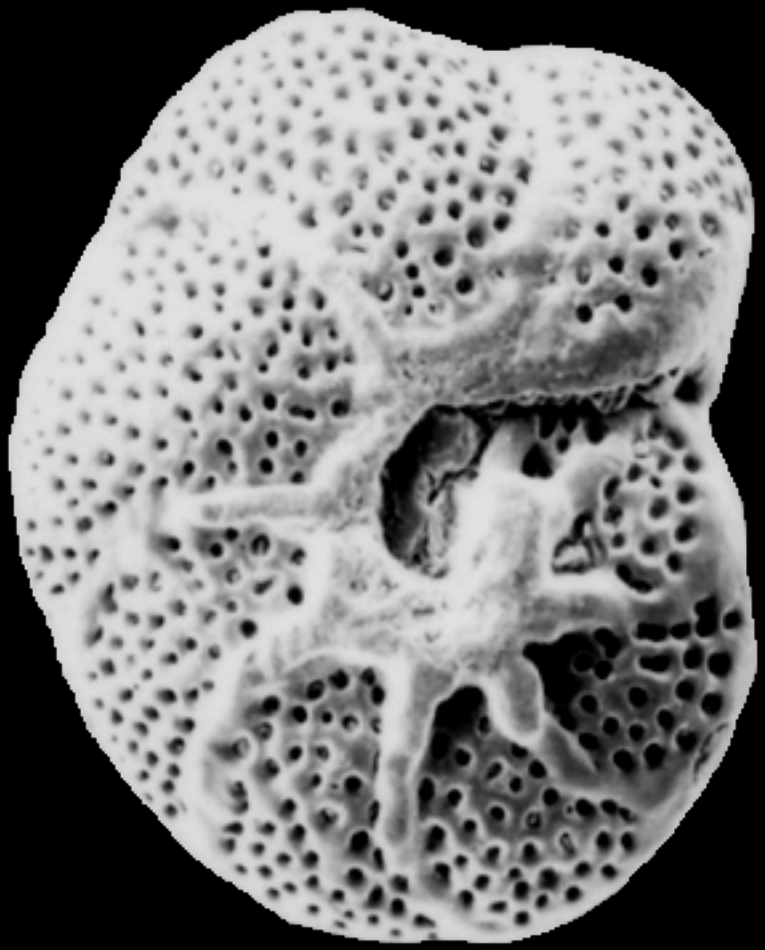
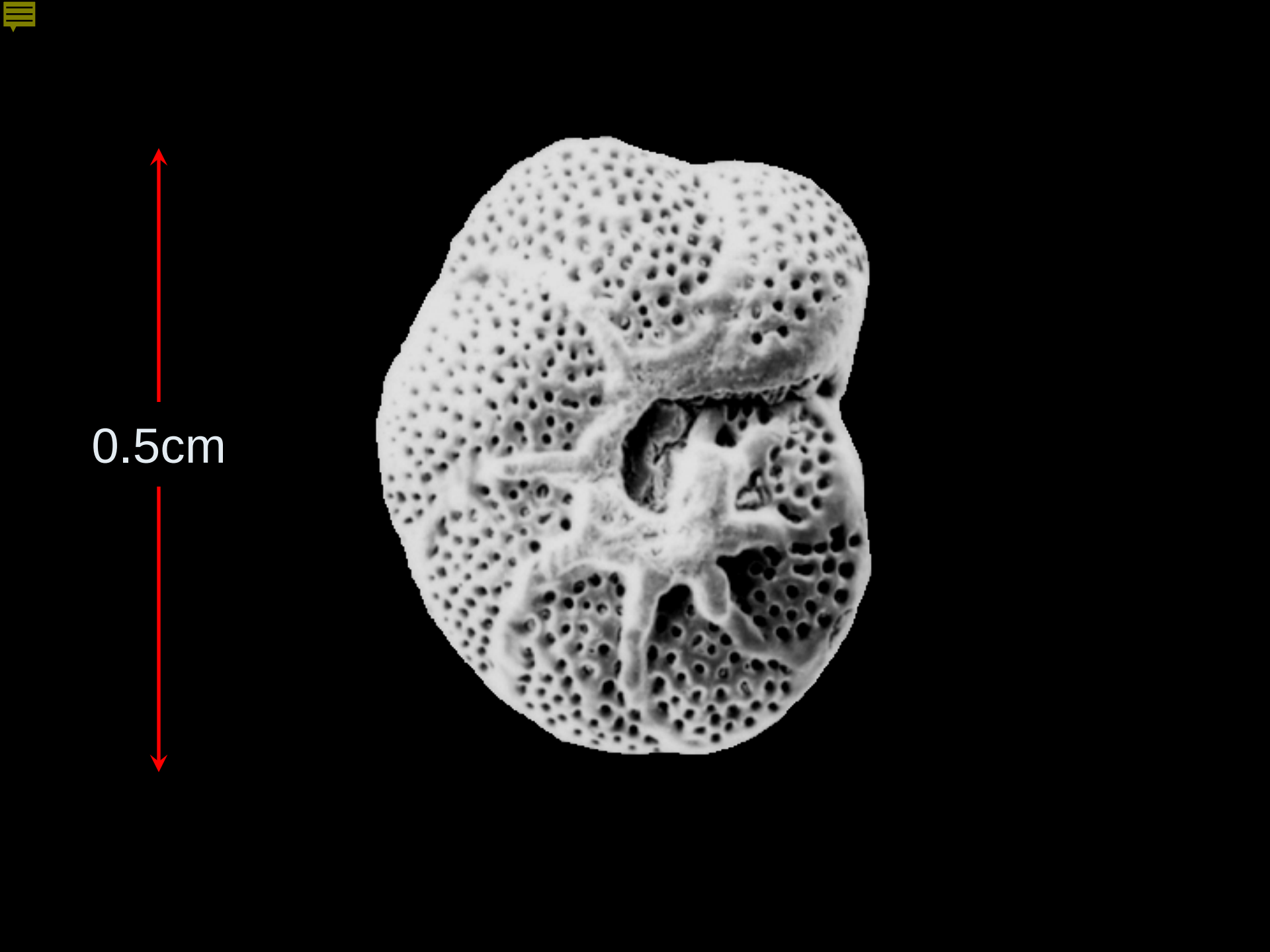
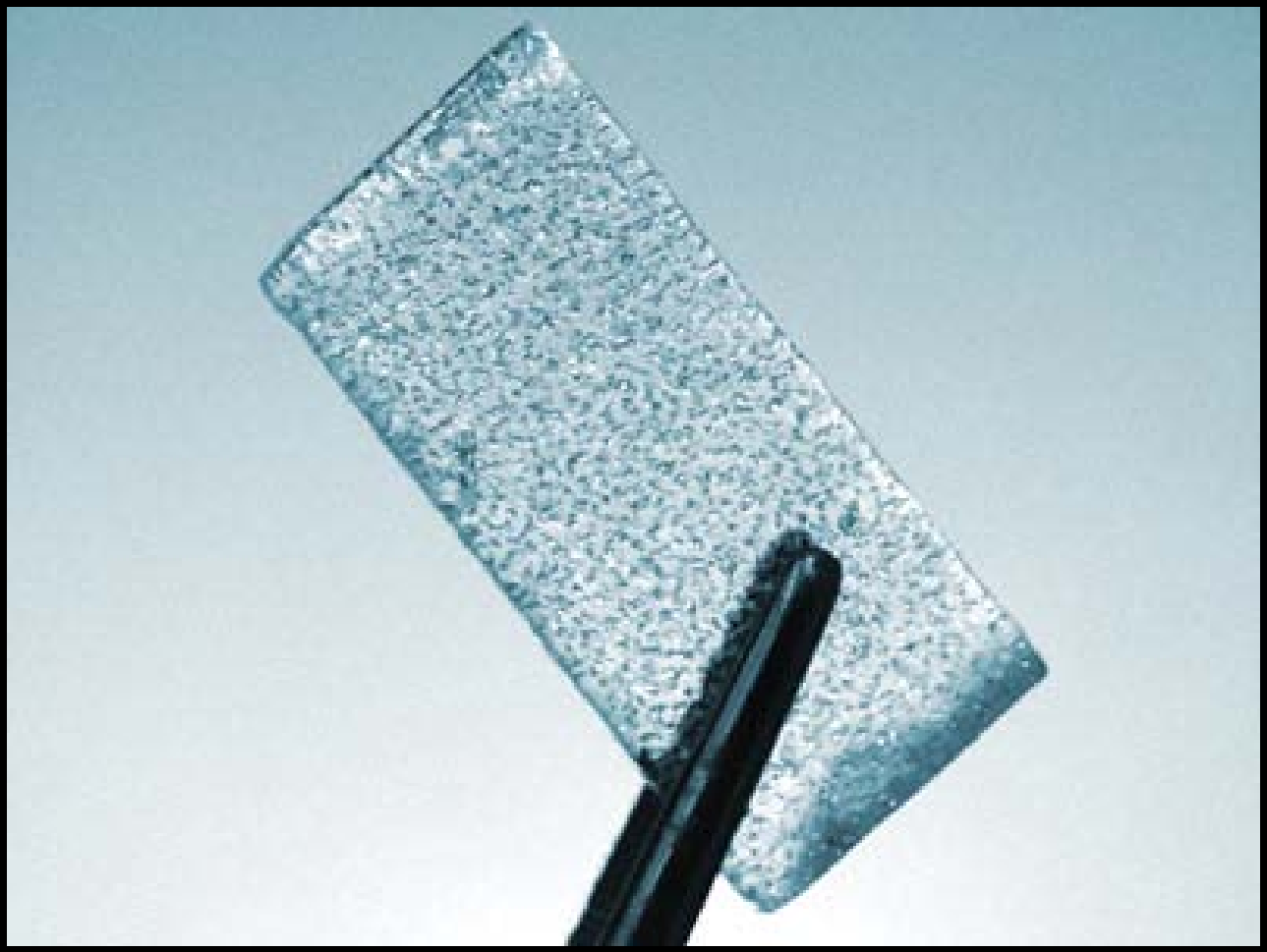
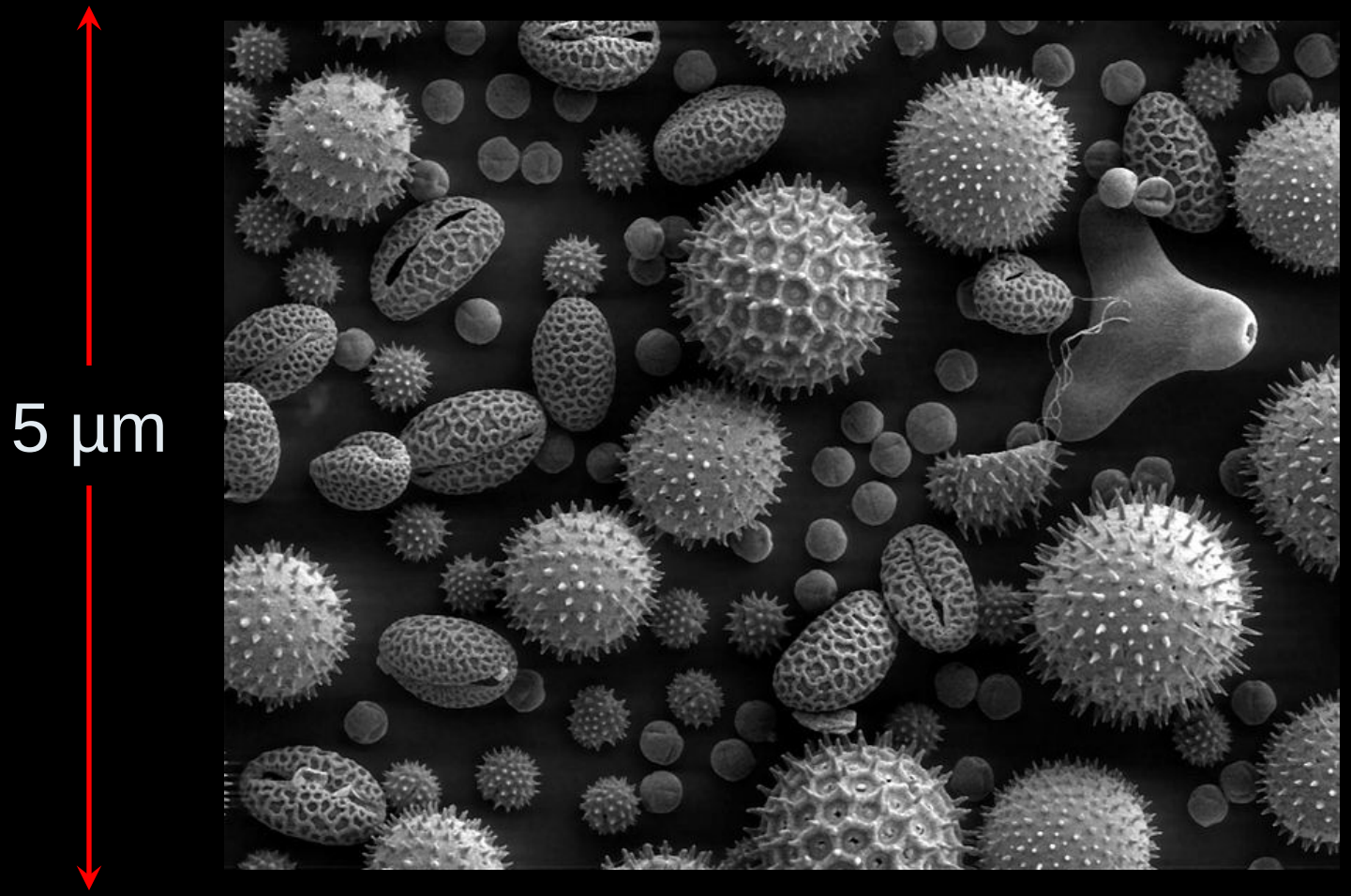
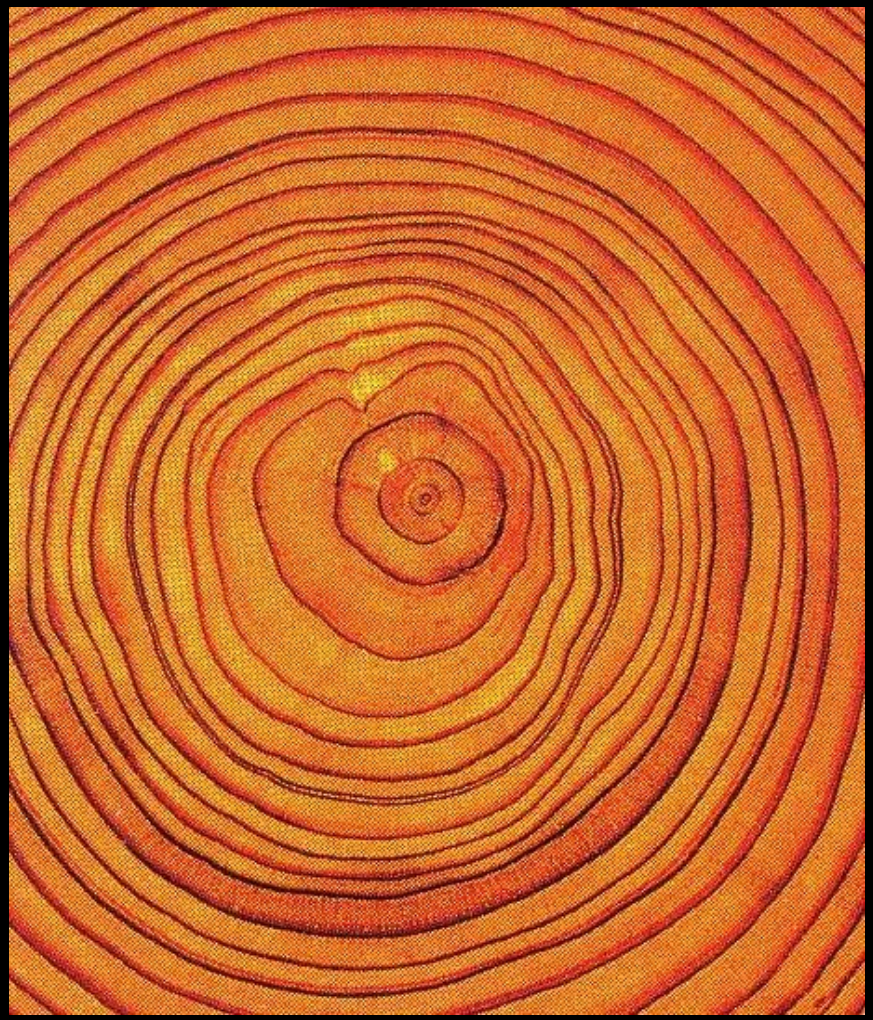



0.5cm




5 µm



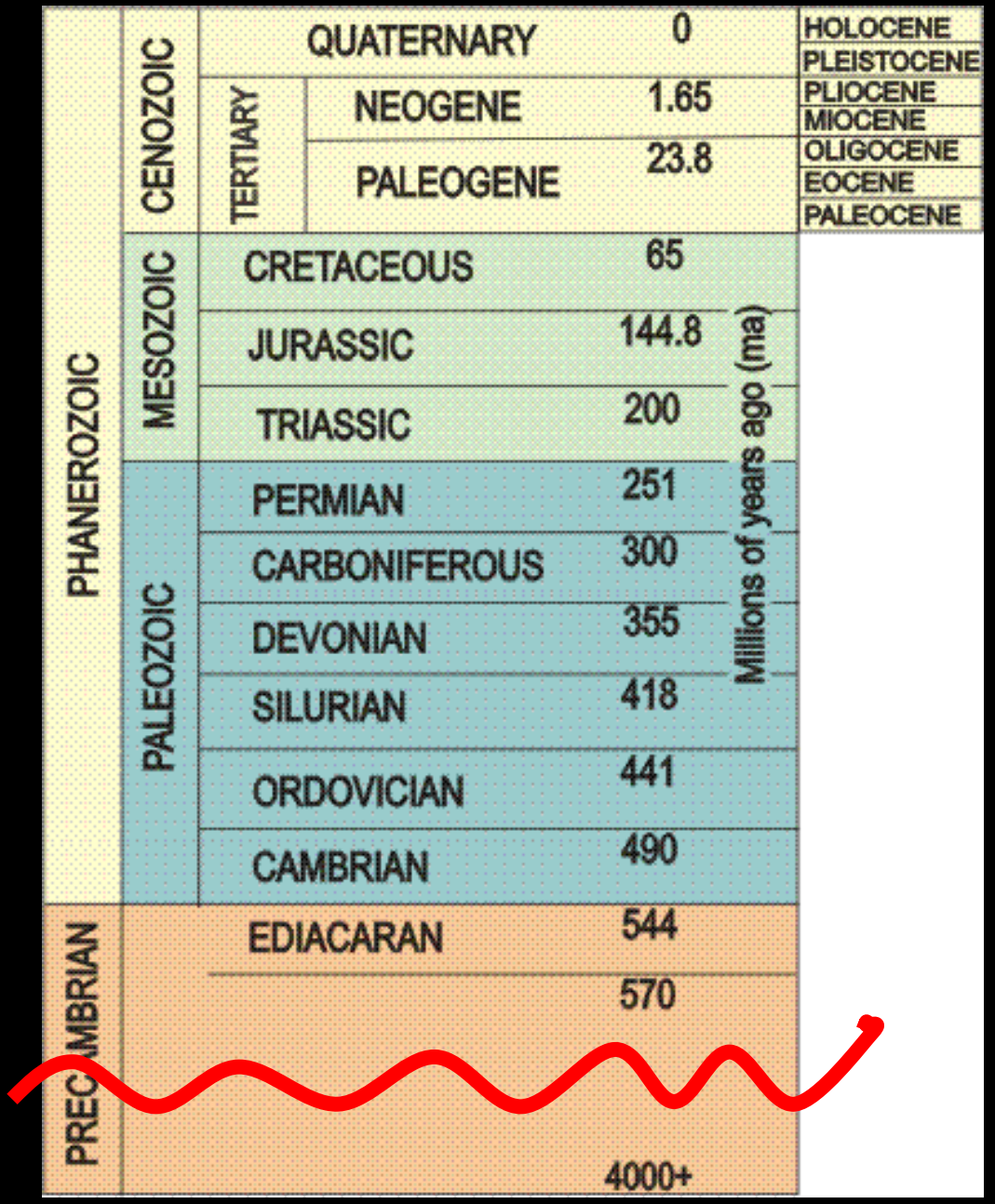
Reconstructing past climate

Talk outline:
A trip through geologic time

Take away points:
• Climate change through time

• What past climate change adds to the climate story

• What type of “archives” and data do we have



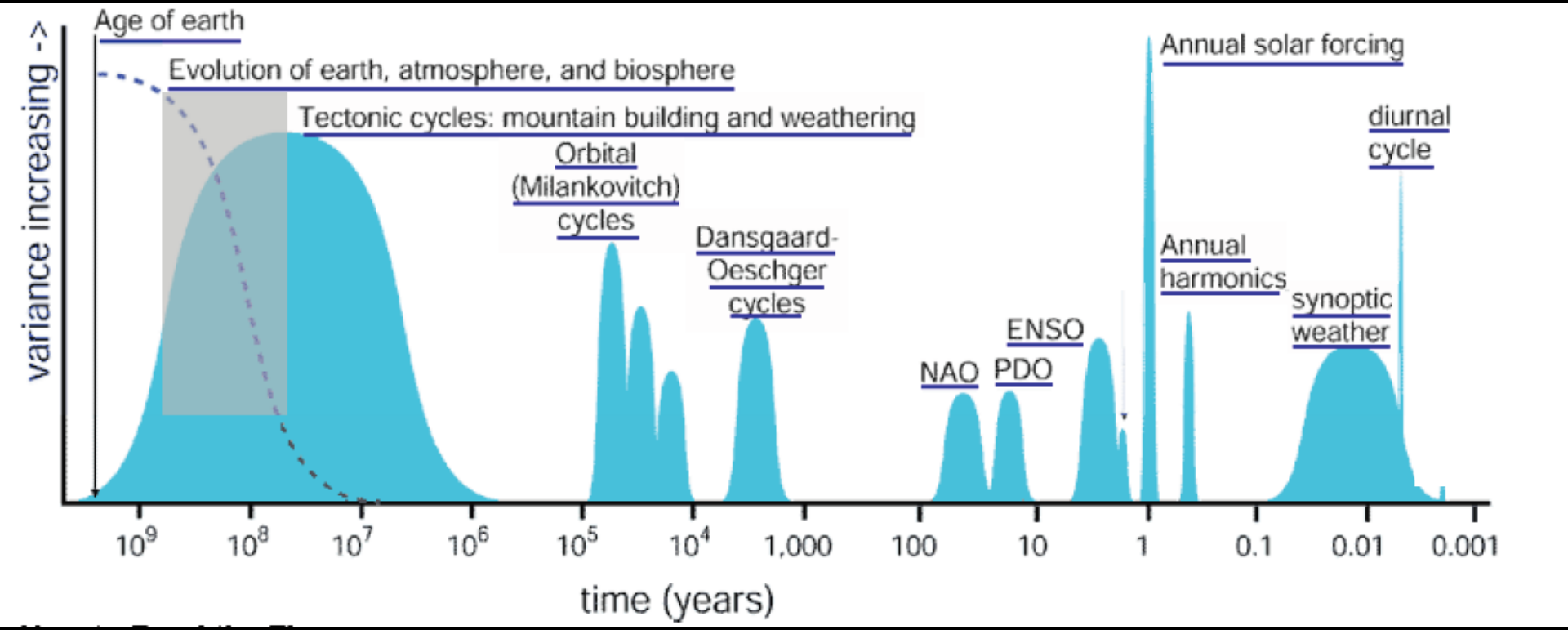
Causes of climate change: natural forcings

- Changes in plate tectonics and the related changes in carbon dioxide (100,000's to millions of years)

