

The Pleistocene Ice Ages

EES 2110

Introduction to Climate Change

Jonathan Gilligan

Class #20: Friday, February 24 2023

Solving the Ice-Age Puzzle

Discovery of the Pleistocene Ice Ages

- Striations in rocks



- Moraines



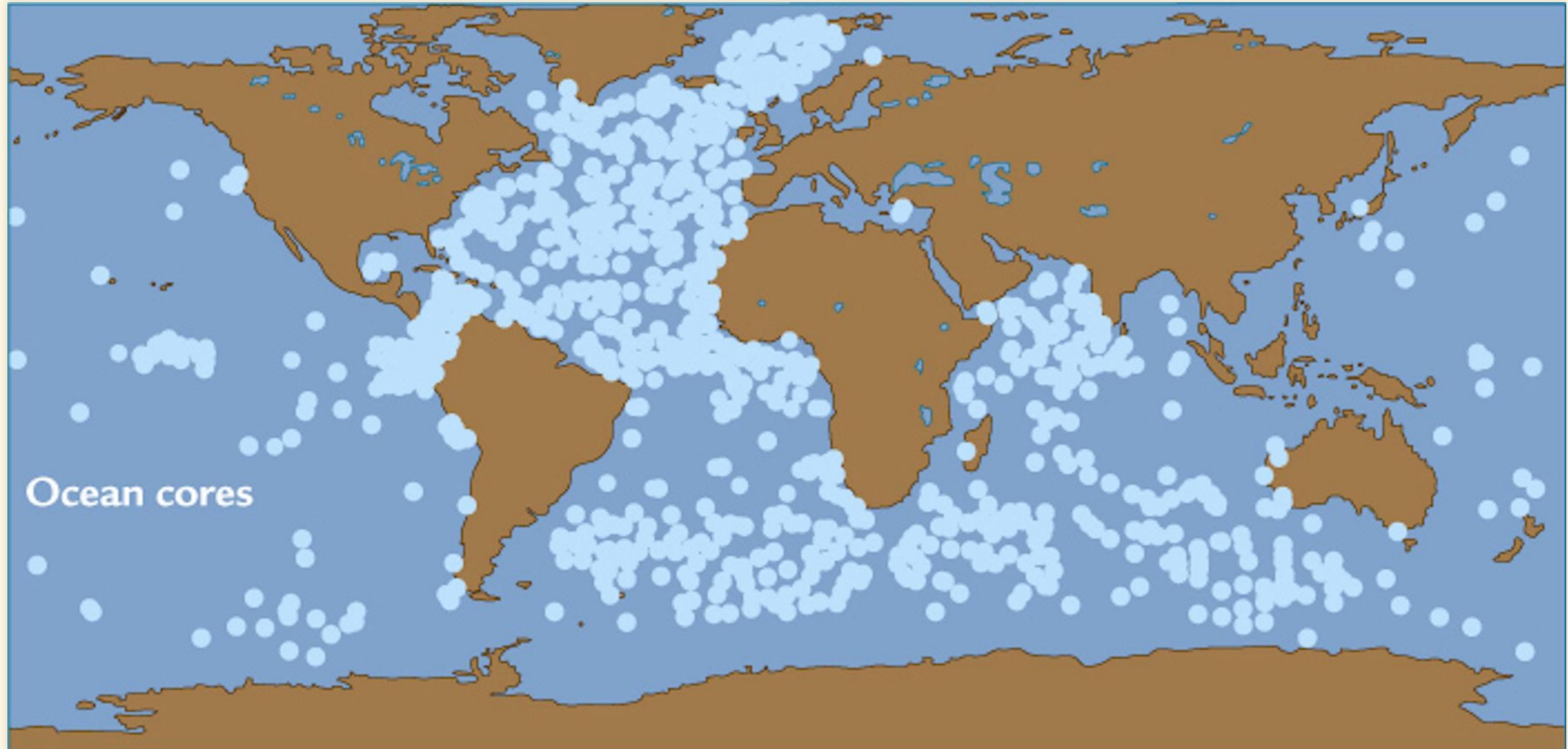
