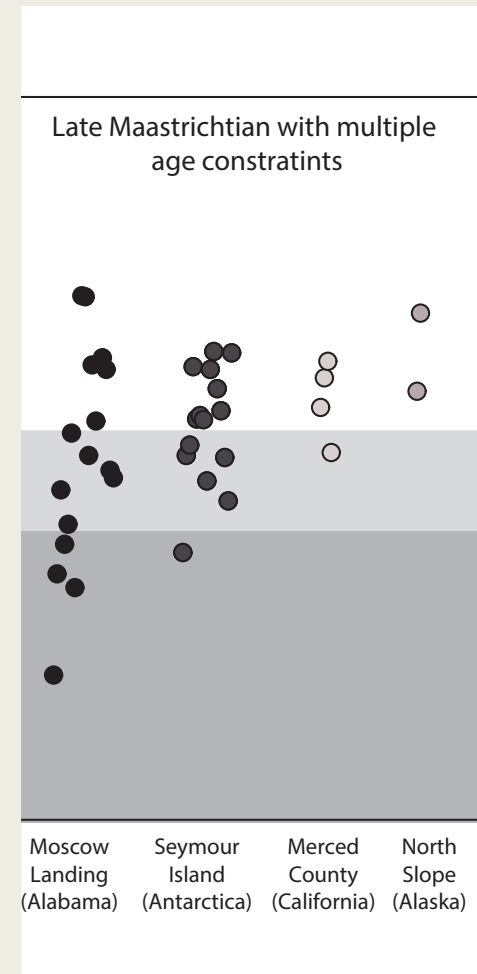
Non-Deccan



Modern

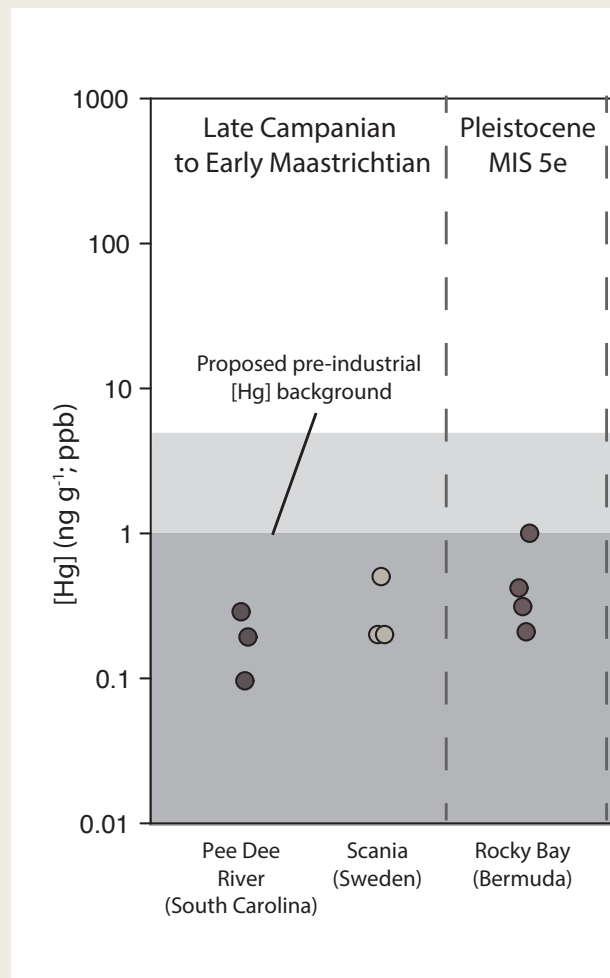


Deccan-aged

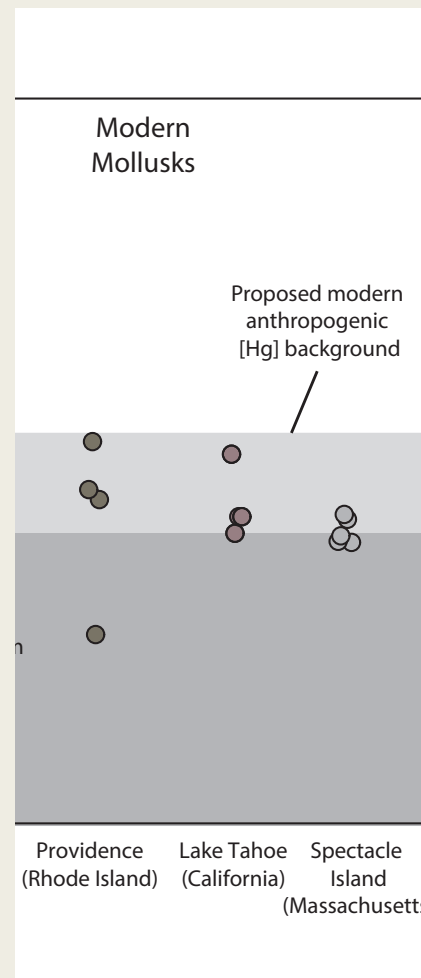


Cretaceous-Paleogene Boundary

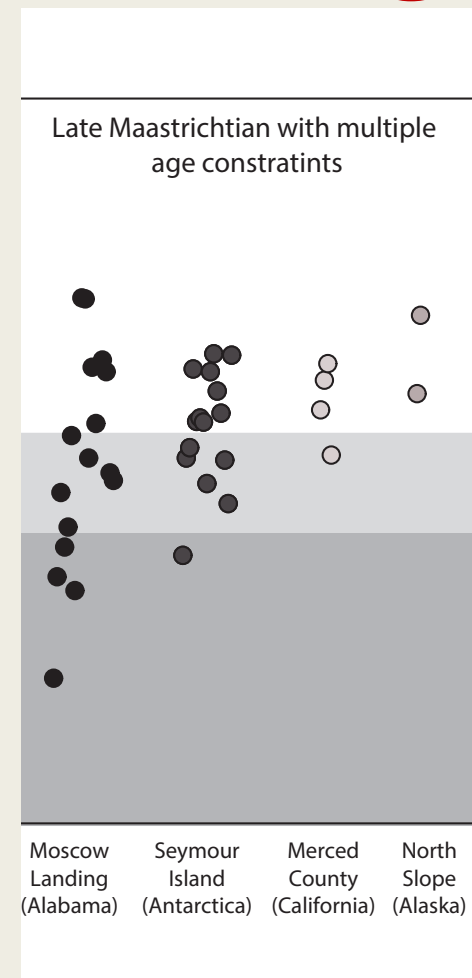
Non-Deccan



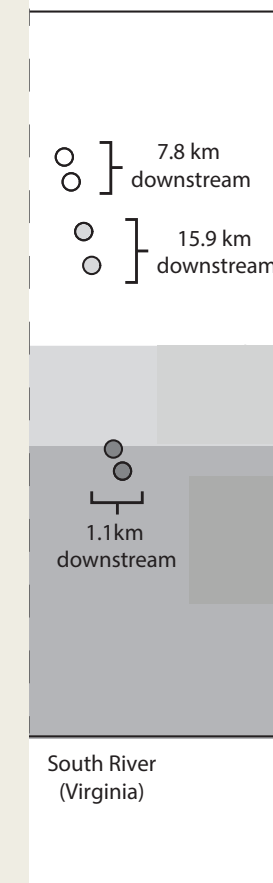
Modern



Deccan-aged



Modern Polluted Site



Hg levels on par with modern polluted site, lasting Myr

Aberrations from background climate...

Shocking in the moment, but possibly not that unusual over geologic time

- PETM
- K-Pg extinction
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