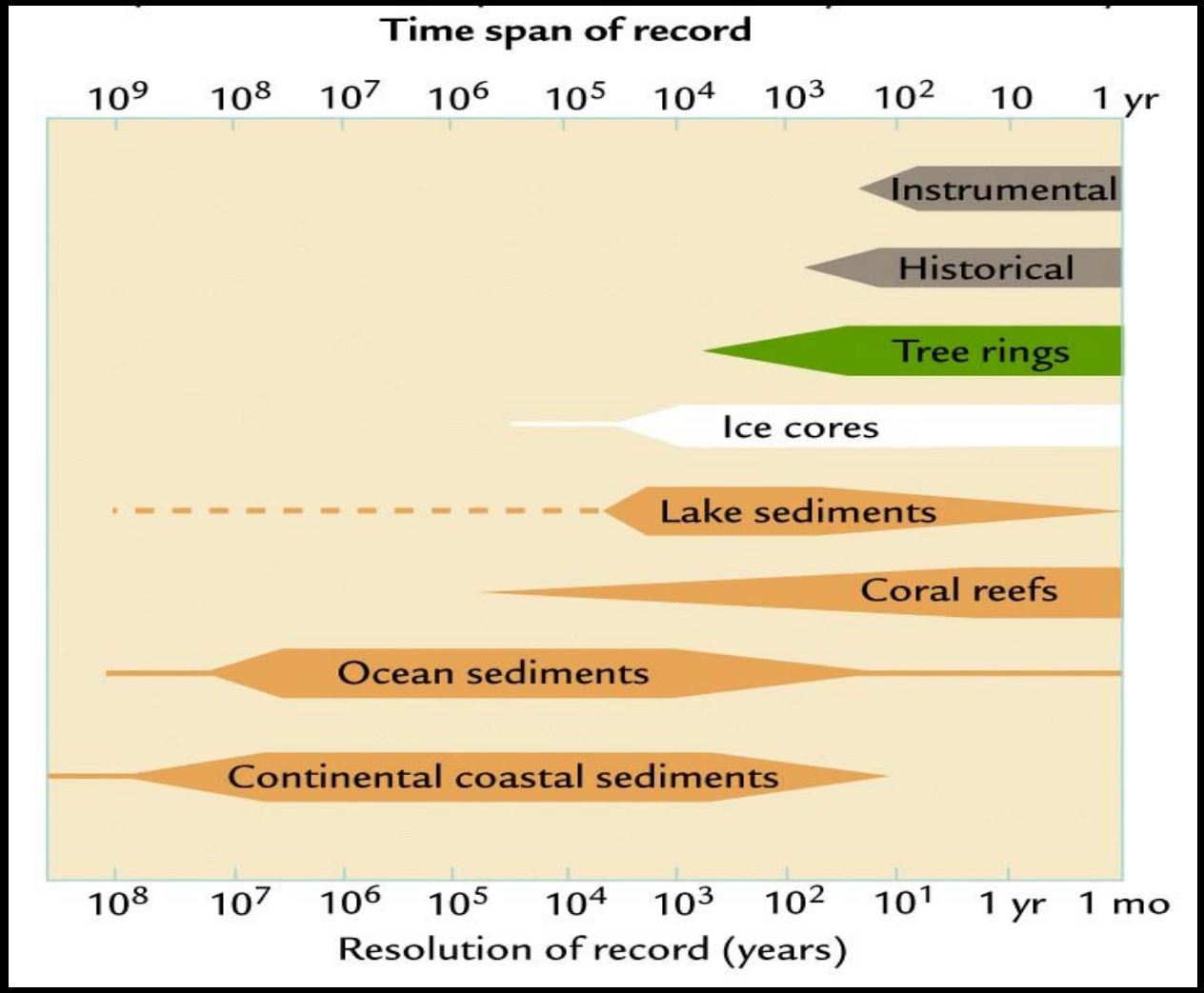
- Changes in the earth's orbit, "Milankovitch" cycles (10,000's to 100,000's years)

- Changes in the sun's strength (very short… to very long)

Timescales of climate variability

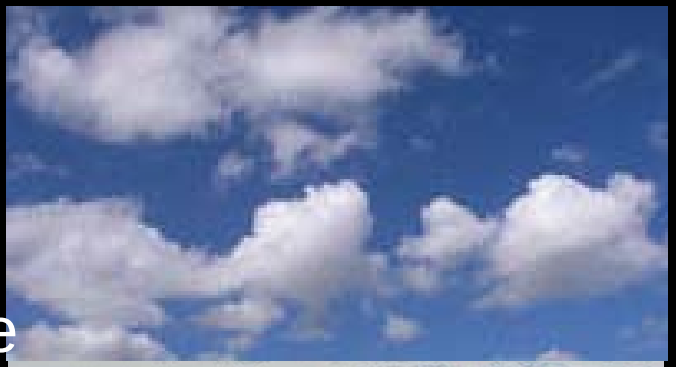


Climate archives: what records do we have?



Climate archives: what information do we need?

Atmosphere

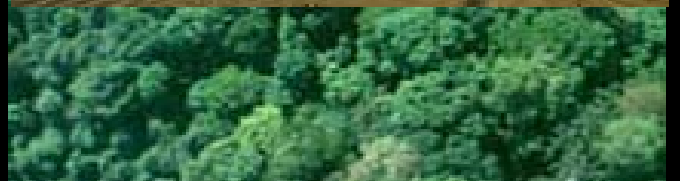


Cryosphere

Hydrosphere

Land

Biosphere



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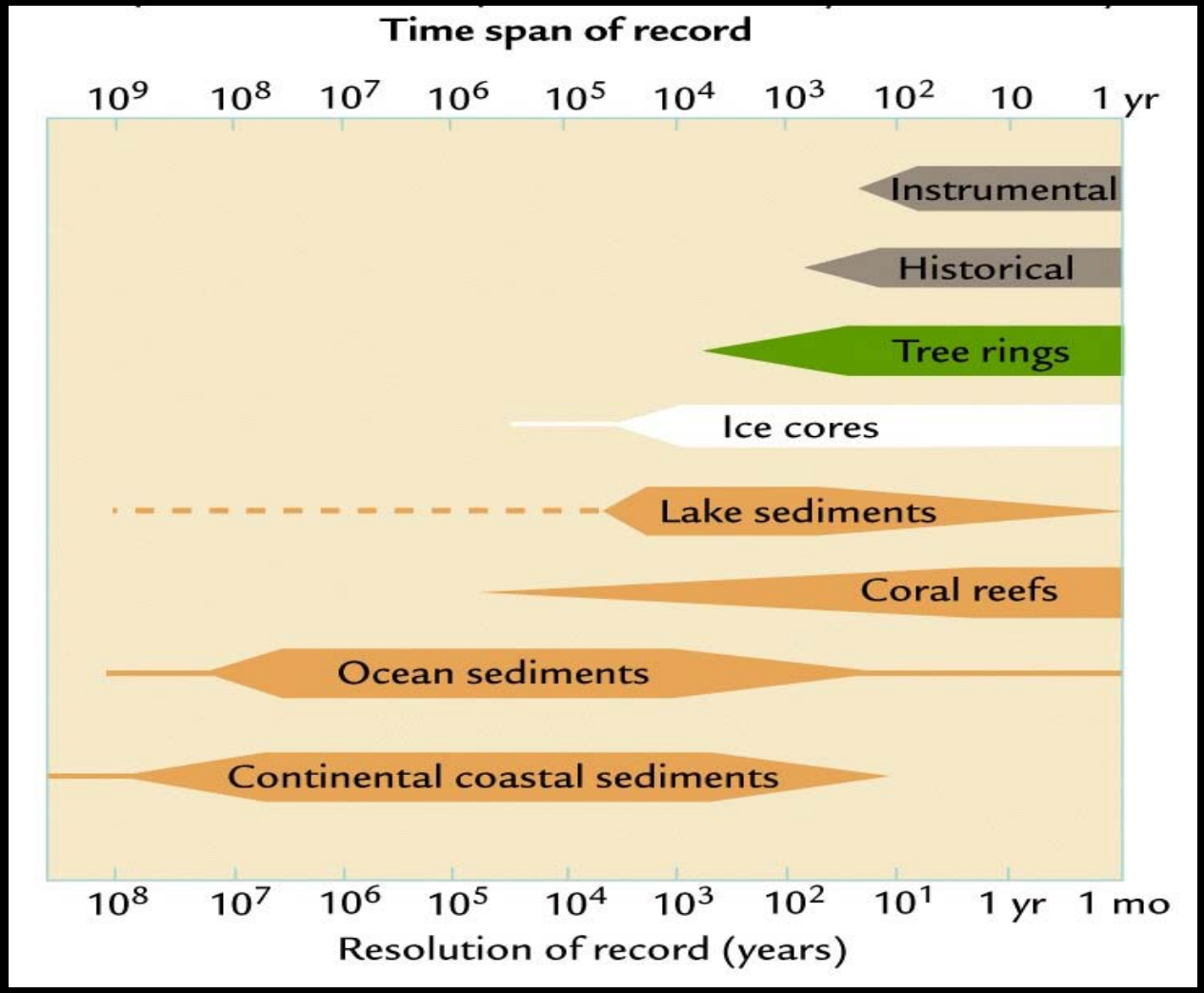
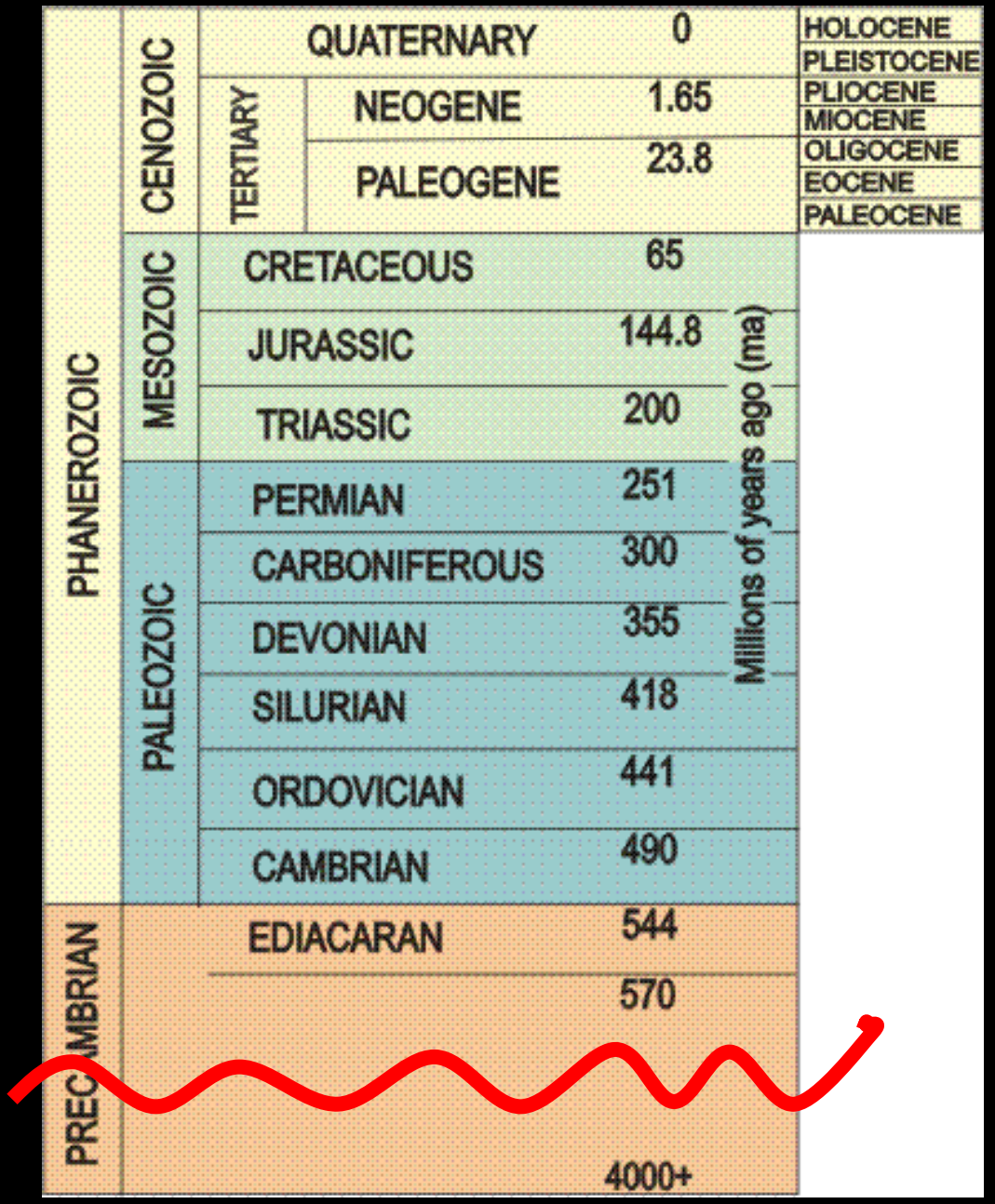


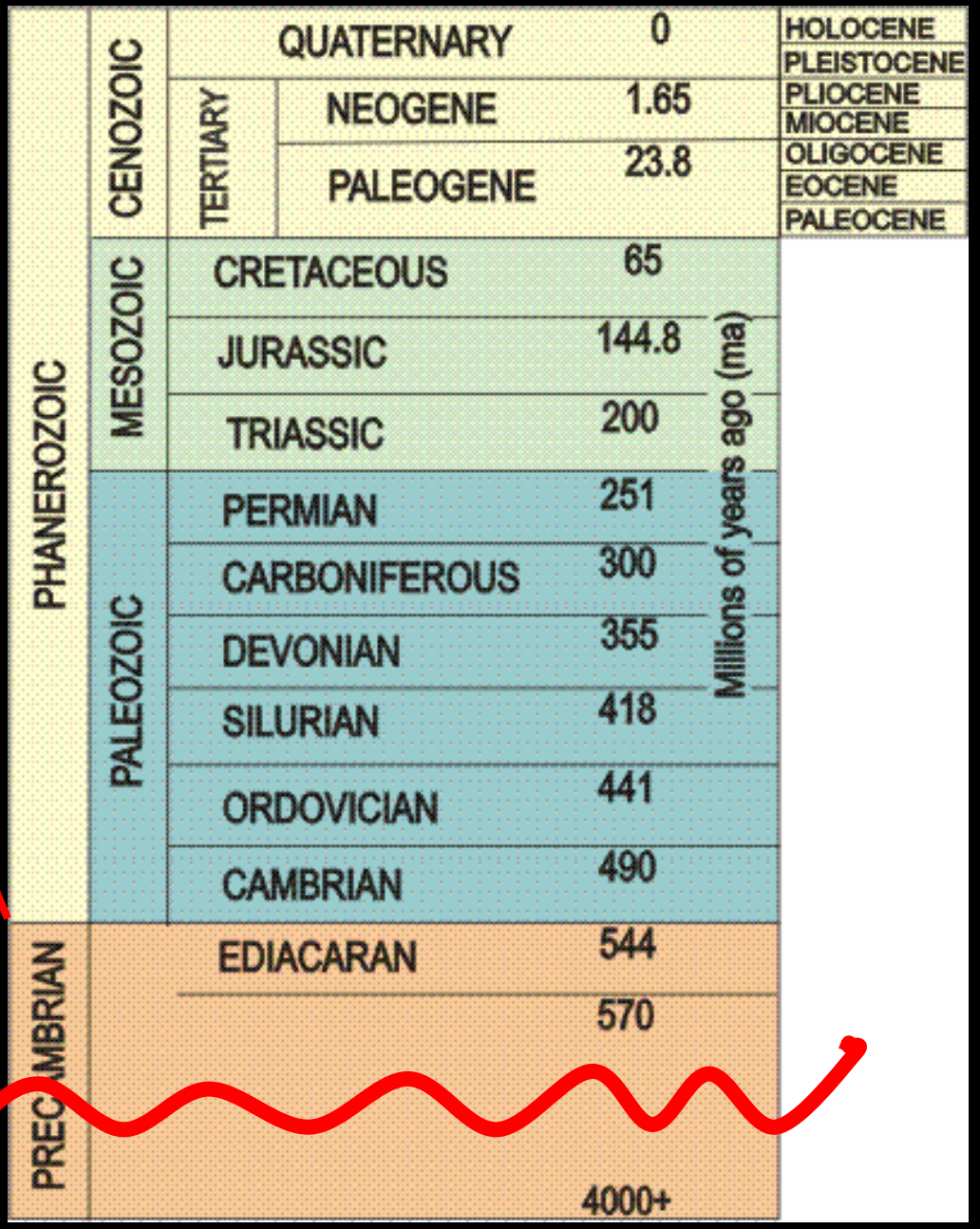
Geologic Time



Geologic Time:
"Deep time problems"

- The Faint Young Sun (and climate homeostasis

- Snowball Earth



Geologic Time:
“Snow ball earth”

Setting the stage:
“different boundary conditions”

- Neoproterozoic, 750 to 550 ma
  (ma = million years ago)
- faint young sun, ~6% fainter

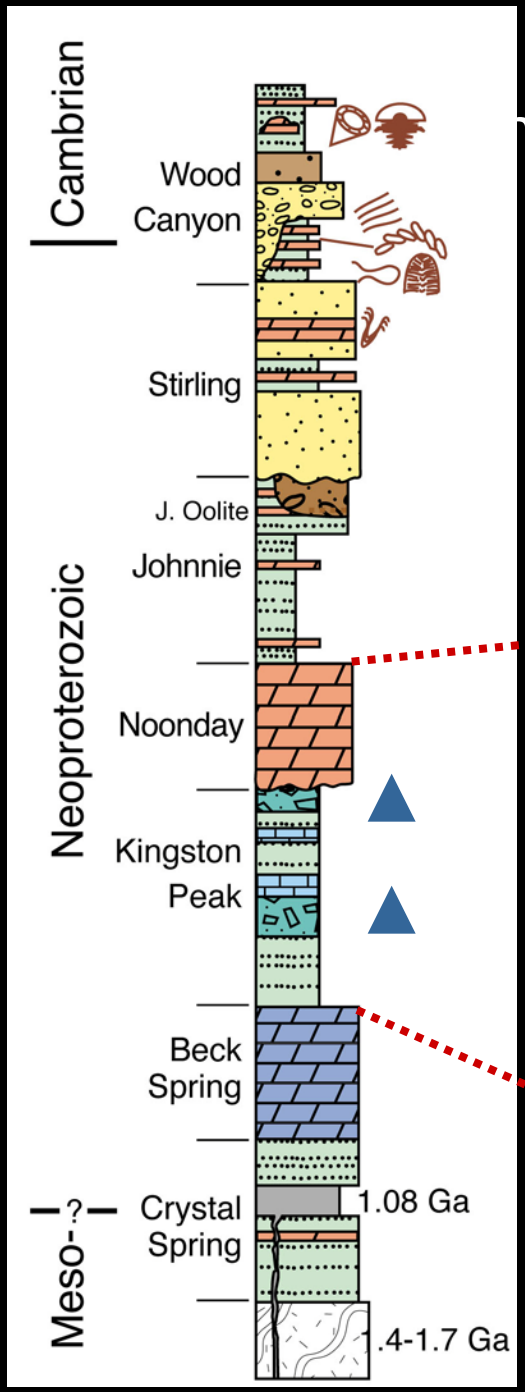
- more continents at low latitudes

- no multicellular life, no land plants:
  precedes the Cambrian explosion

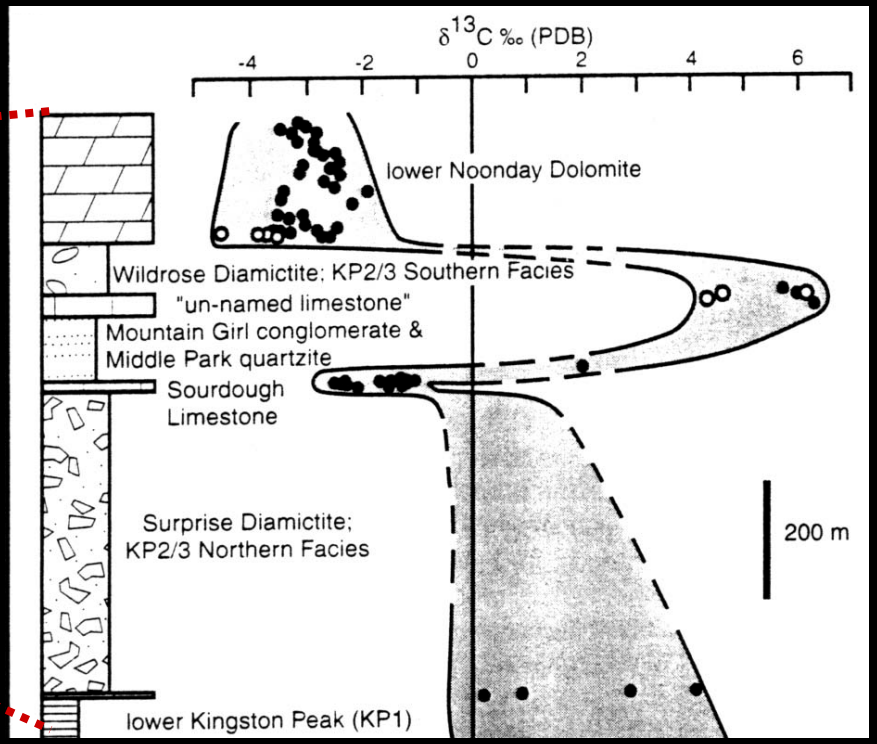
Geologic Time:
“Snow ball earth”

Paleo-data

Death Valley Rock record



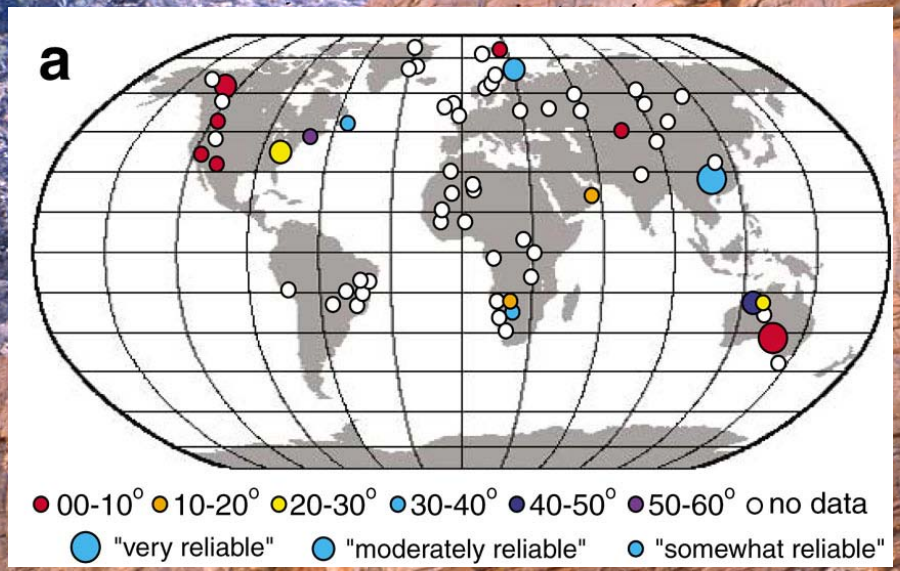
"2 diamictites, 2 excursions, 2 glaciation



Prave, 1999

Geologic Time:
“Snow ball earth”