- Erratic boulders



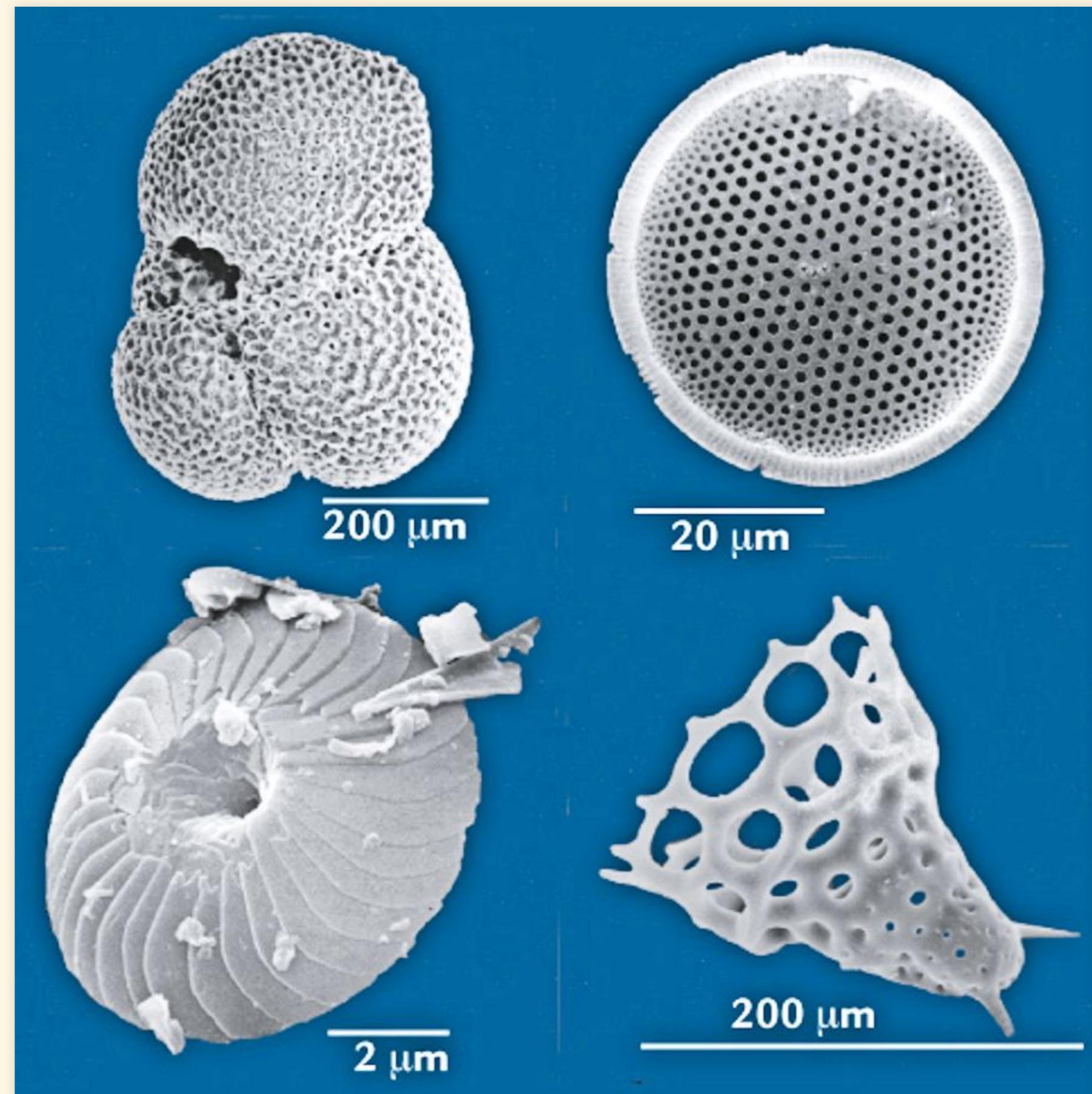
- 1830s: Louis Agassiz observed glacial traces throughout Northern Europe:

... great sheets of ice, resembling those now existing in Greenland, once covered all the countries in which unstratified gravel (boulder drift) is found.

Solving the Ice-Age Puzzle

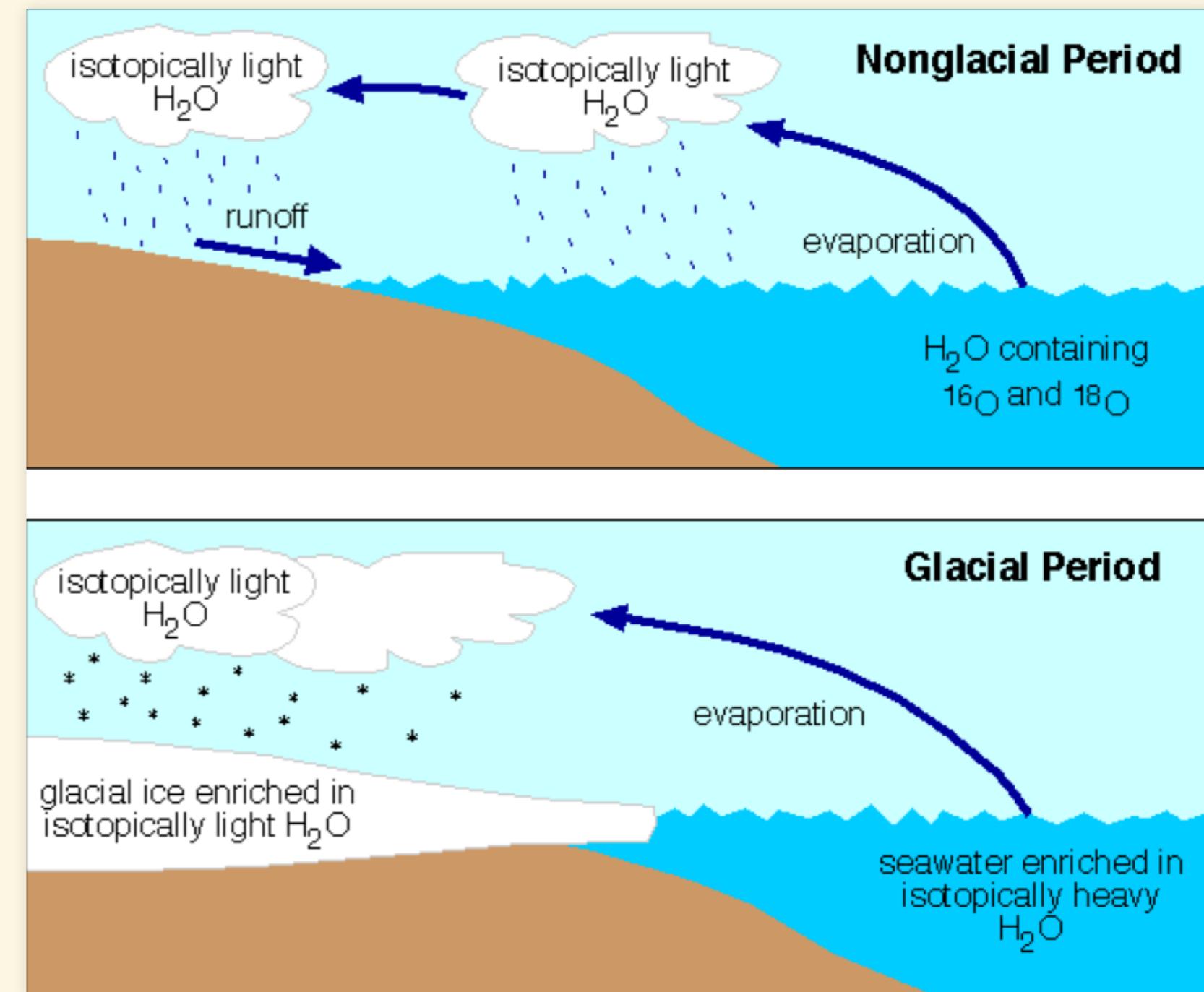


Deep-Sea Sediments

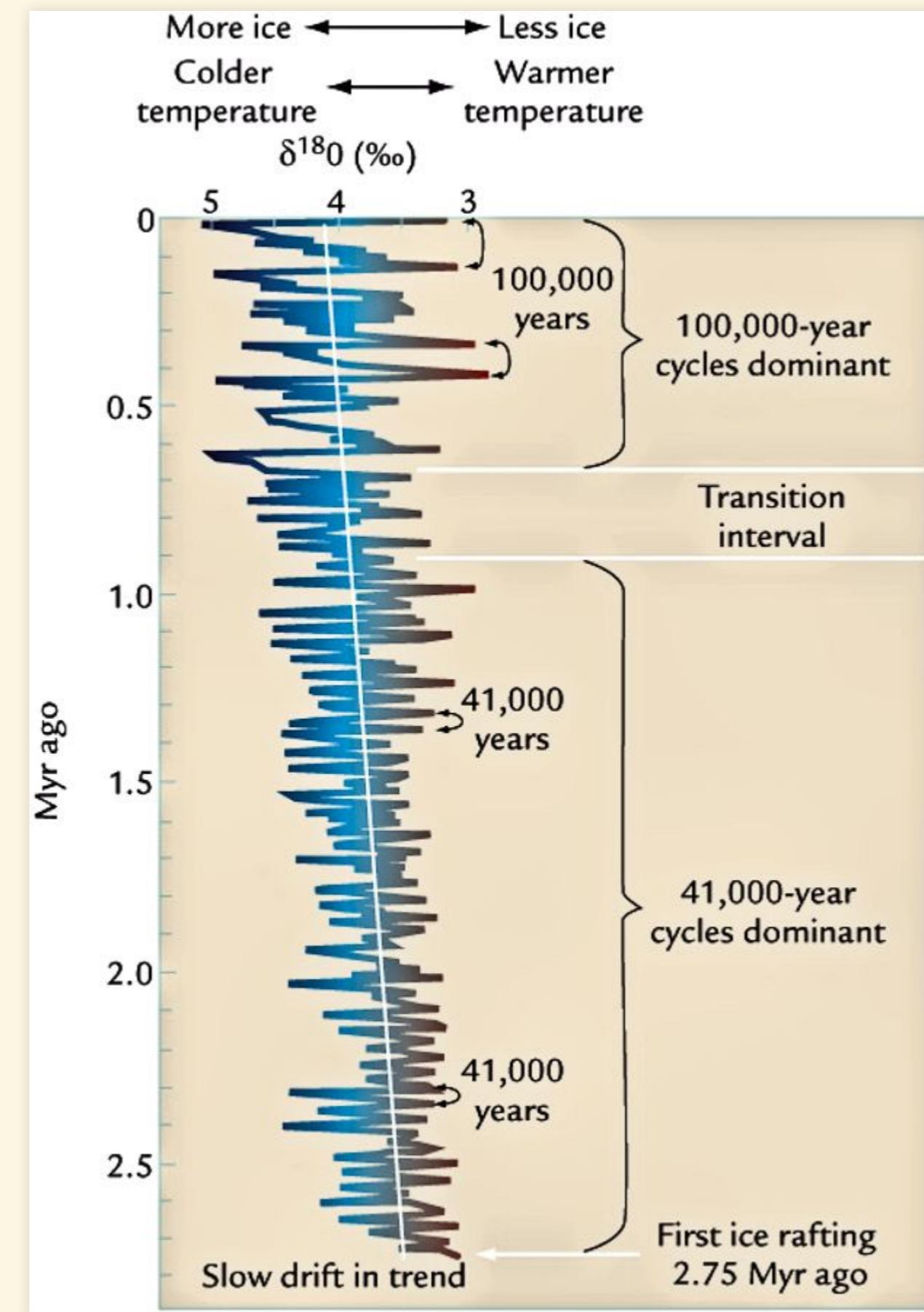


Past Sea Levels

- Water vapor, rain, snow is always isotopically lighter than sea water
- Snow, ice on land remove light isotopes from ocean
- Bigger glaciers:
 - Lower sea-level
 - Greater (positive) $\delta^{18}\text{O}$ in ocean sediments
- Smaller glaciers:
 - Higher sea-level
 - Smaller $\delta^{18}\text{O}$ in ocean sediments