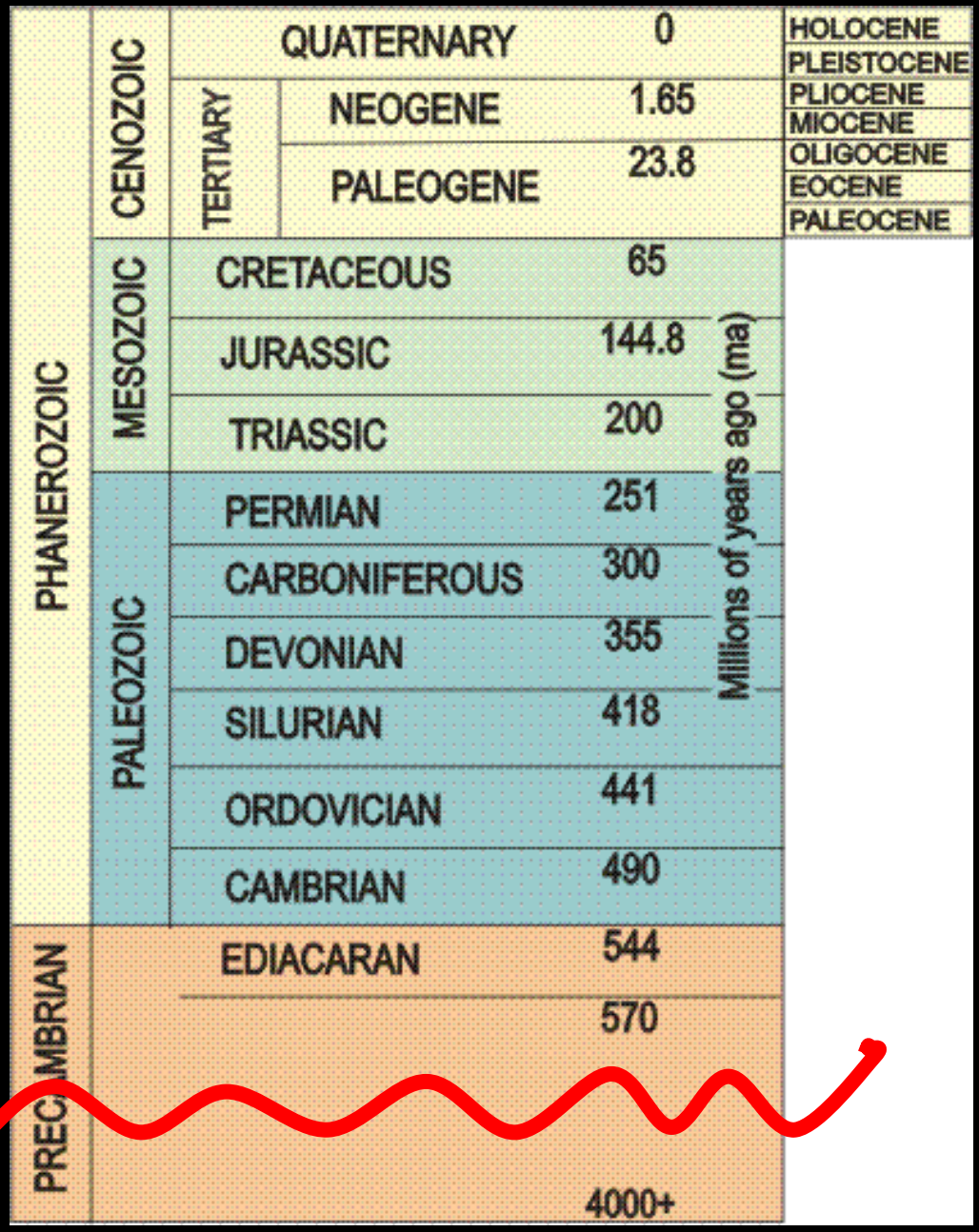
Paleo-data



Global distribution

Geologic Time:
"Deep time problems"

- Warm ("Equable) climates



Geologic Time:
“Warm climates”

Setting the stage:
“different boundary conditions”

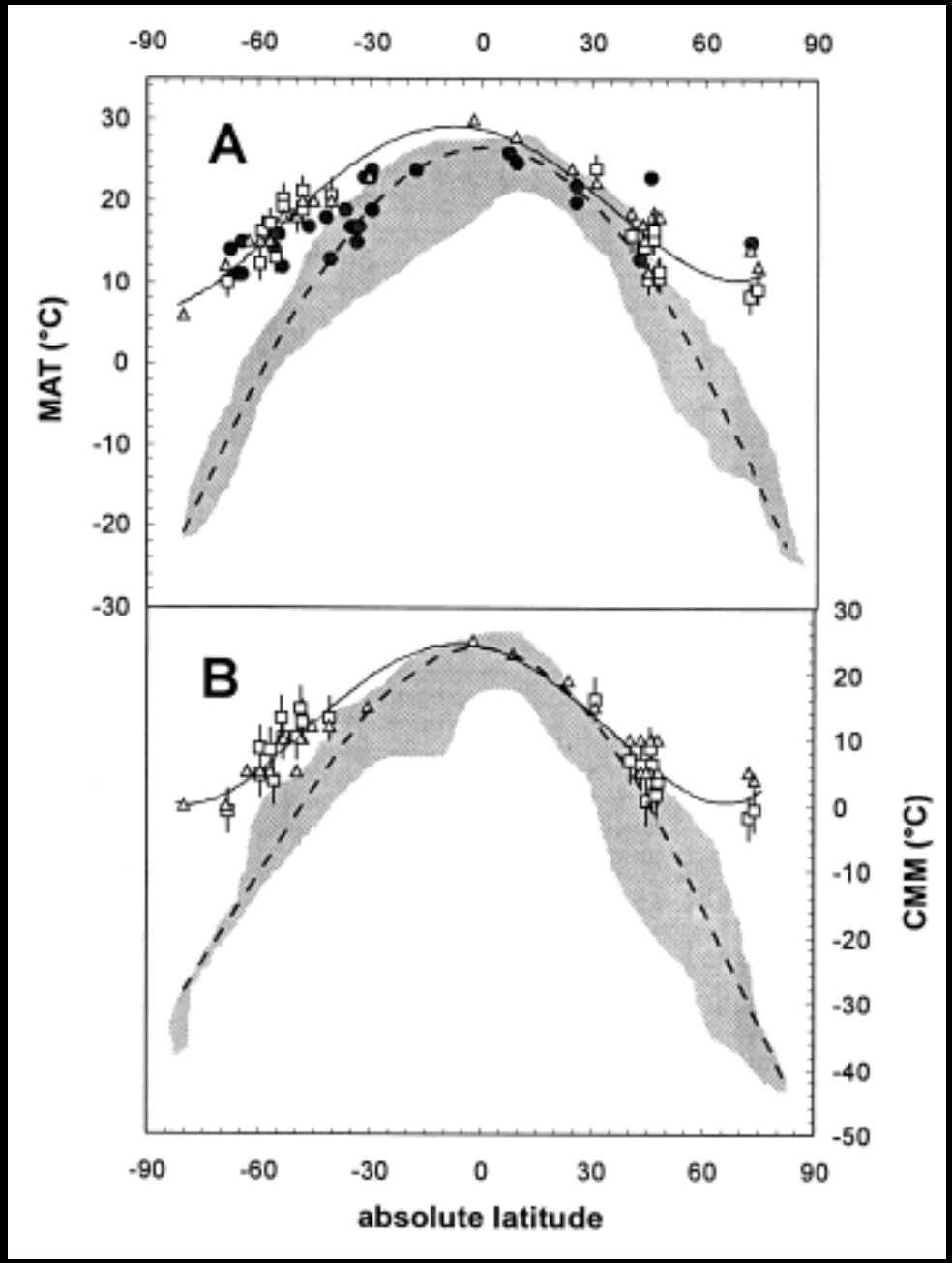
- Paleozoic, Mesozoic, start of the Cenozic
- Often modeling focuses on: Late Cretaceous and Early Paleogene

(~100-35 MaYr)

- continents migrated so there are now polar continents

An example of an equable climate: Eocene Temperature

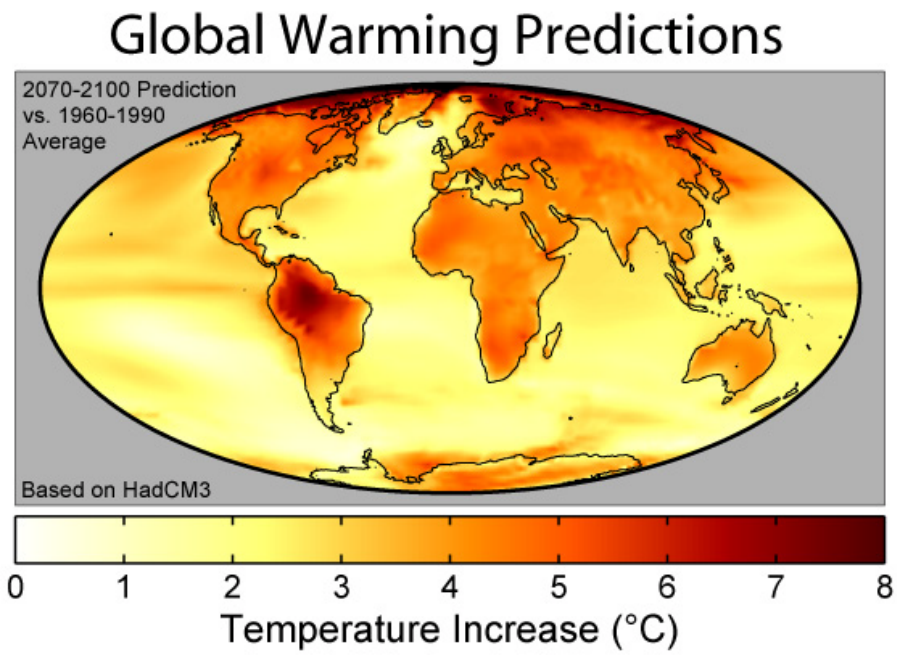
- Modern land temp.
- Eocene sea surface temp.
- Eocene Model
- Eocene Model

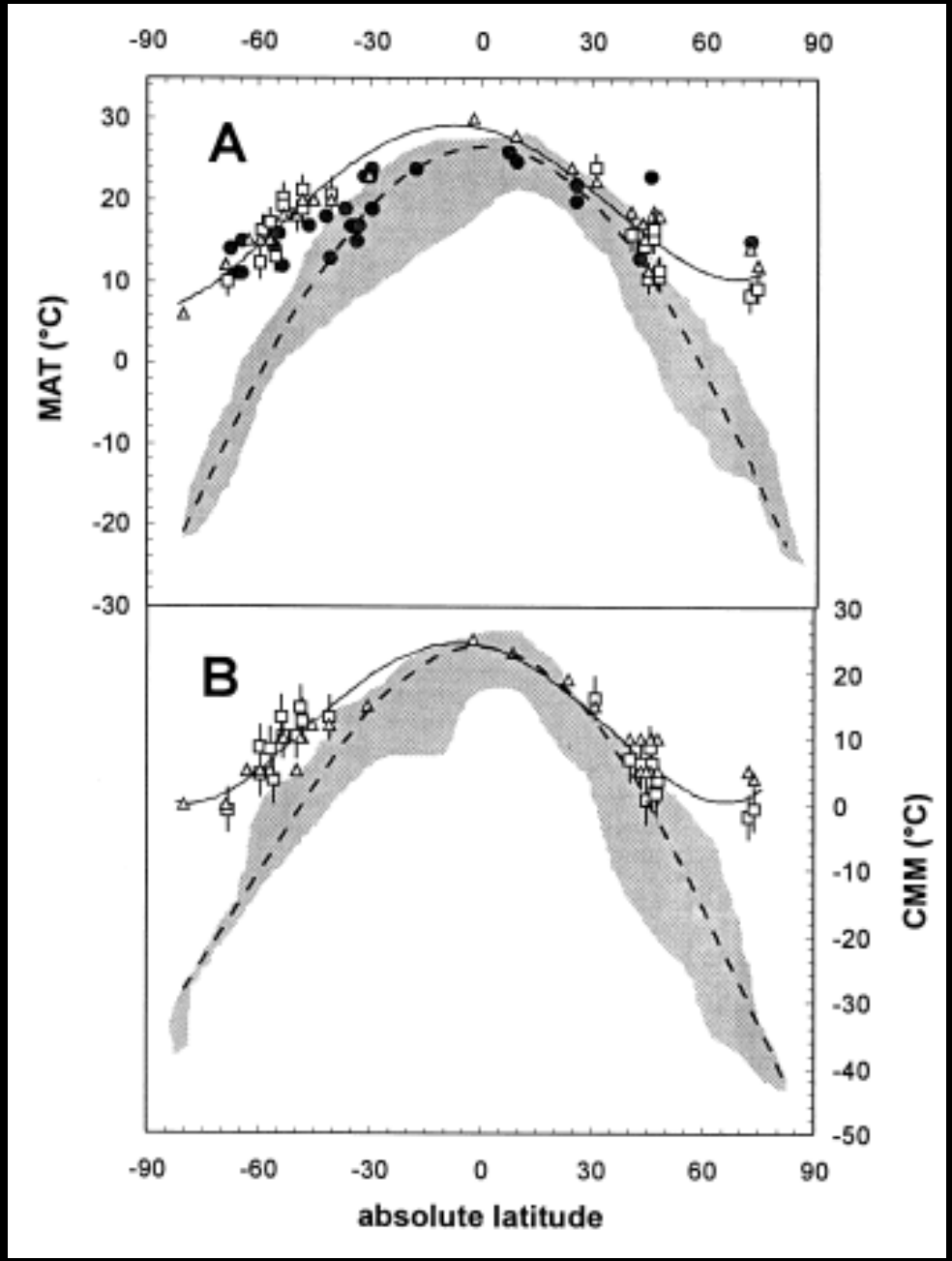


[Greenwood and Wing, 1995]

An example of an equable climate: Global warming?

- Modern land temp.
- Eocene sea surface temp.
- Eocene Model
- Eocene Model

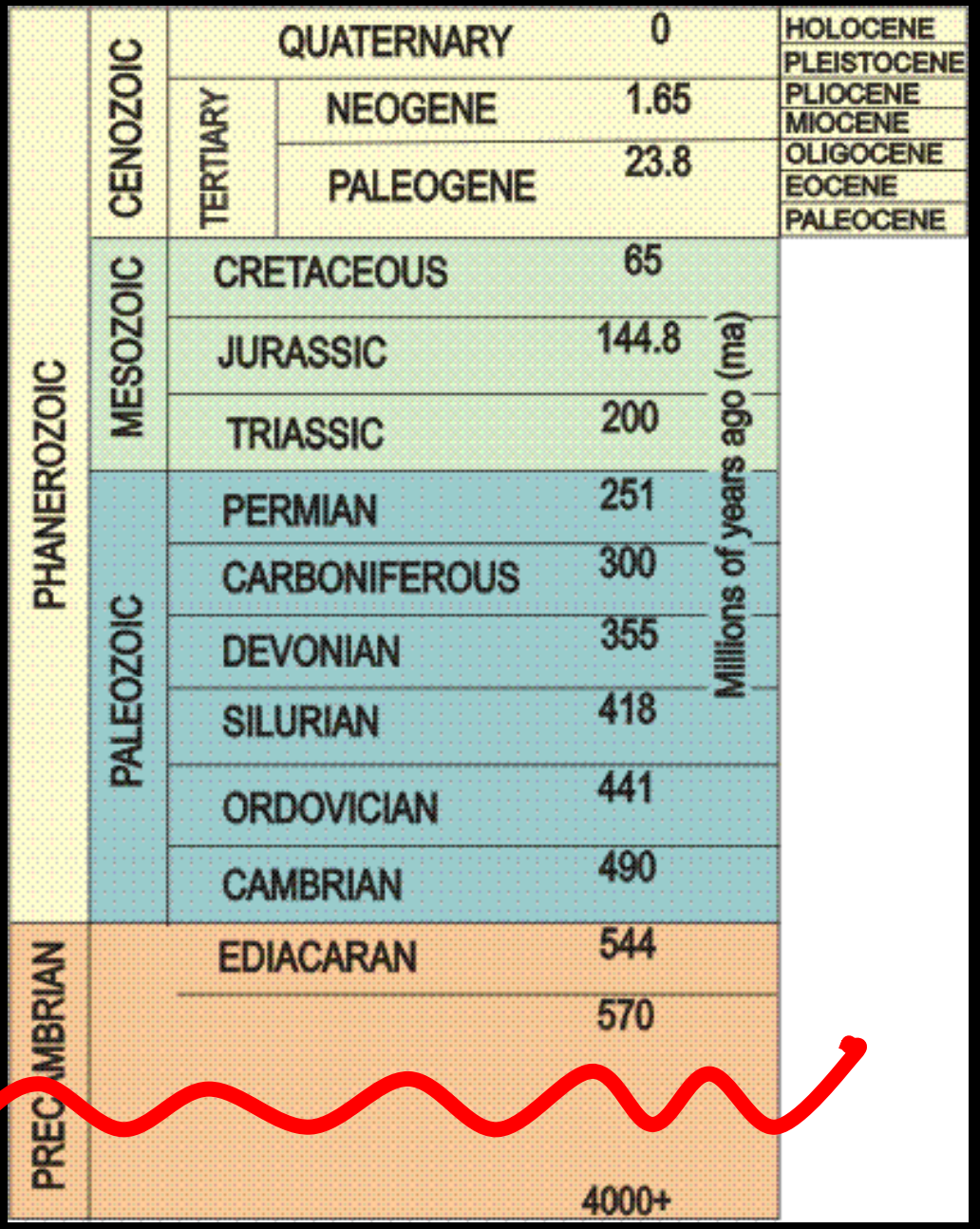




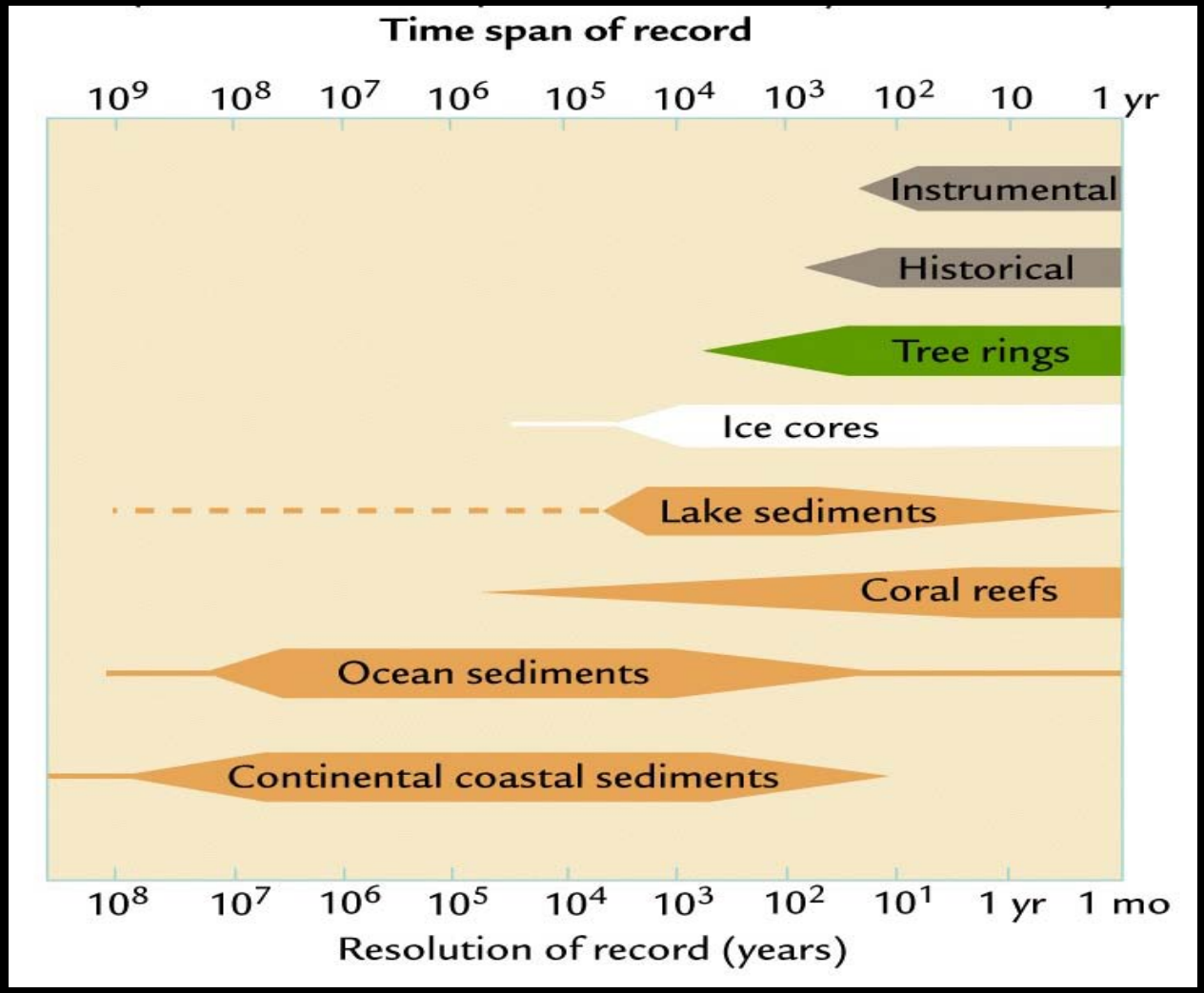
[sorry no ref!]

Geologic Time: "Cenozoic"

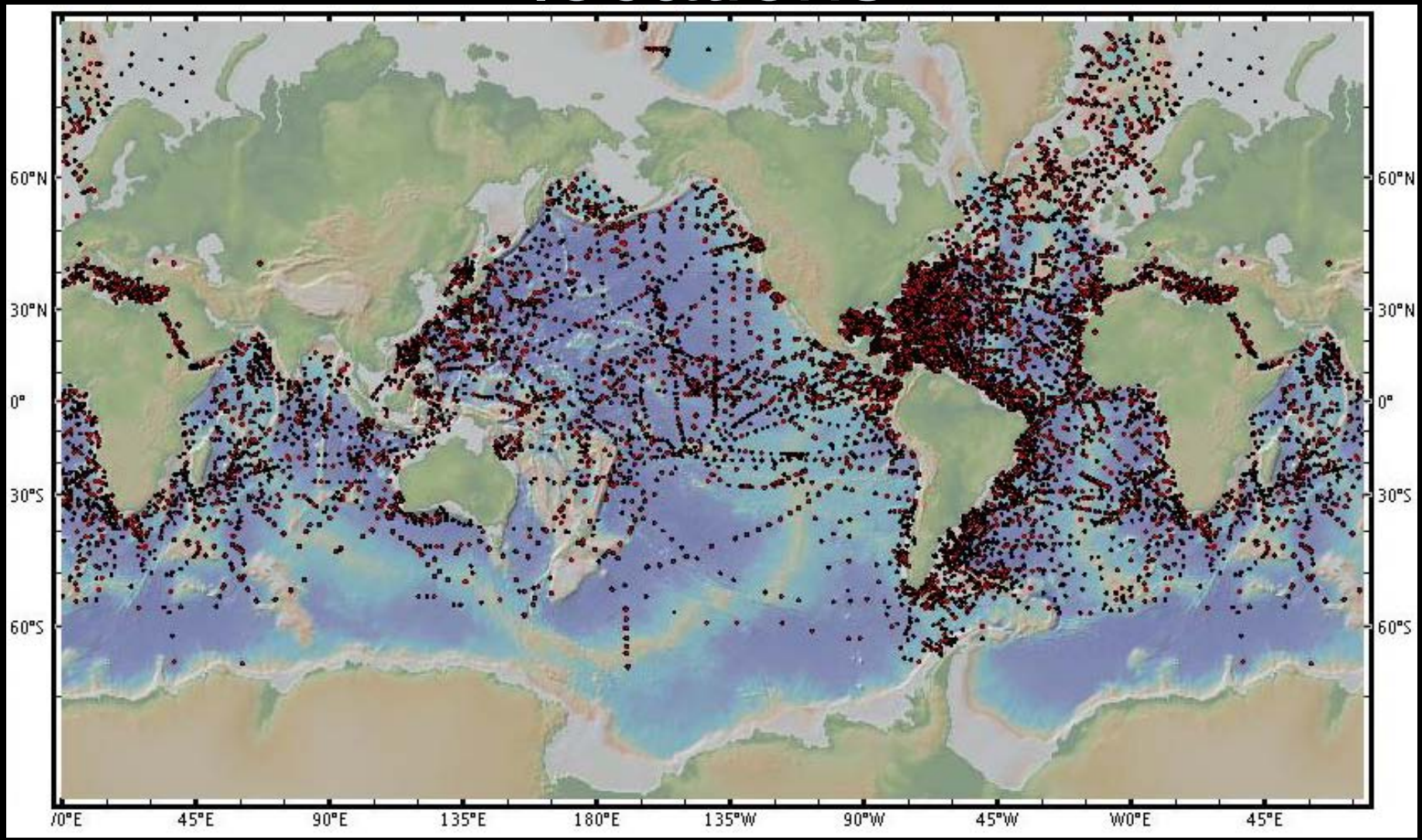
- Equable climates
- Tipping points
- Glacial cyclicity
- Abrupt climate



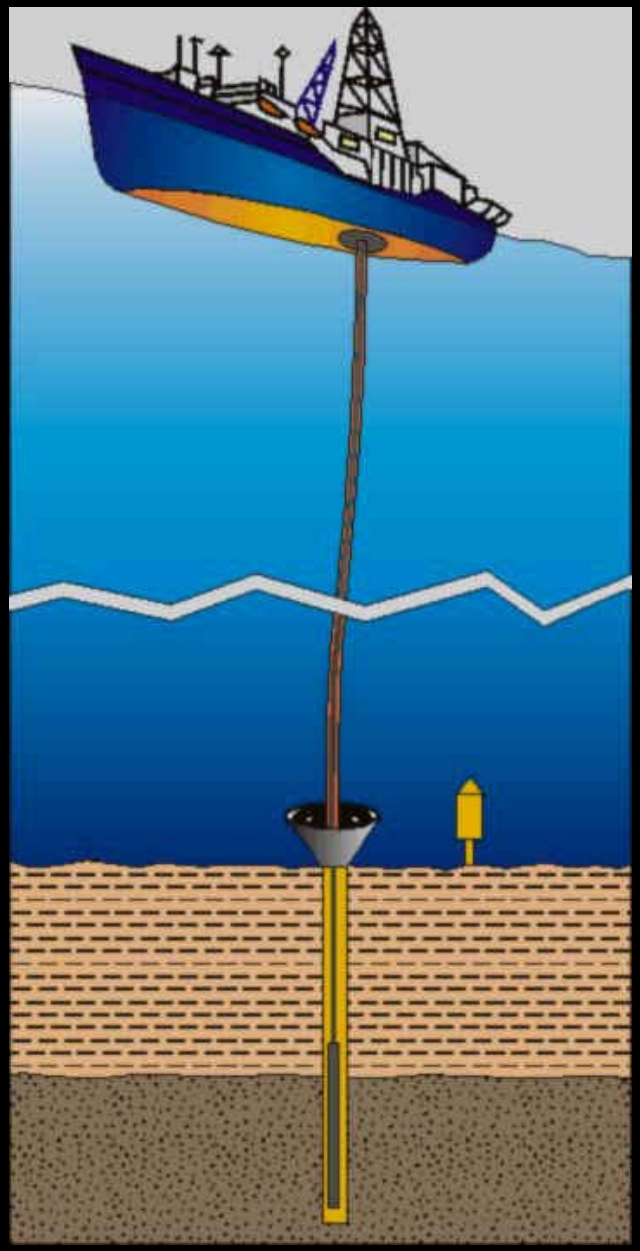
Climate archives: what records do we have?