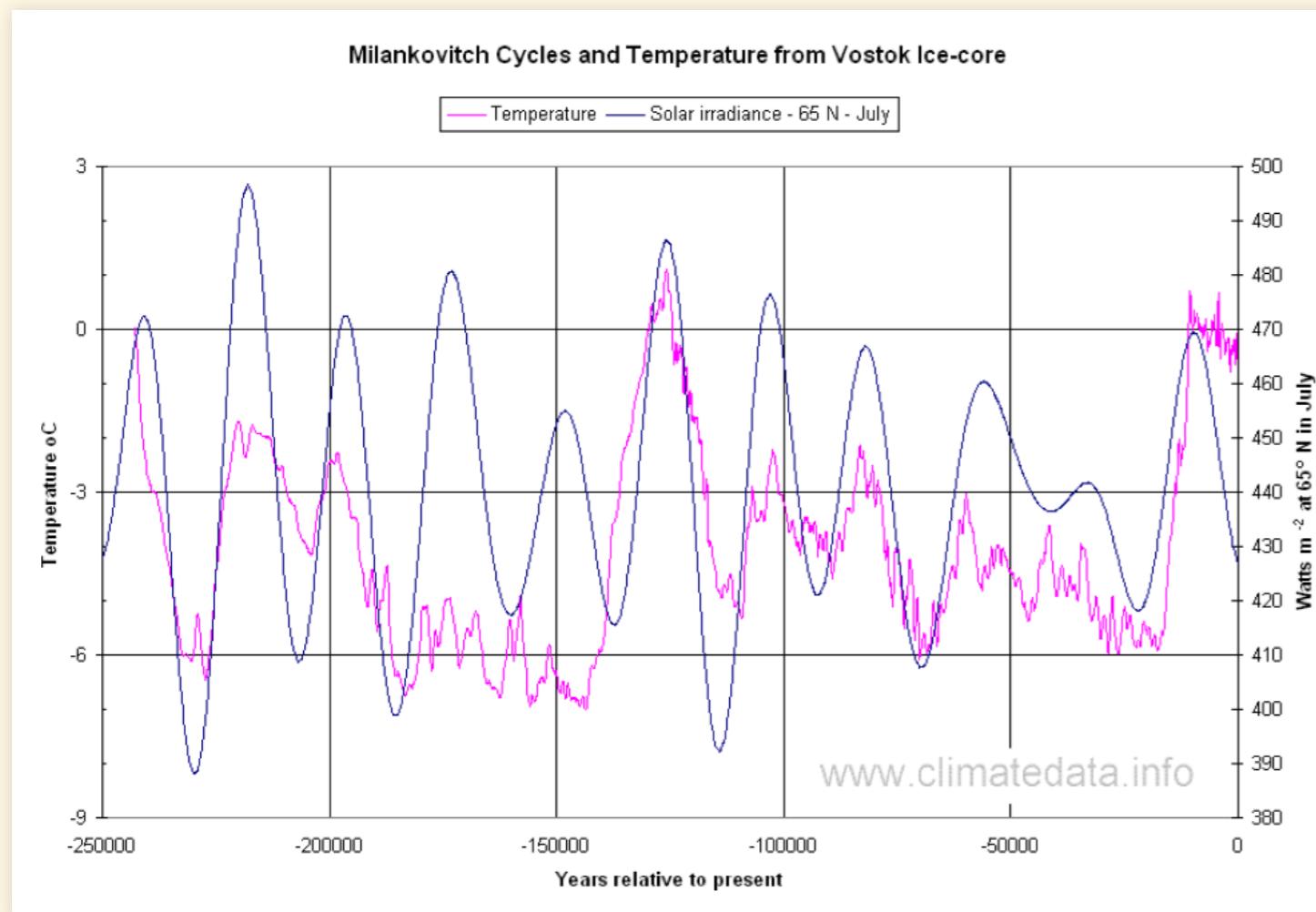


Sediment Climate Record



Sediments and Ice Ages

- Deep-sea sediments provide dates for Pleistocene glaciations and deglaciations.