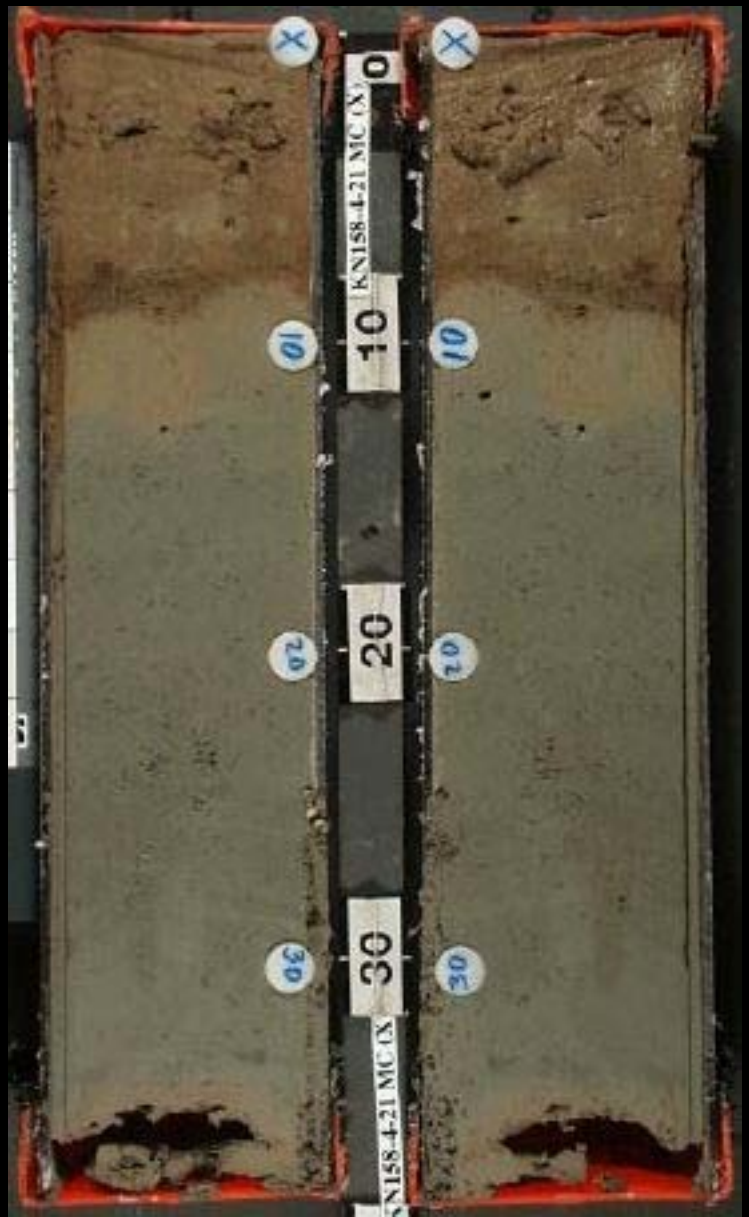
Ocean sediment-core locations



Ocean Drilling



Deep sea cores



younger

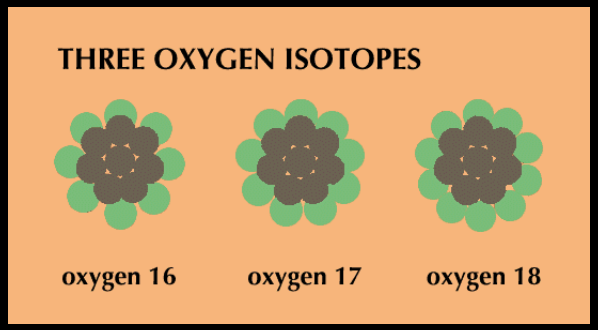
older

Ocean Plankton:
live near surface

Foraminifera

Oxygen isotopes

Forams.

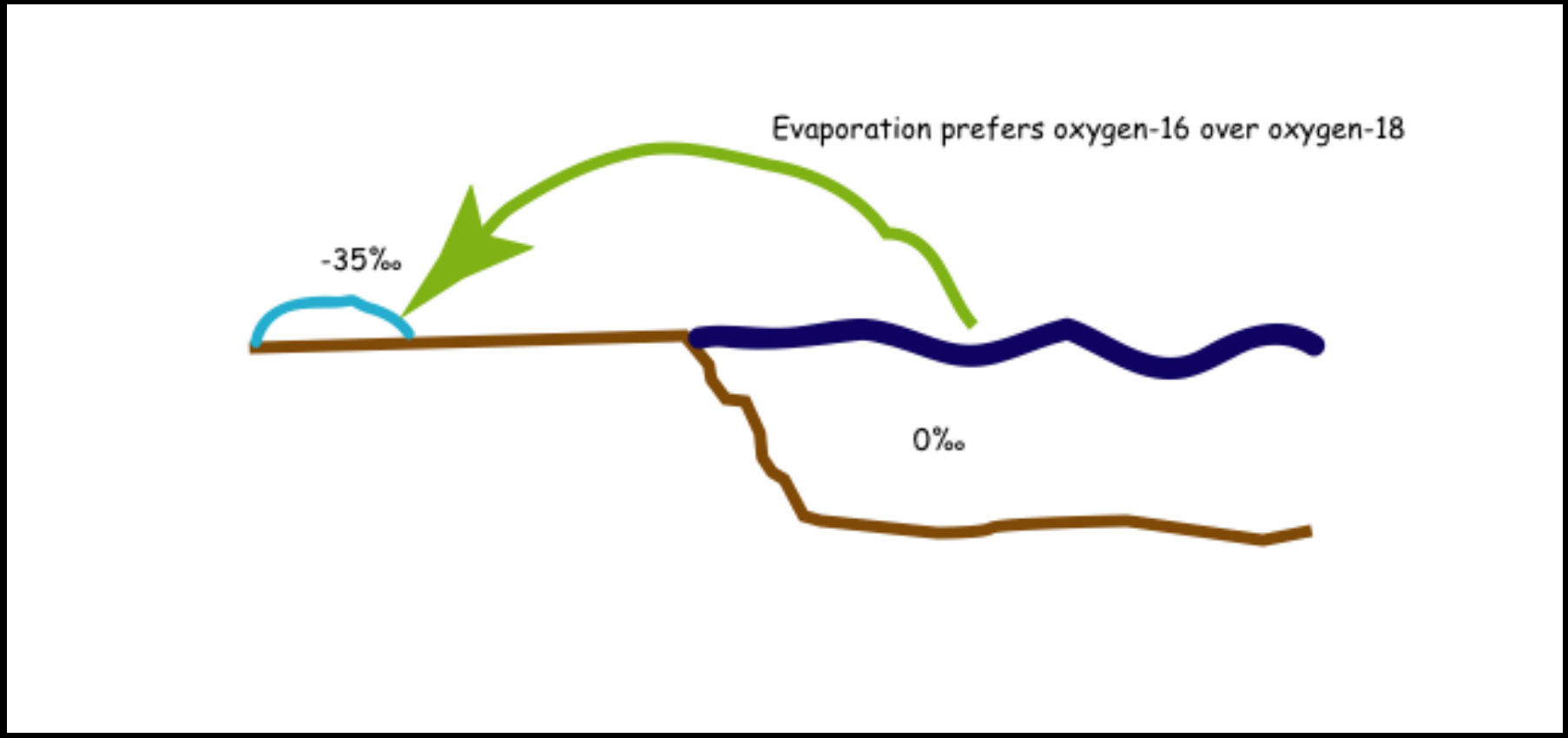


Drill

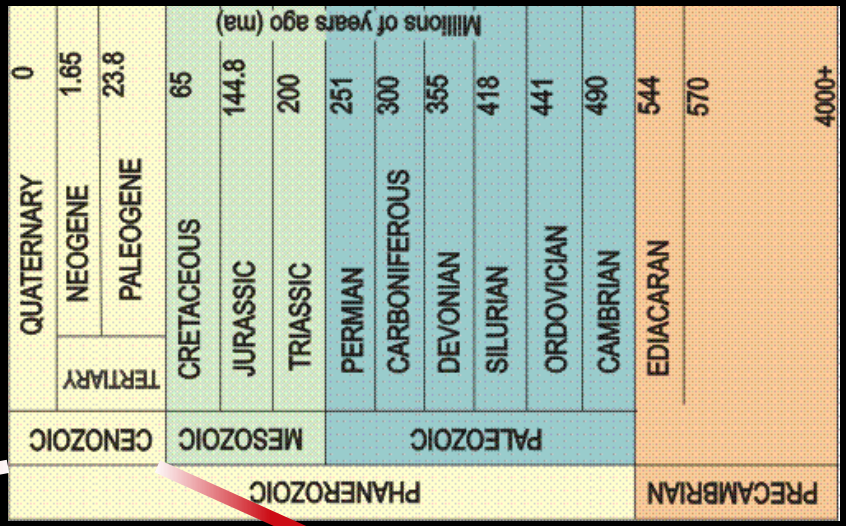
Die and Settle
To Bottom

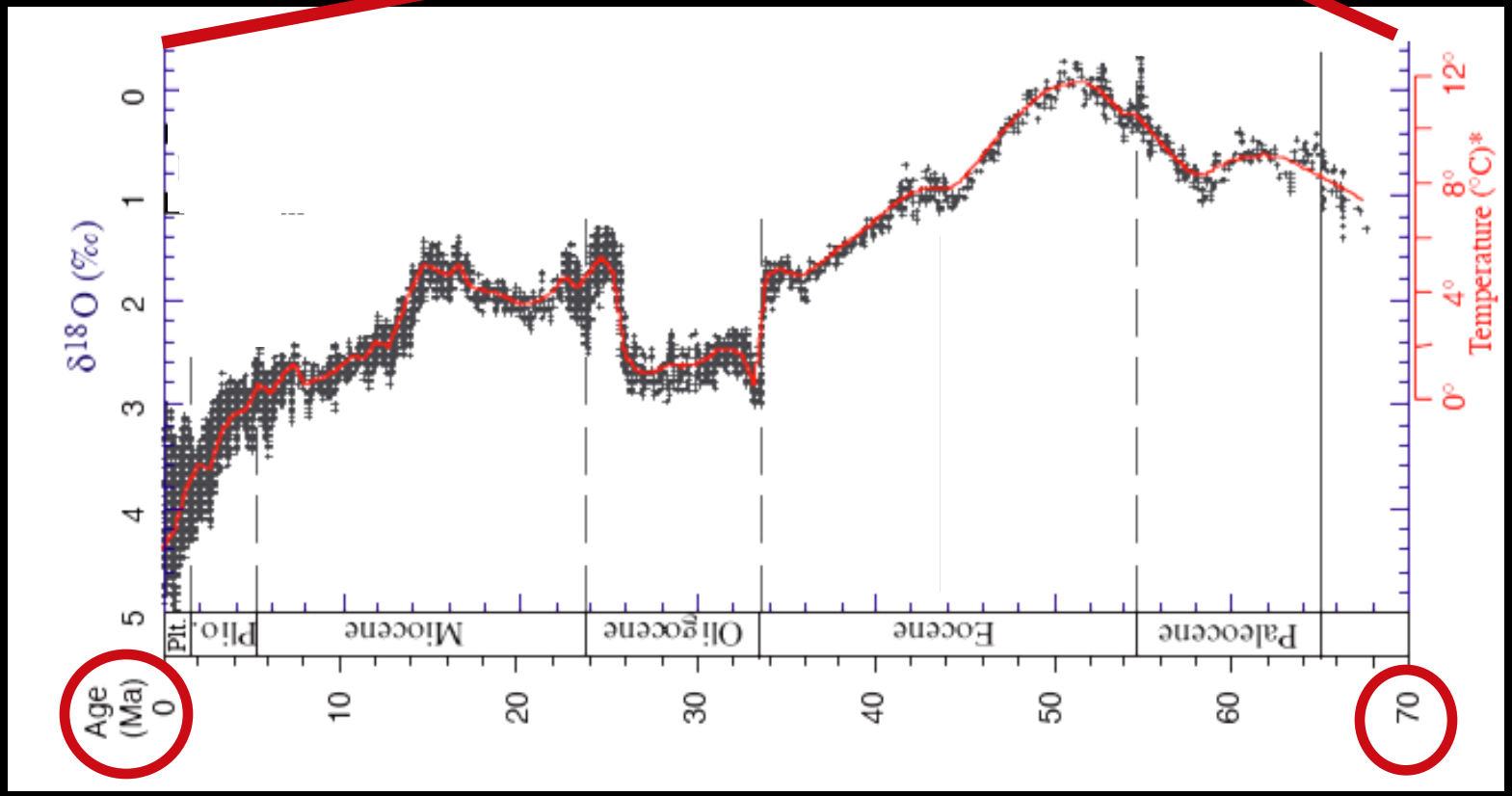
Mud!

Ice volume changes the water composition



Climate data: A 65 million year ("Cenozoic") environmental record from deep sea sediments





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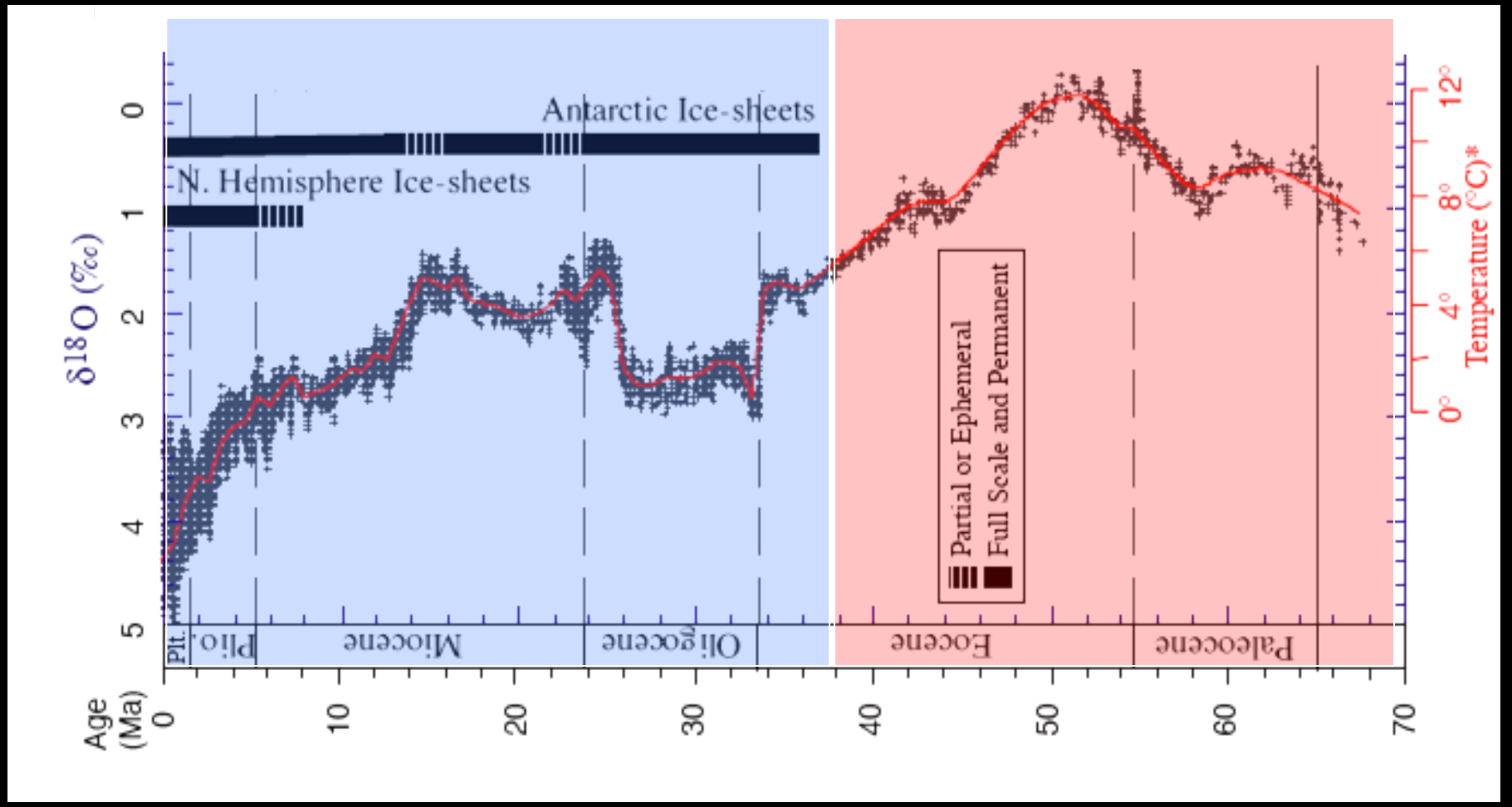

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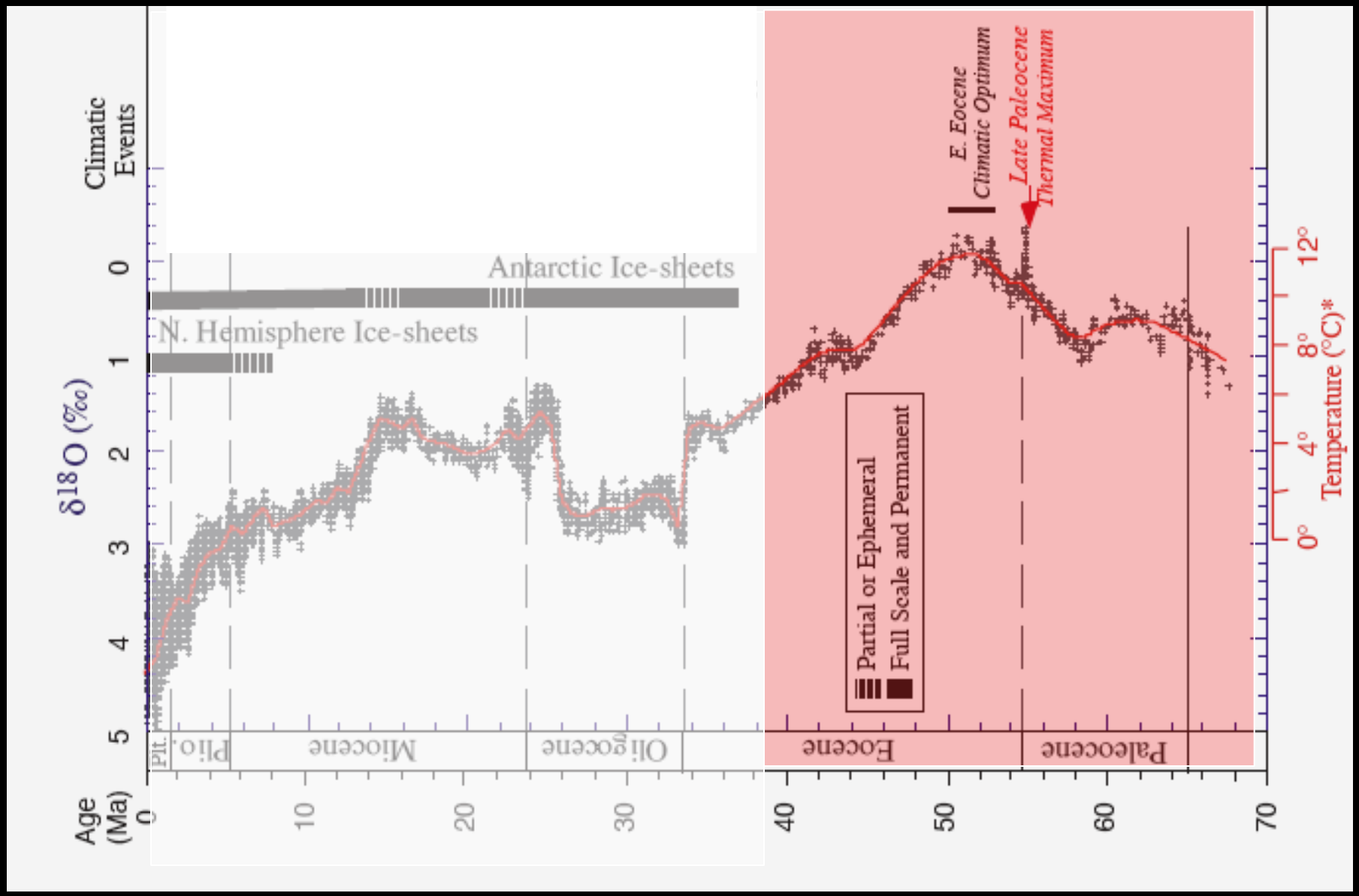

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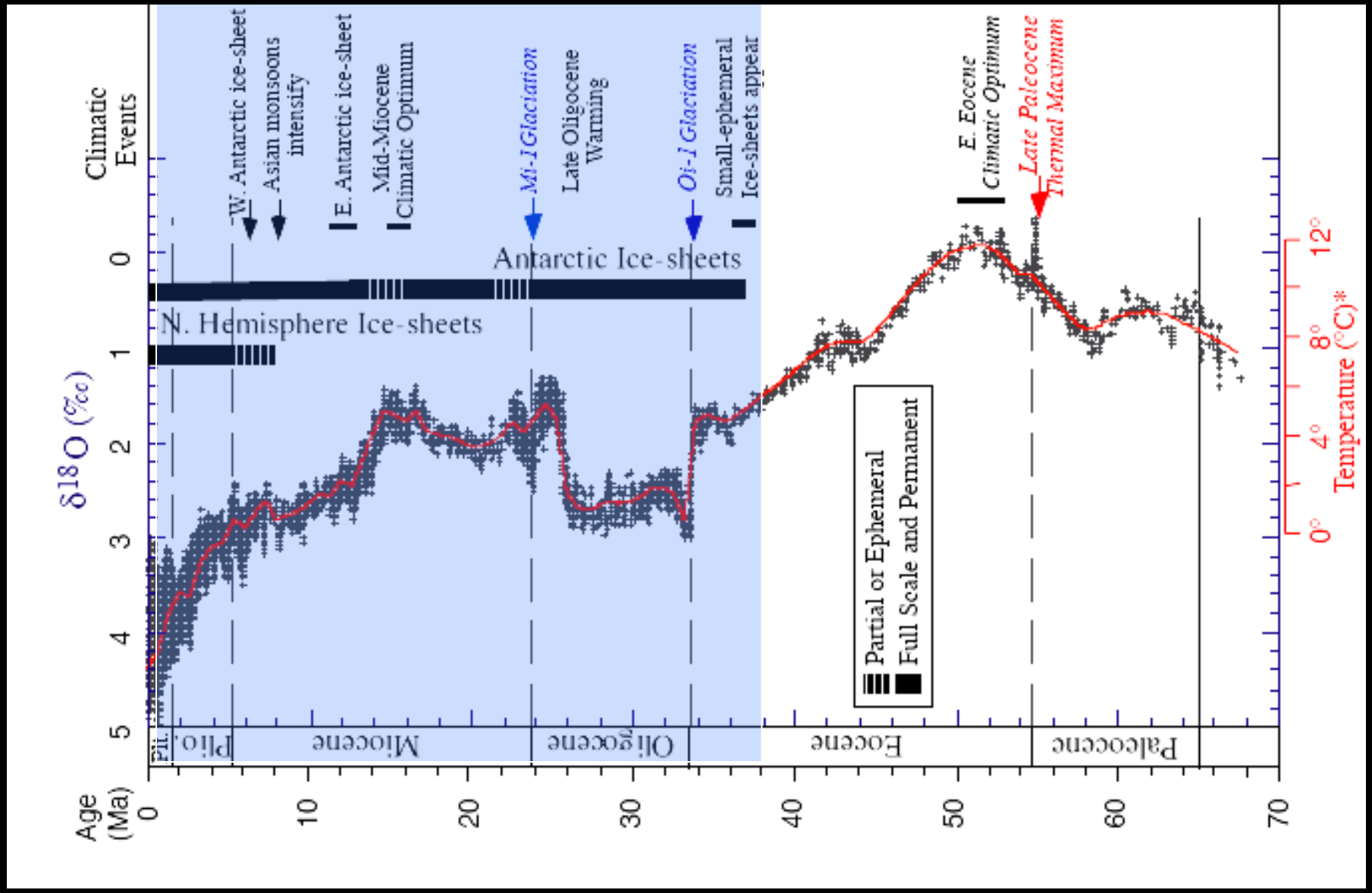
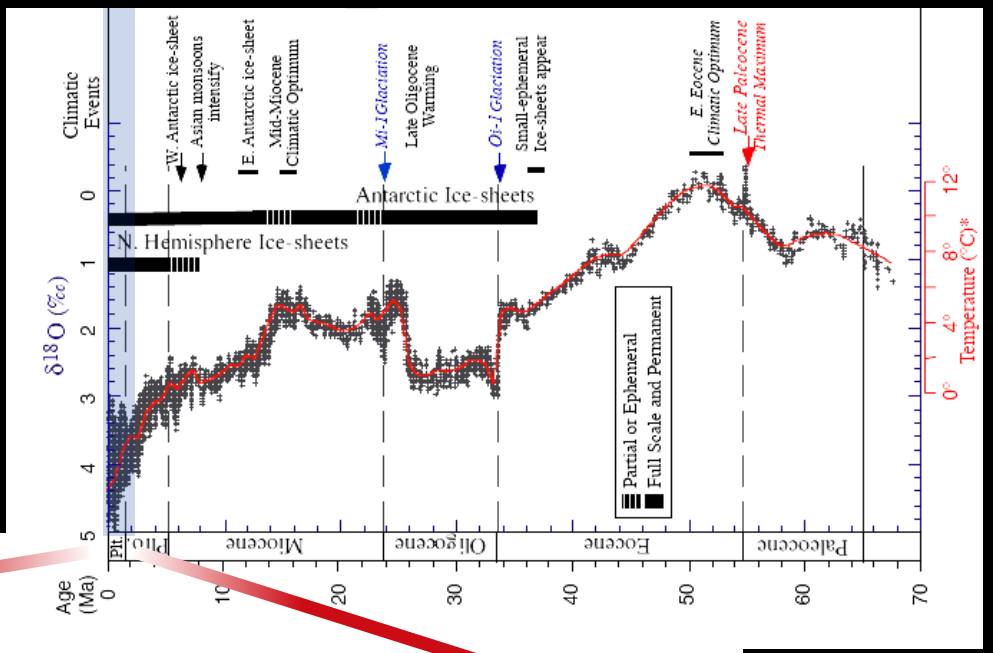
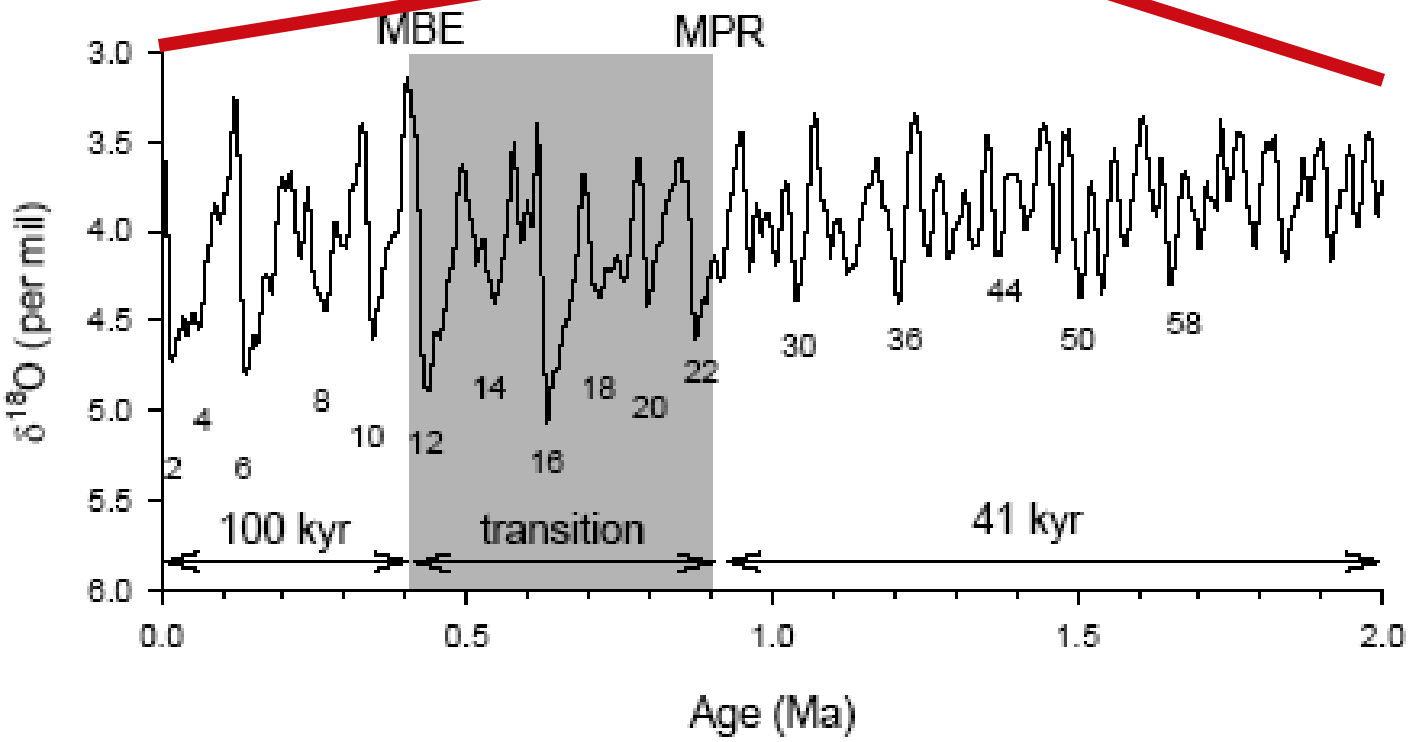
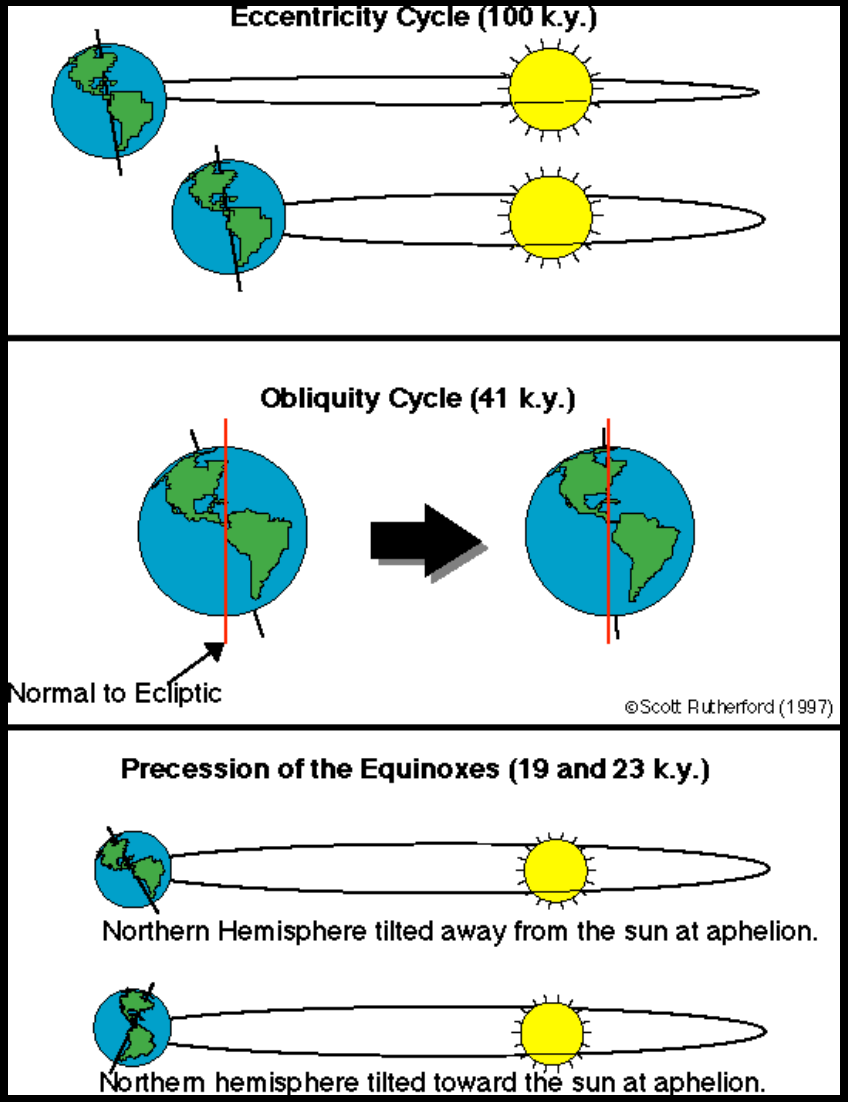


Glacial-interglacial cycles

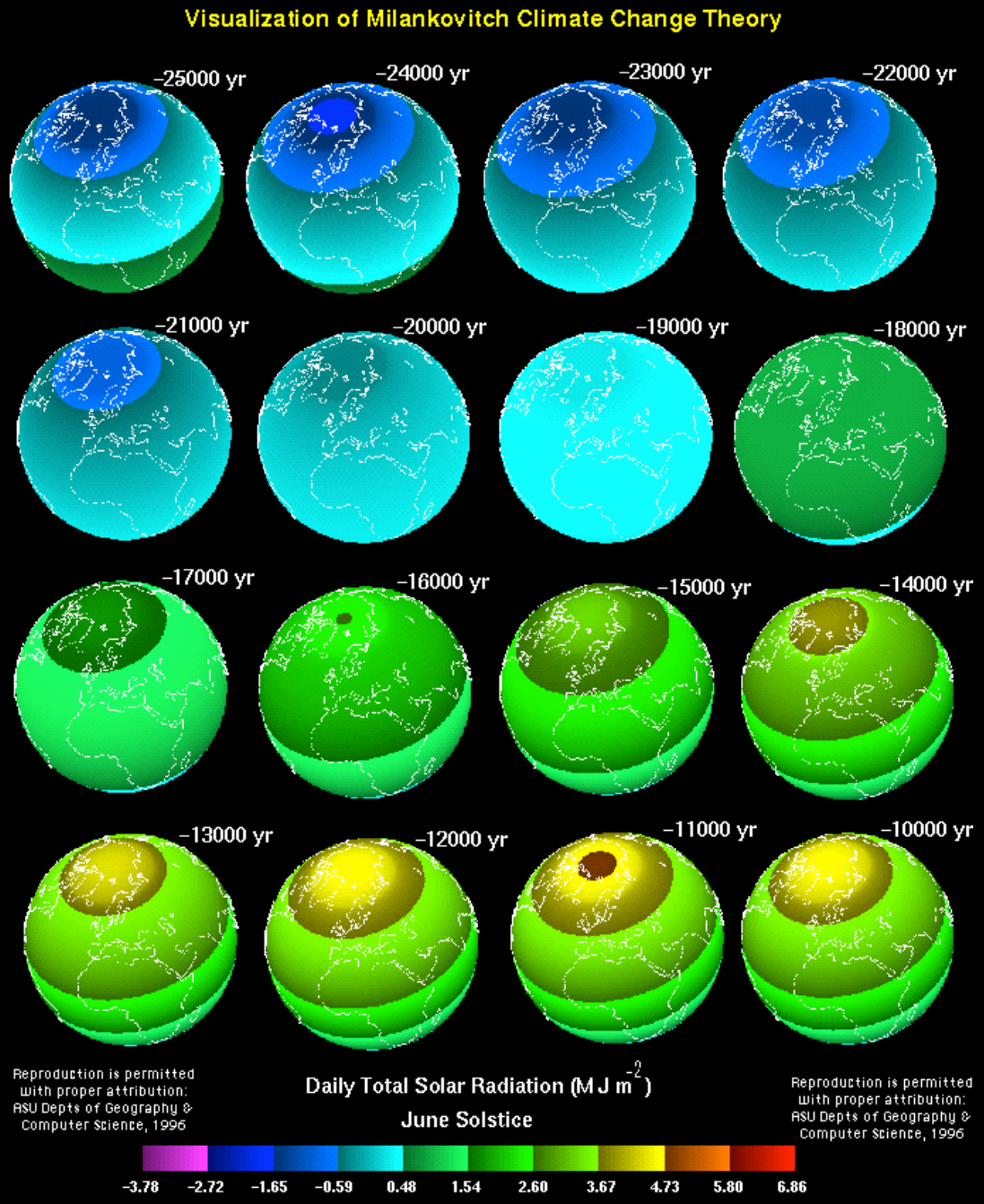




Glacial-interglacial cycles

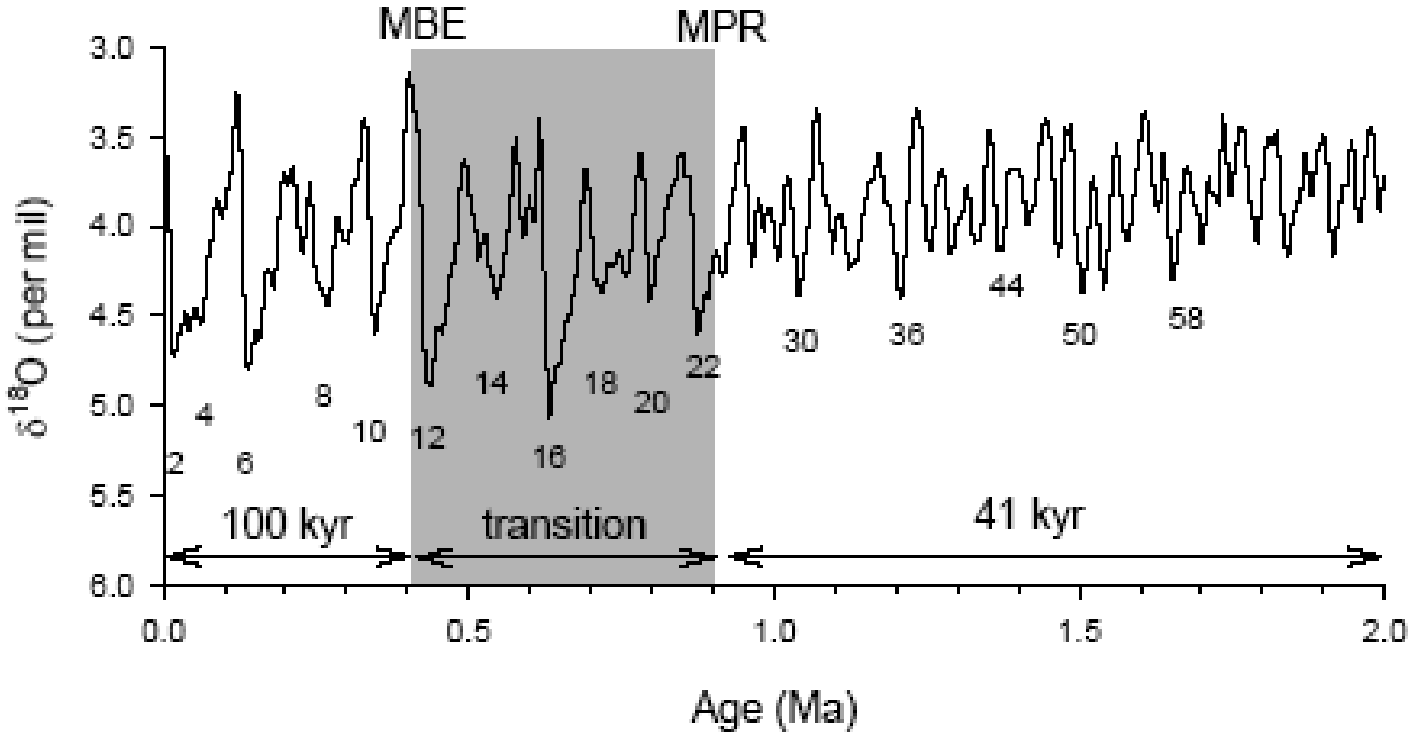


- Earth orbitals



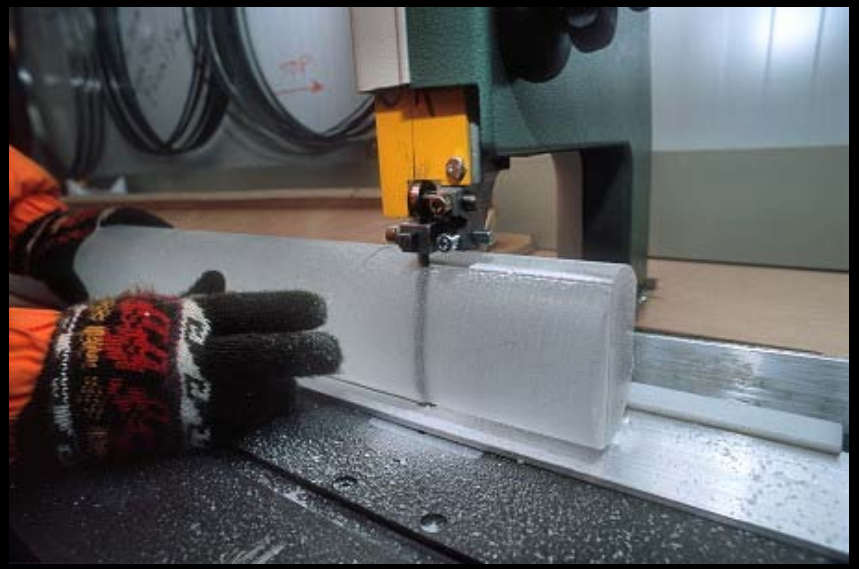
Glacial-intergla cial cycles

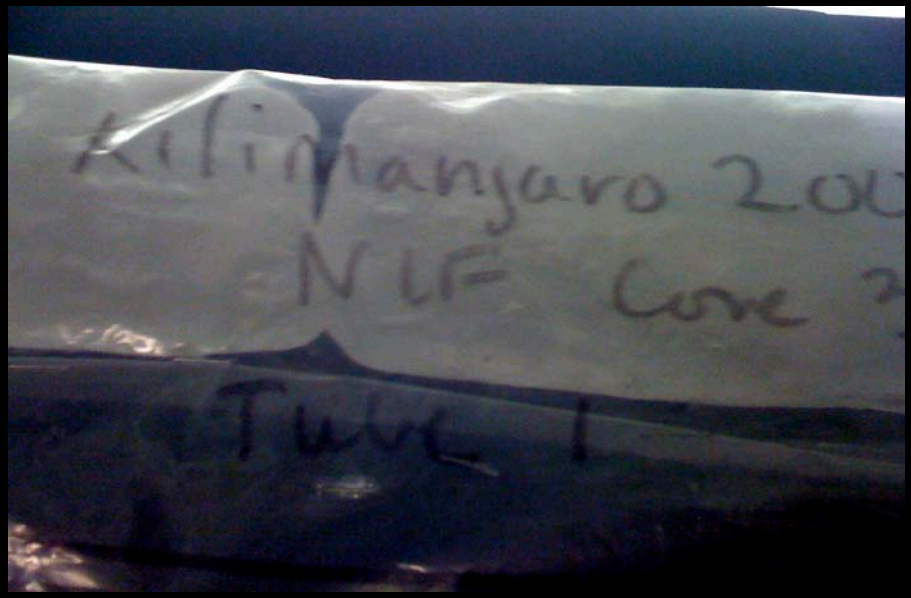
Glacial-interglacial cycles



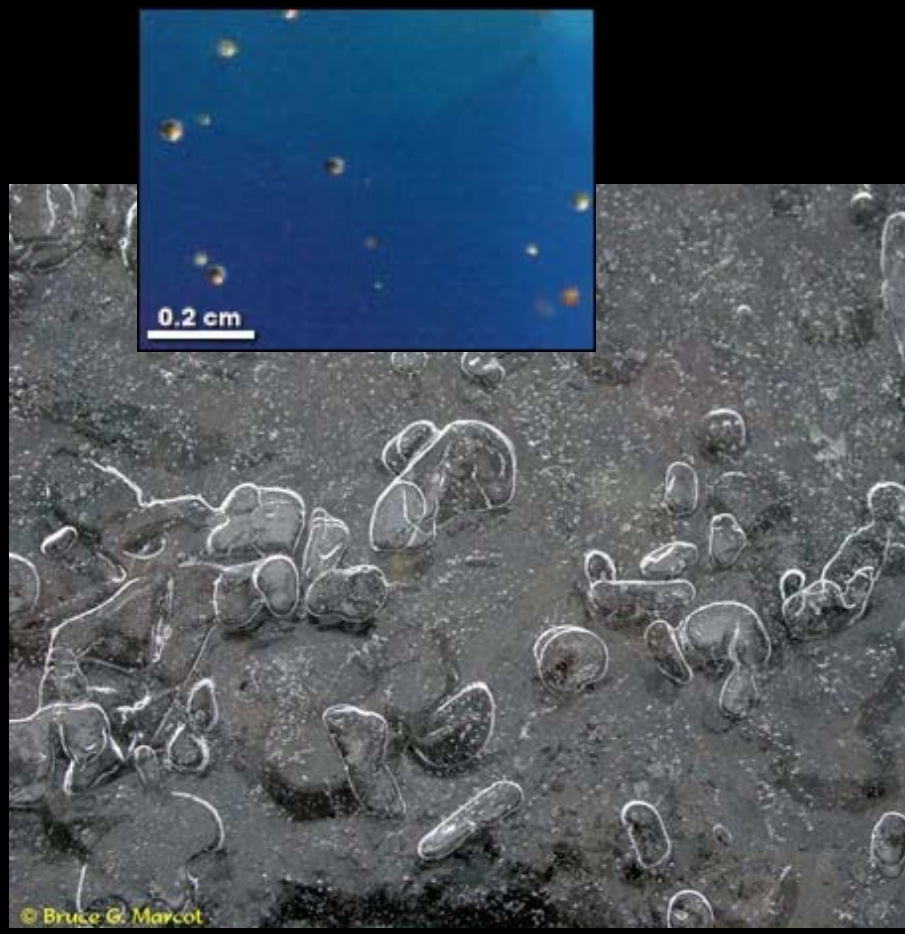
Glacial climate in ice cores

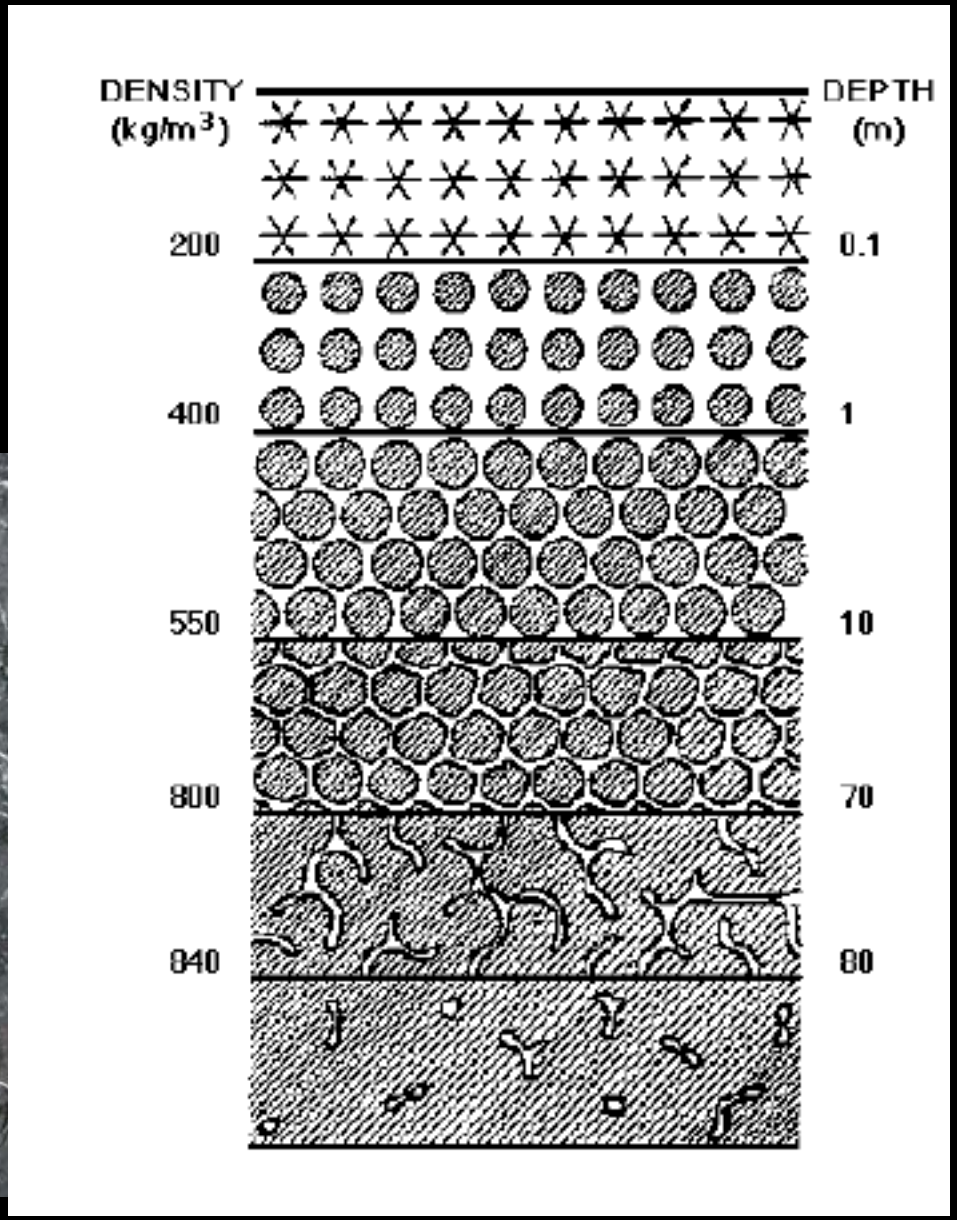
Drilling into the ice



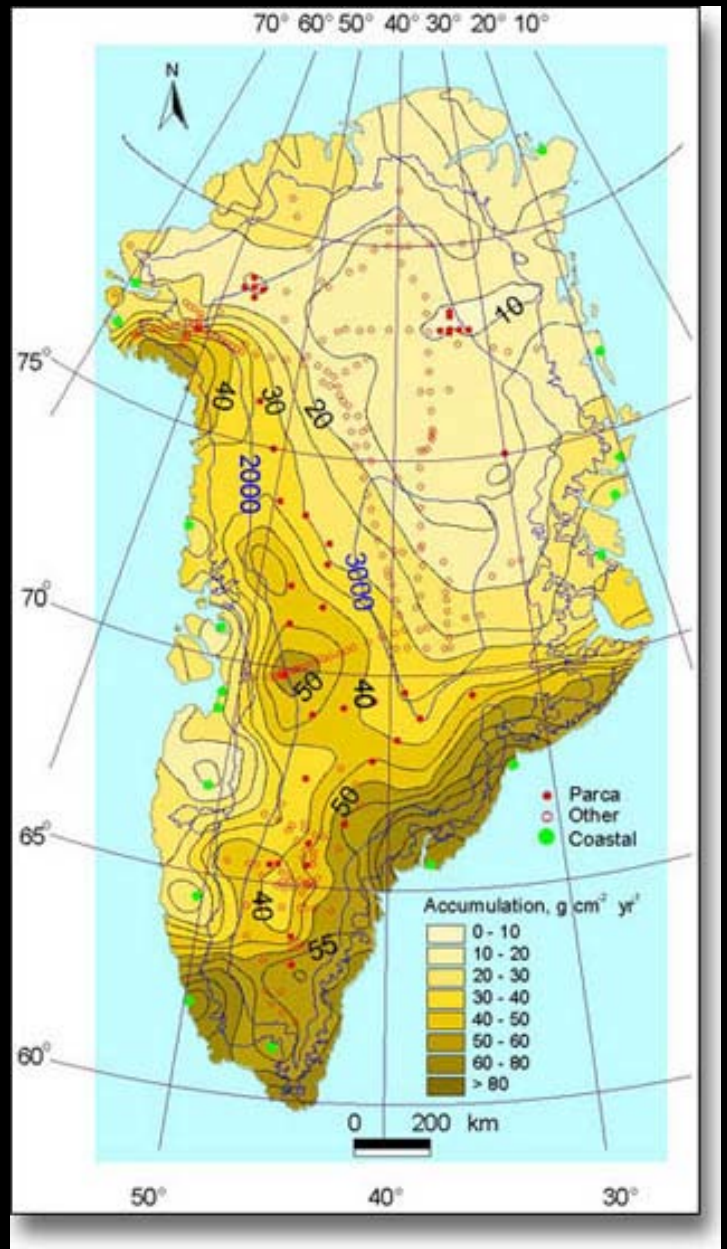


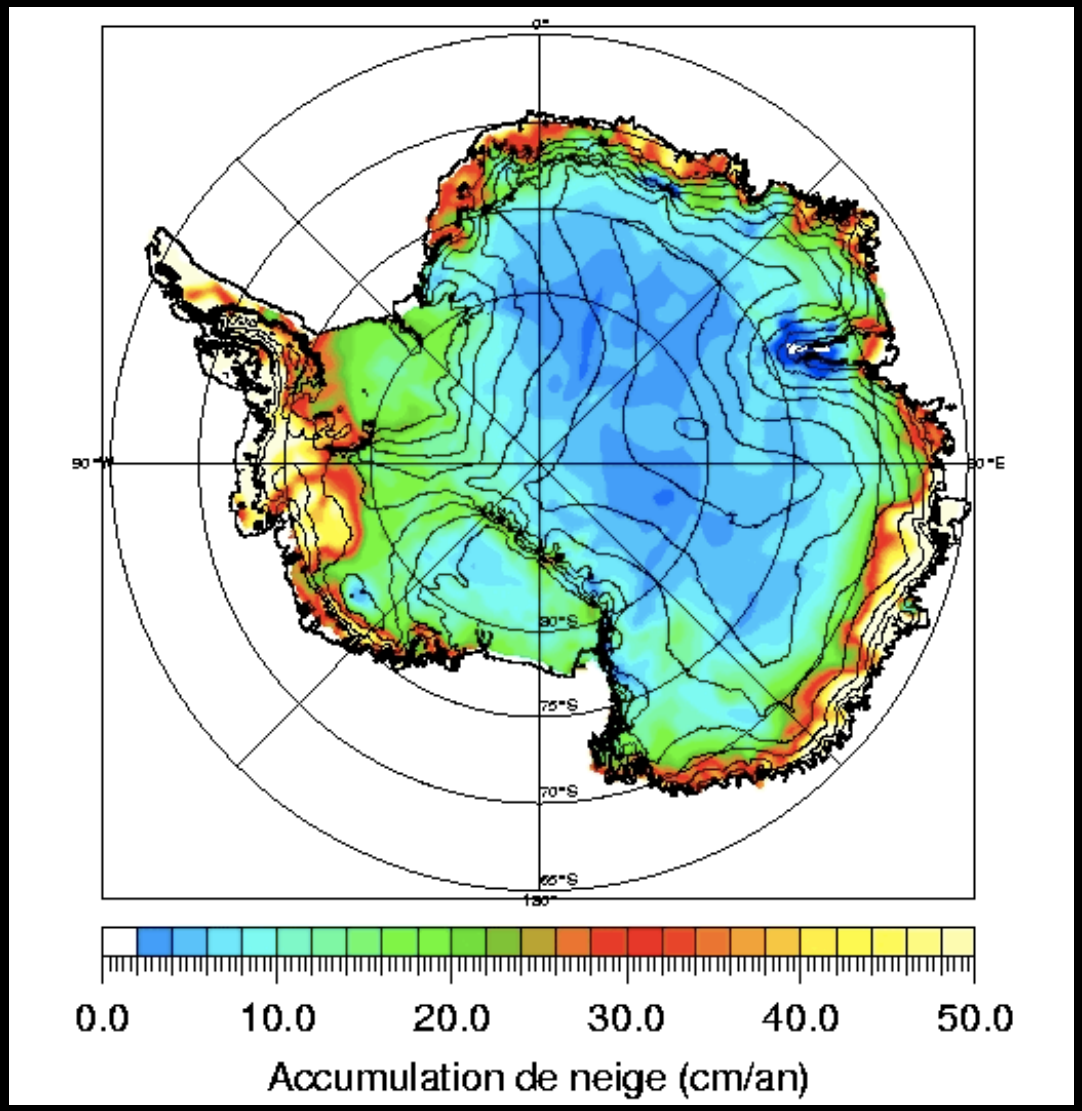
Air trapped as bubbles…



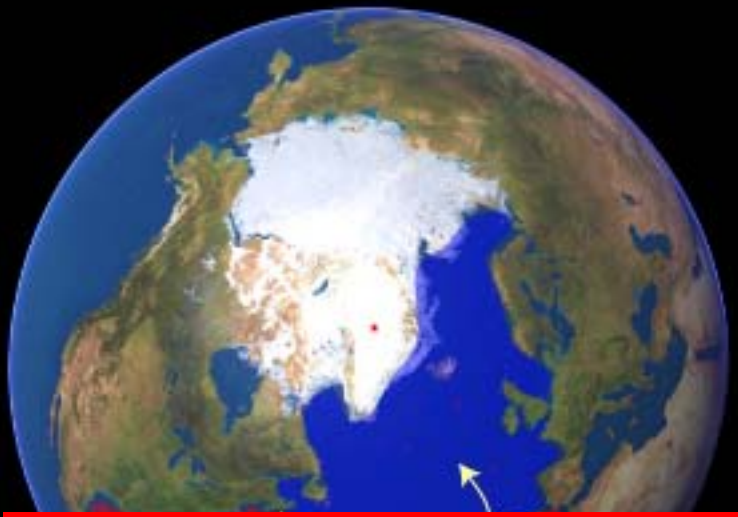


Snow Accumulation Rates

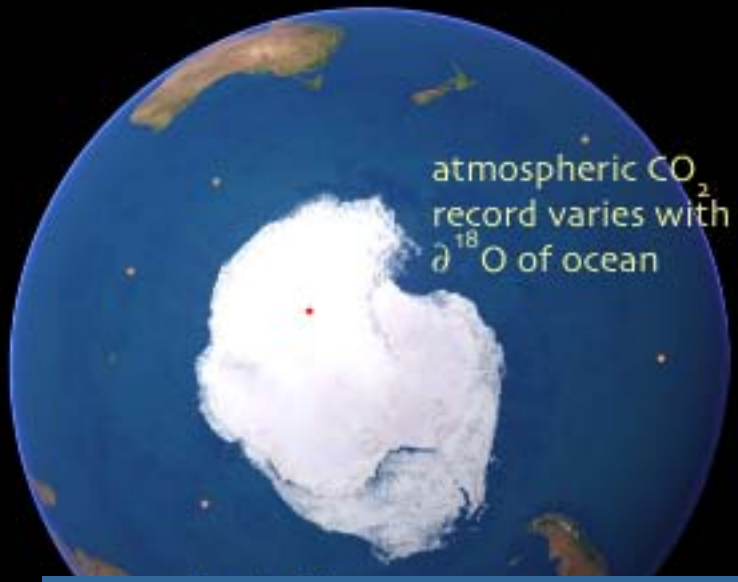




How does this manifest in the climate records?

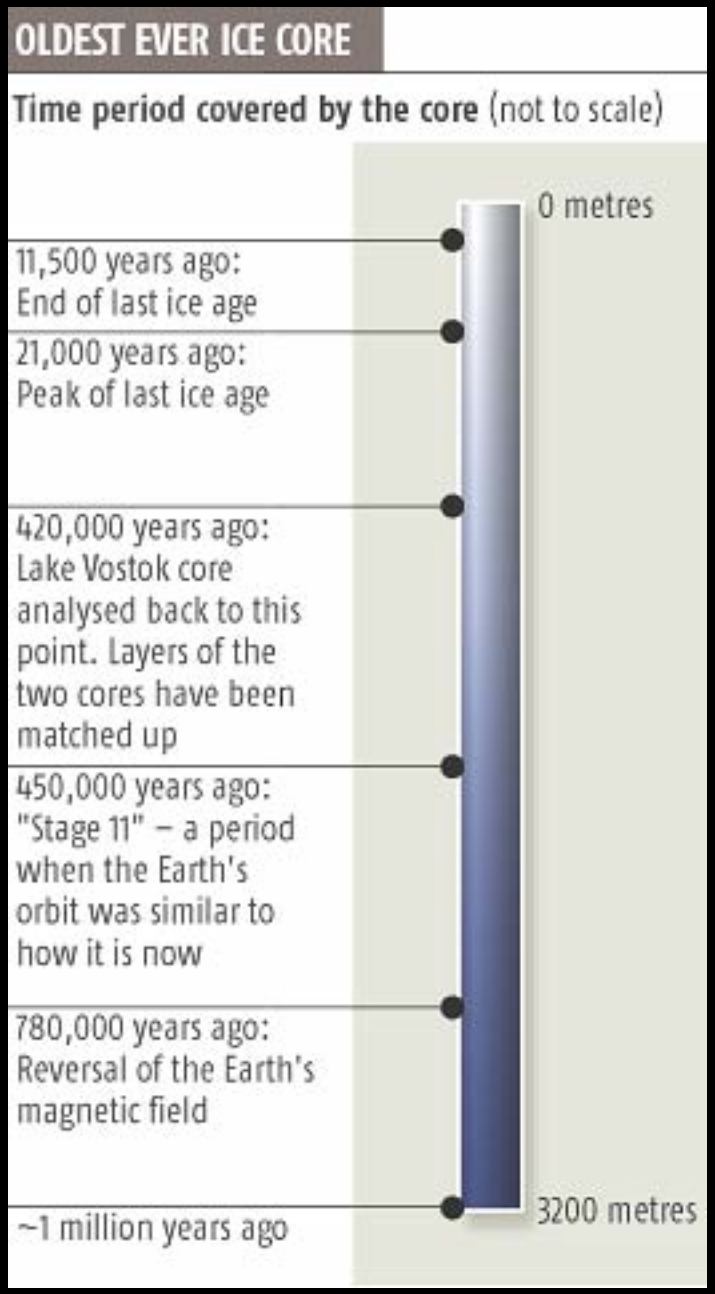


North Pole:
Shorter, high resolution records

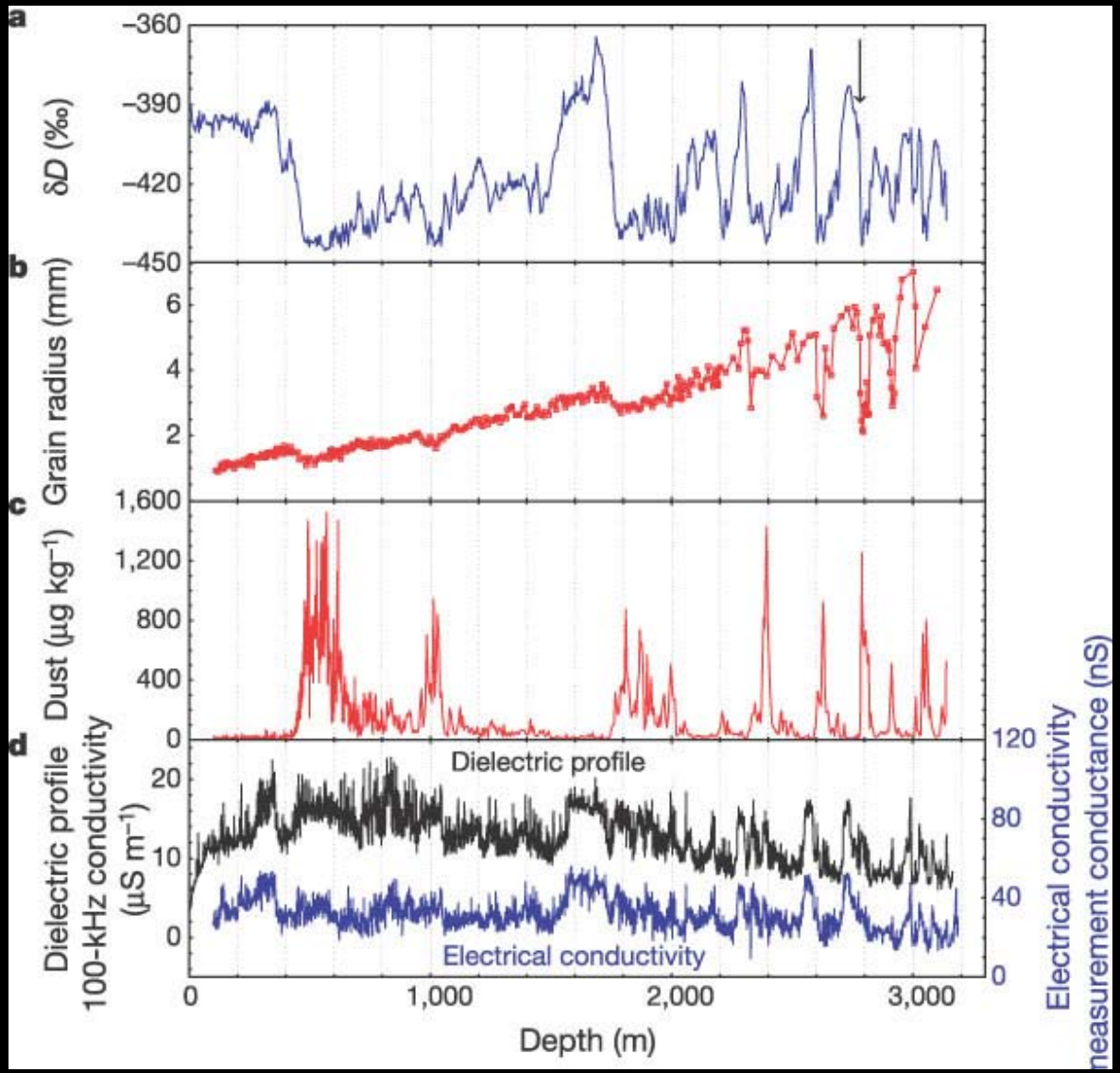


South Pole:
Longer, low resolution records

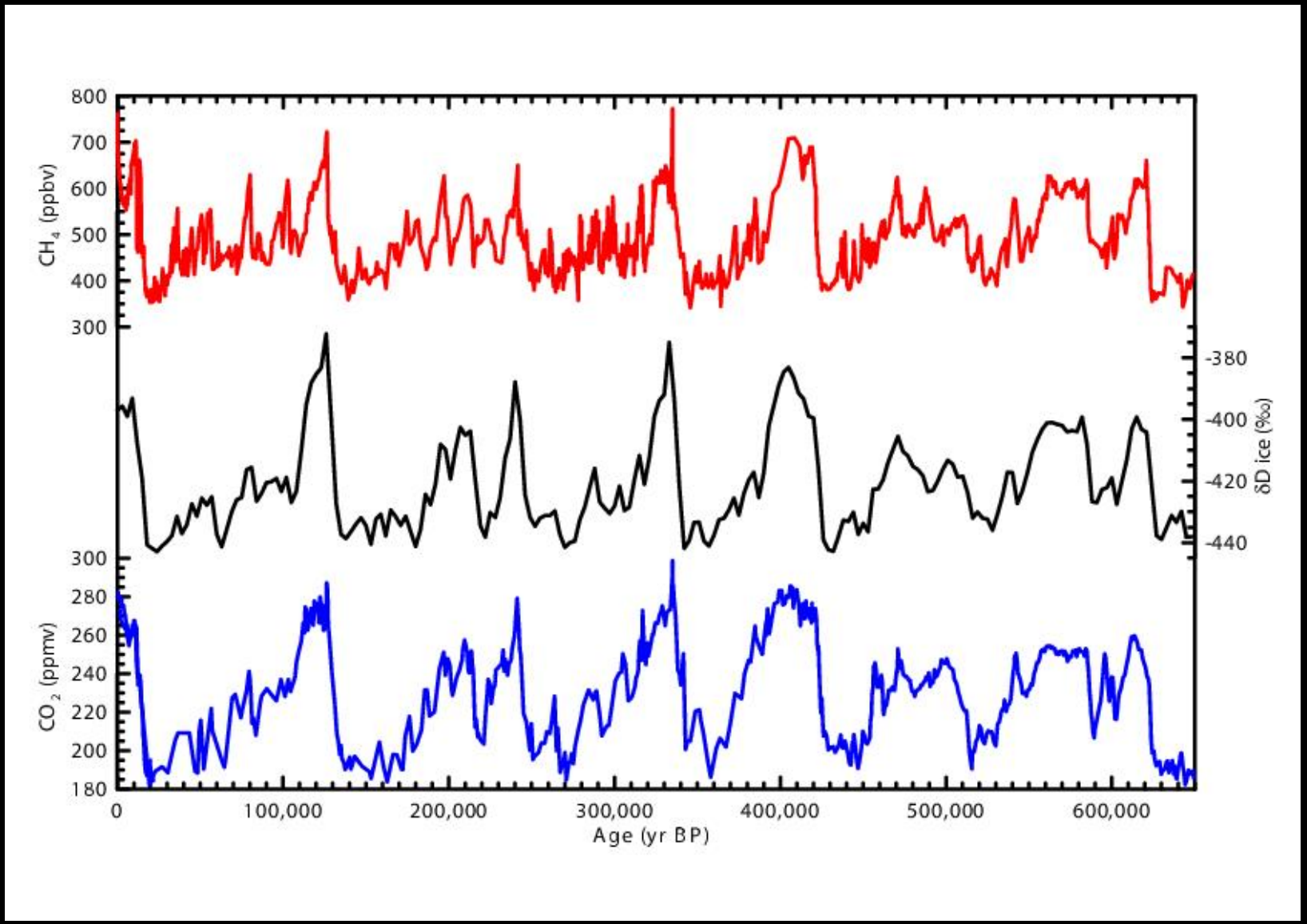
“EPICA”… the oldest ice core records so far



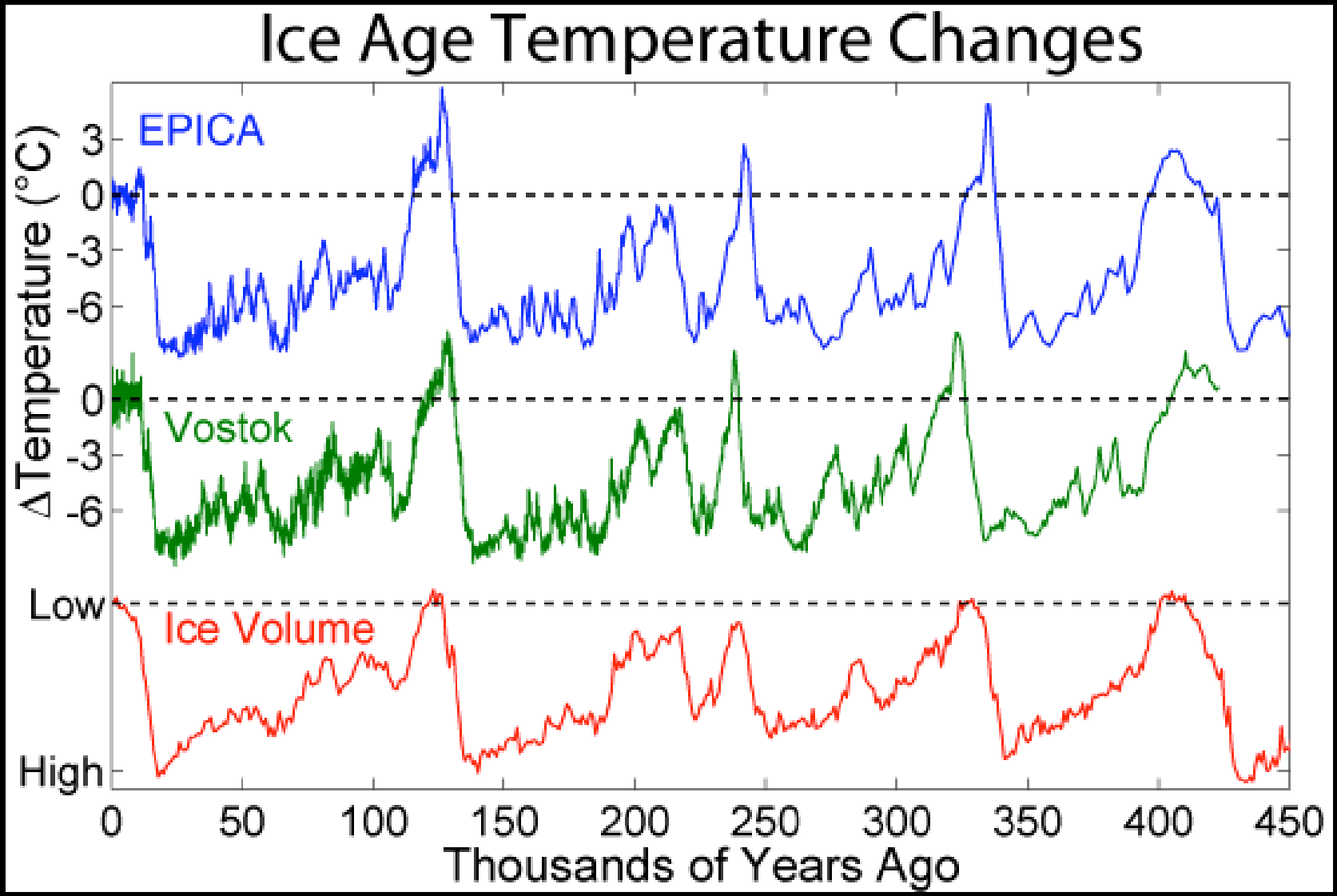
Epica… the raw records



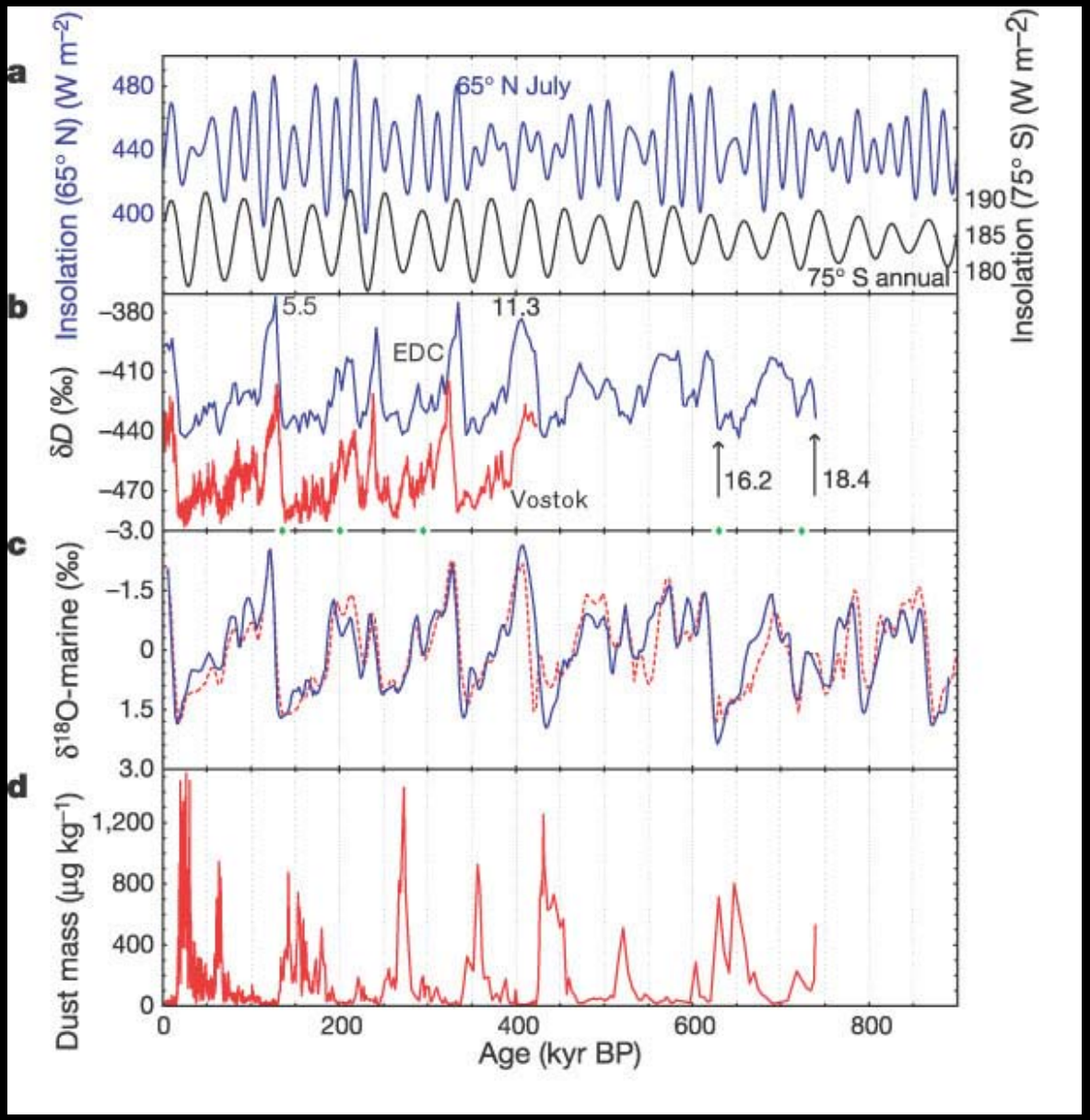
Atmospheric gases…



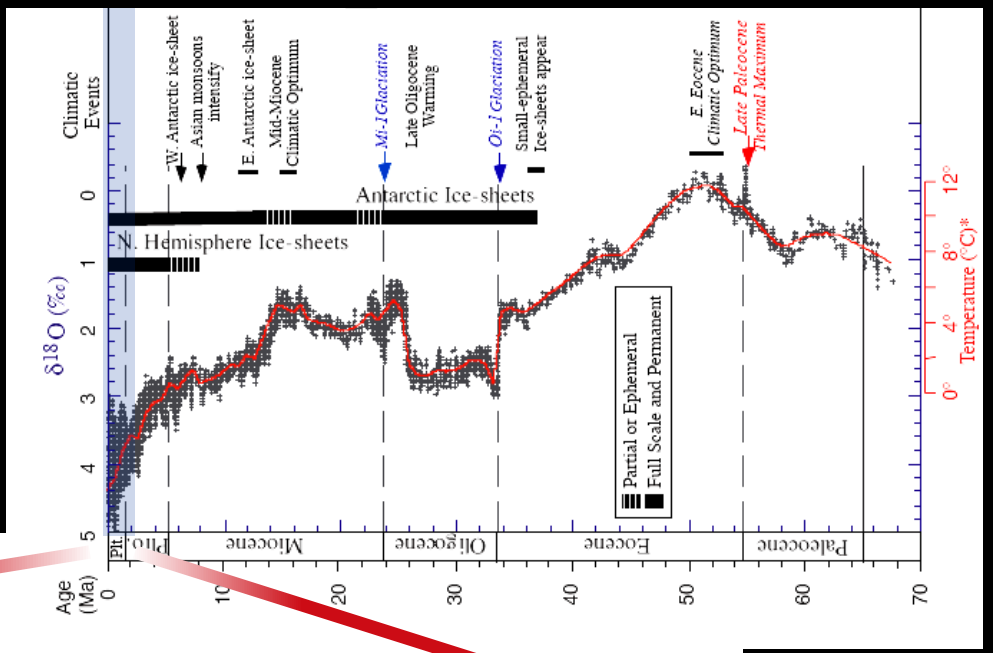
Air temperature and glaciers

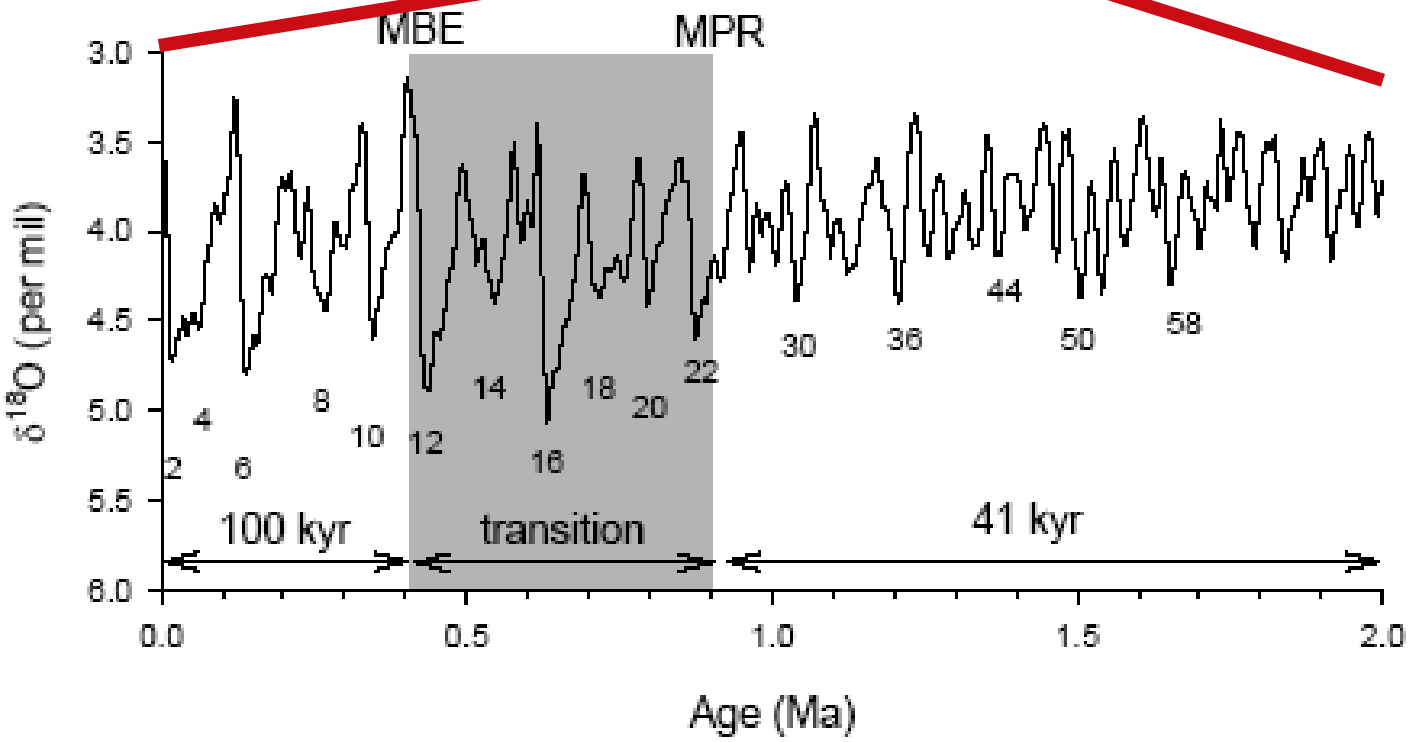


Comparison of climate records

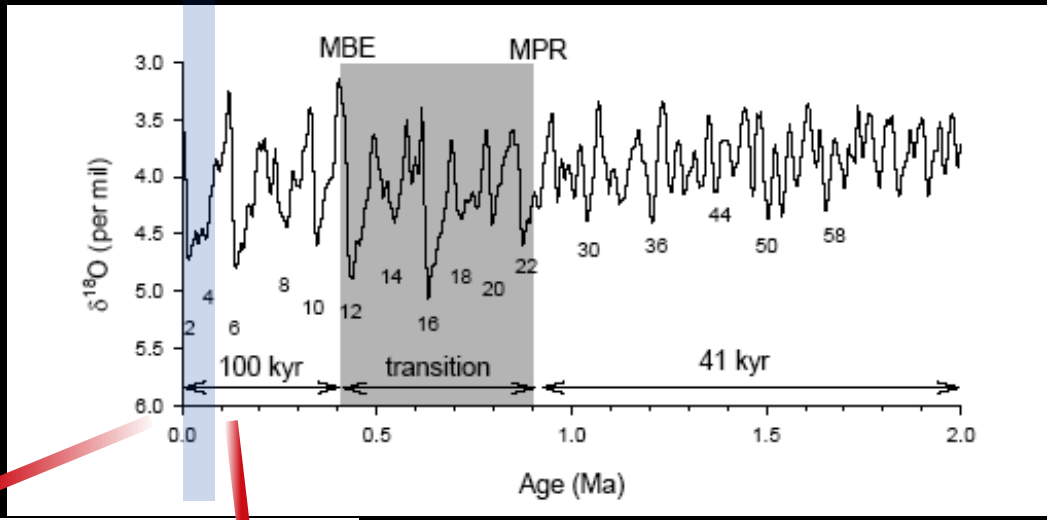


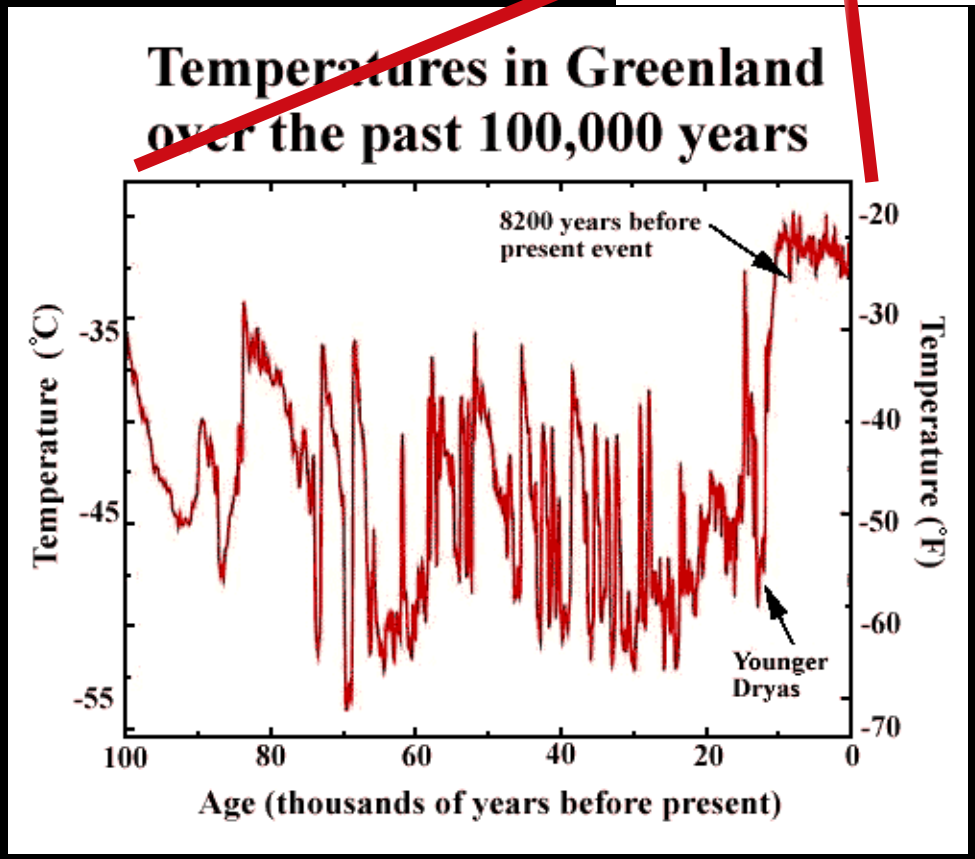
Glacial-interglacial cycles



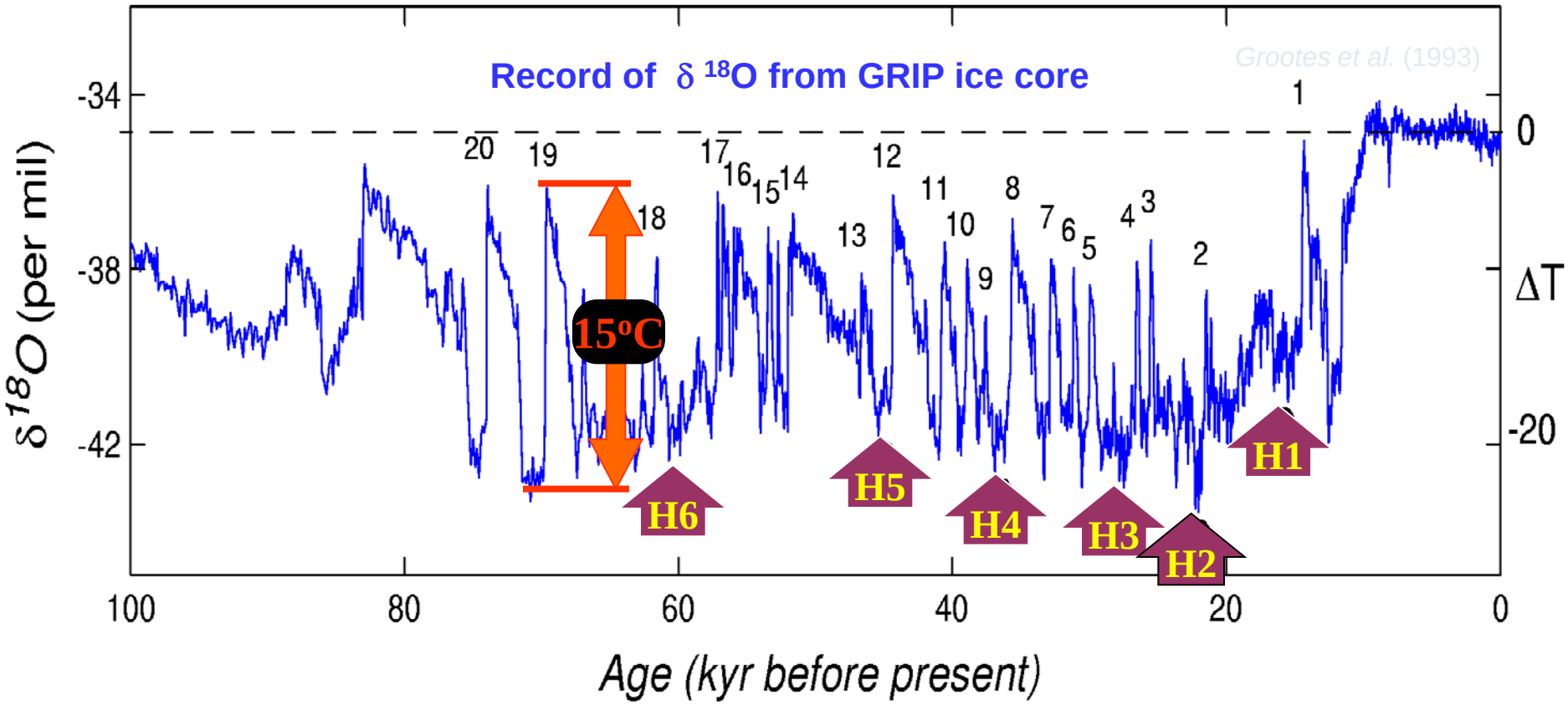


Abrupt climate oscillations



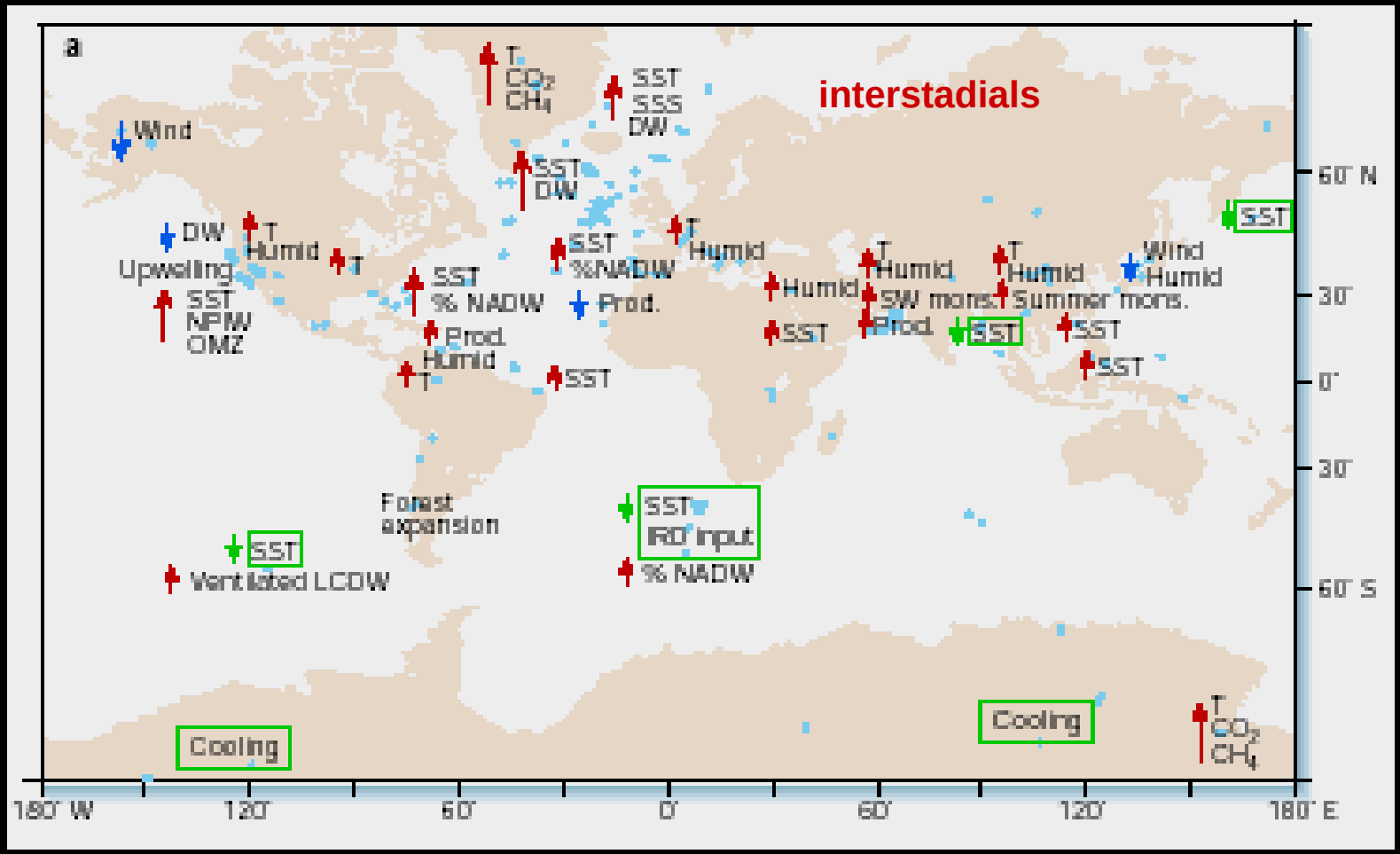


Abrupt climate change recorded in greenland…



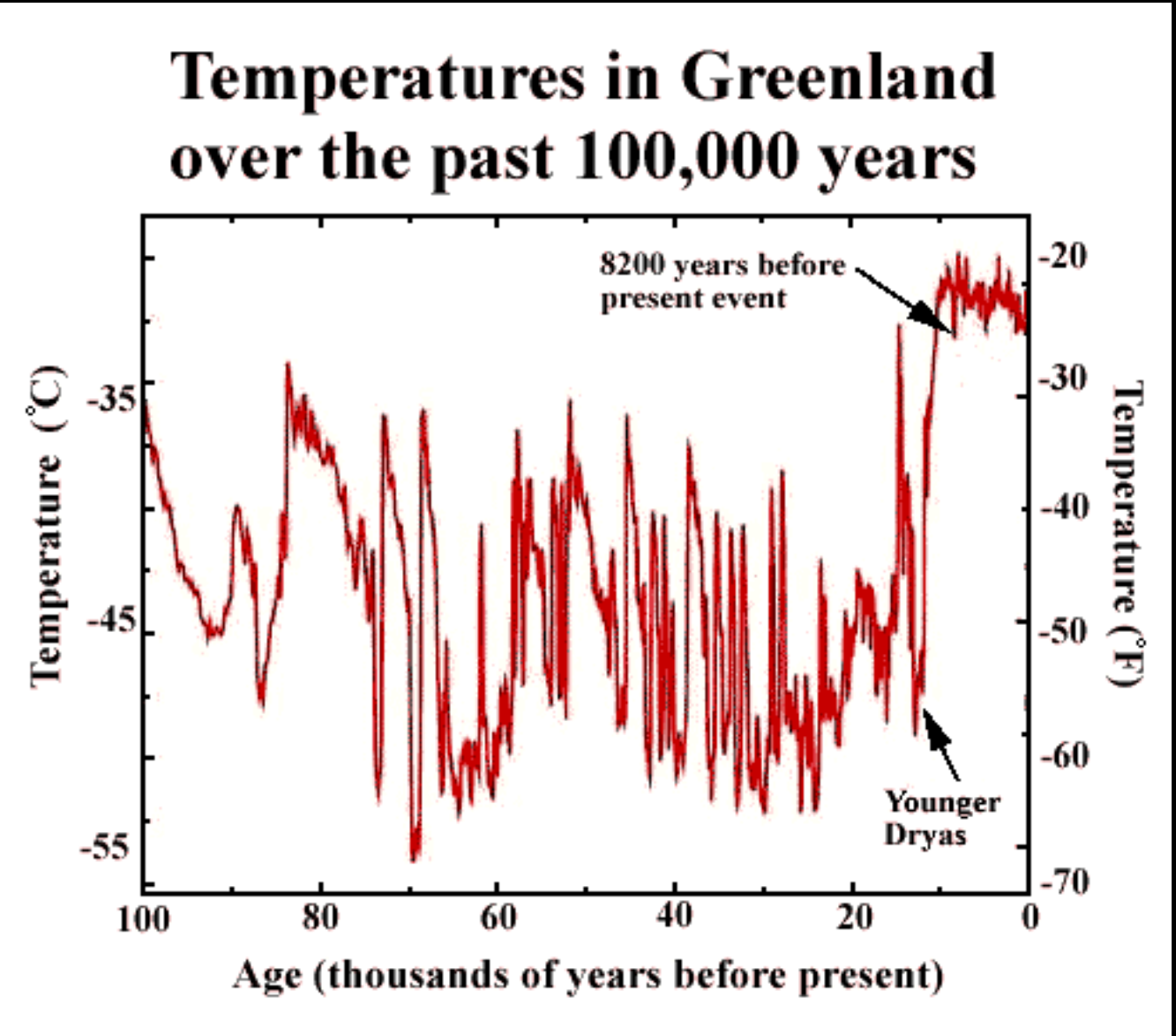
Grootes et al. (1993)

Where else?

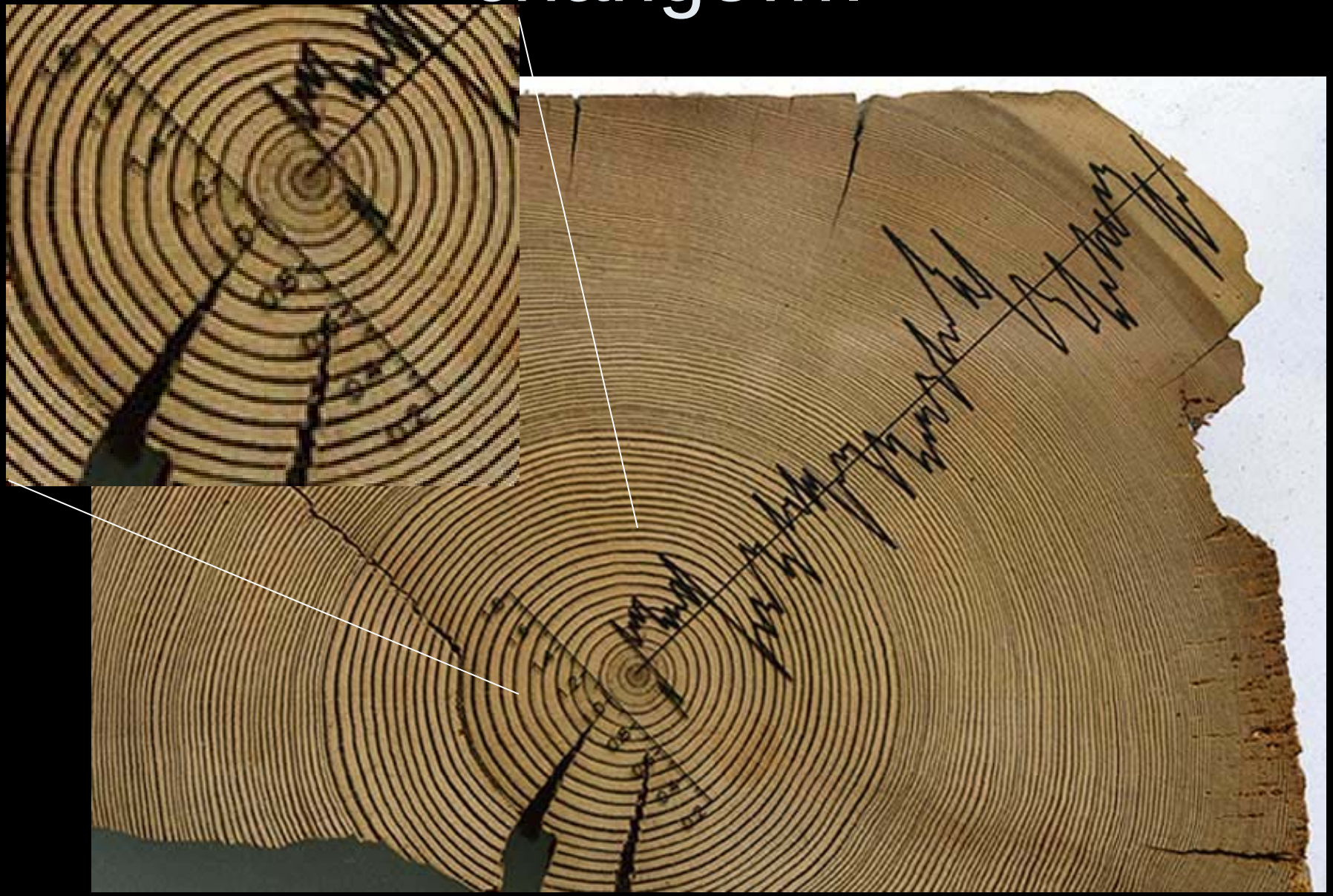


Voelker et al (2002)

Abrupt events recorded in ice cores



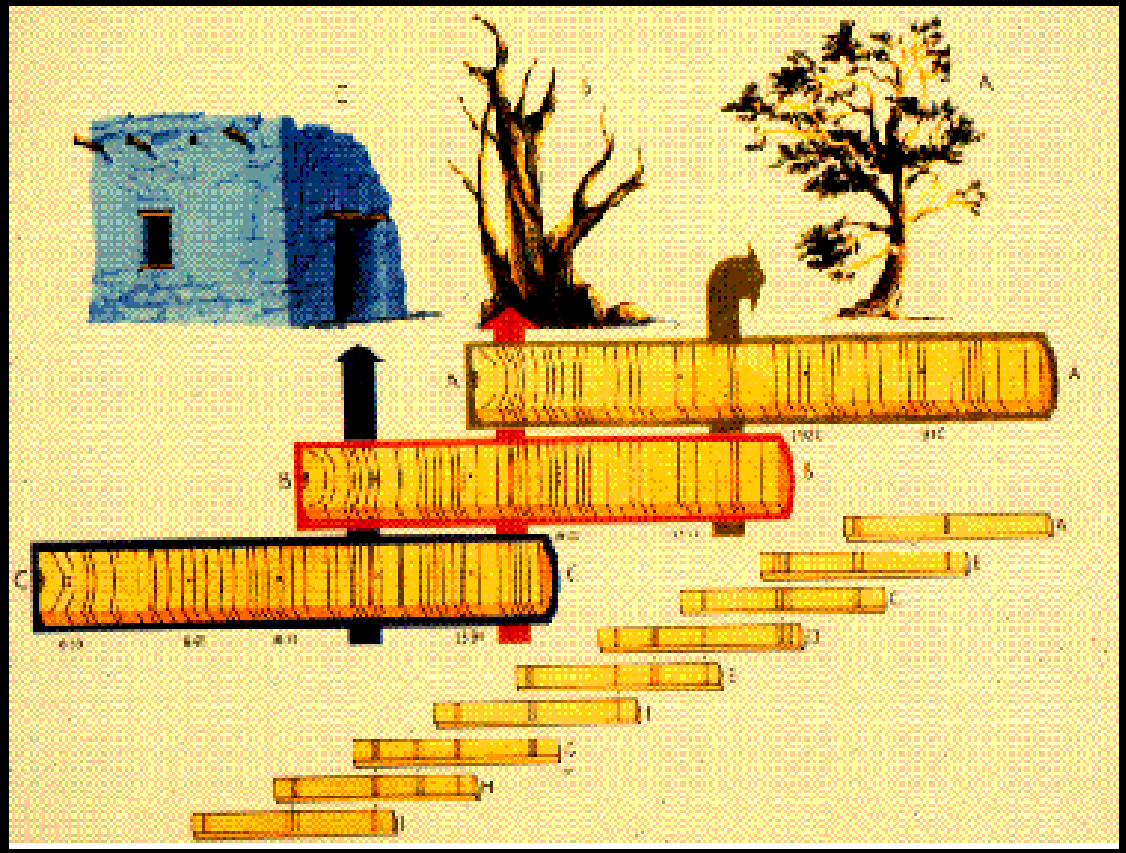
A record of temperature change….



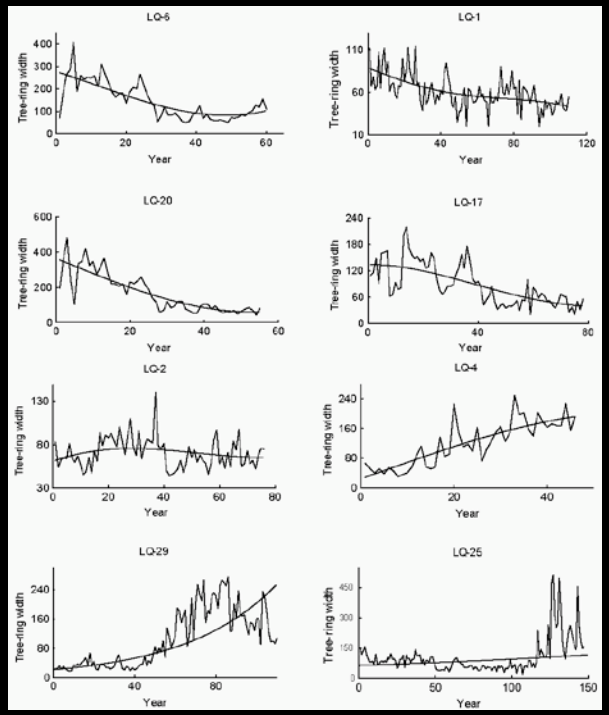
Trees that get really old….

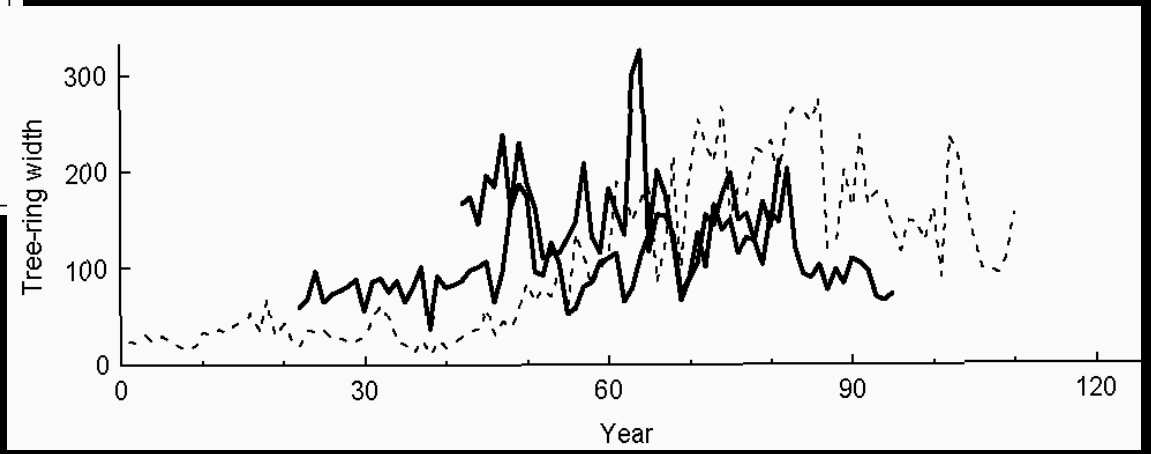
- Intermountain bristlecone pine **4,844 yrs**
- Alerce **3,620**
- Giant sequoia **3,300**
- Rocky Mountain bristlecone pine **2,425**
- Coast redwood **2,200**
- Foxtail pine **2,110**
- Rocky Mountain juniper **1,889**
- Limber pine **1,670**
- Alaska yellow-cedar **1,636**
- Baldcypress **1,622**
- Western juniper **1,288**
- Douglas-fir **1,275**
- Himalayan Hemlock **1,011**

How do we go older?
Correlation and Crossdating

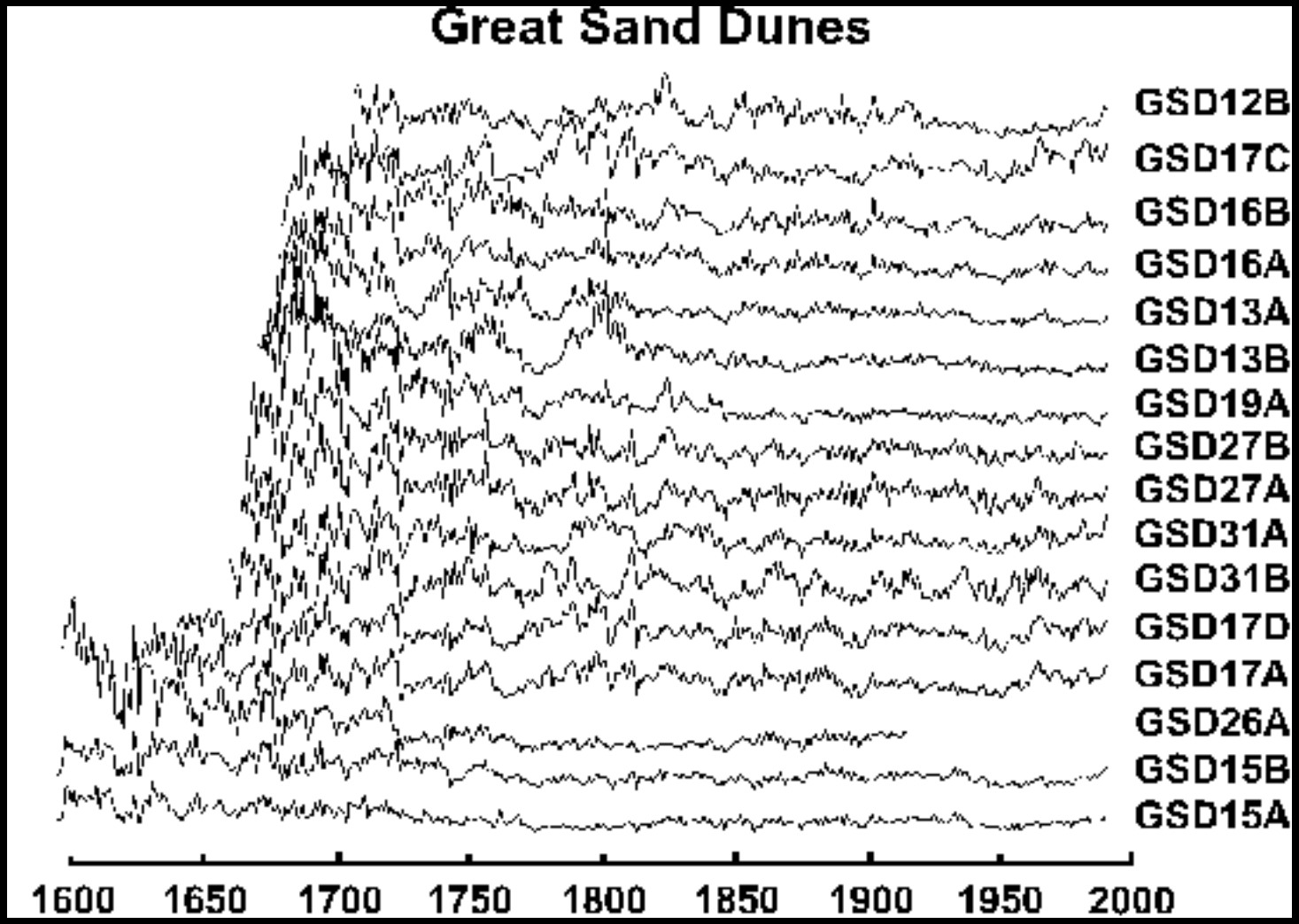


Correlation and Crossdating

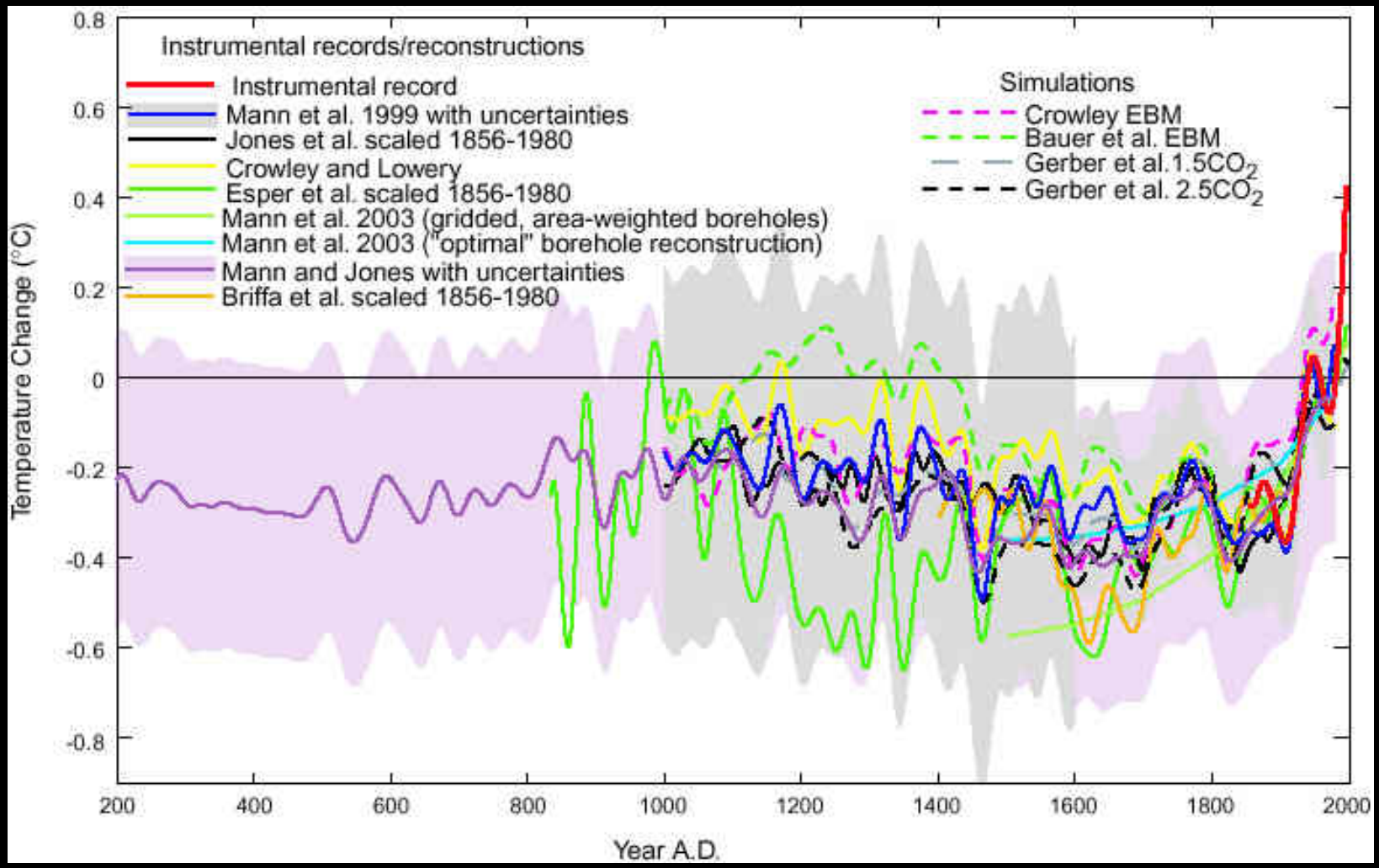




some principles applied in dendro studies.. ‘replication’



Reconstructing temperature change… the controversy



Talk outline:
A trip through geologic time

Take away points:
• Climate change through time

• What past climate change adds to the climate story

• What type of “archives” and data do we have