- Timing lines up with orbital forcing
 - Summer sunlight intensity in high Northern latitudes

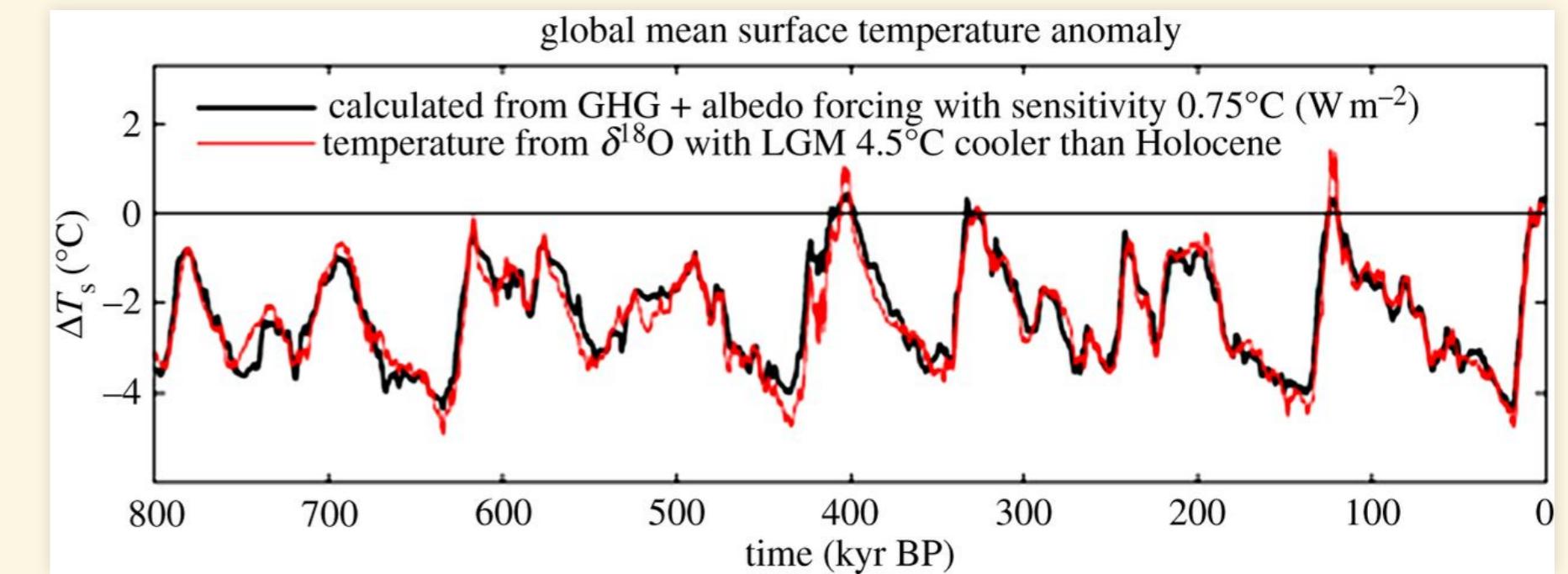
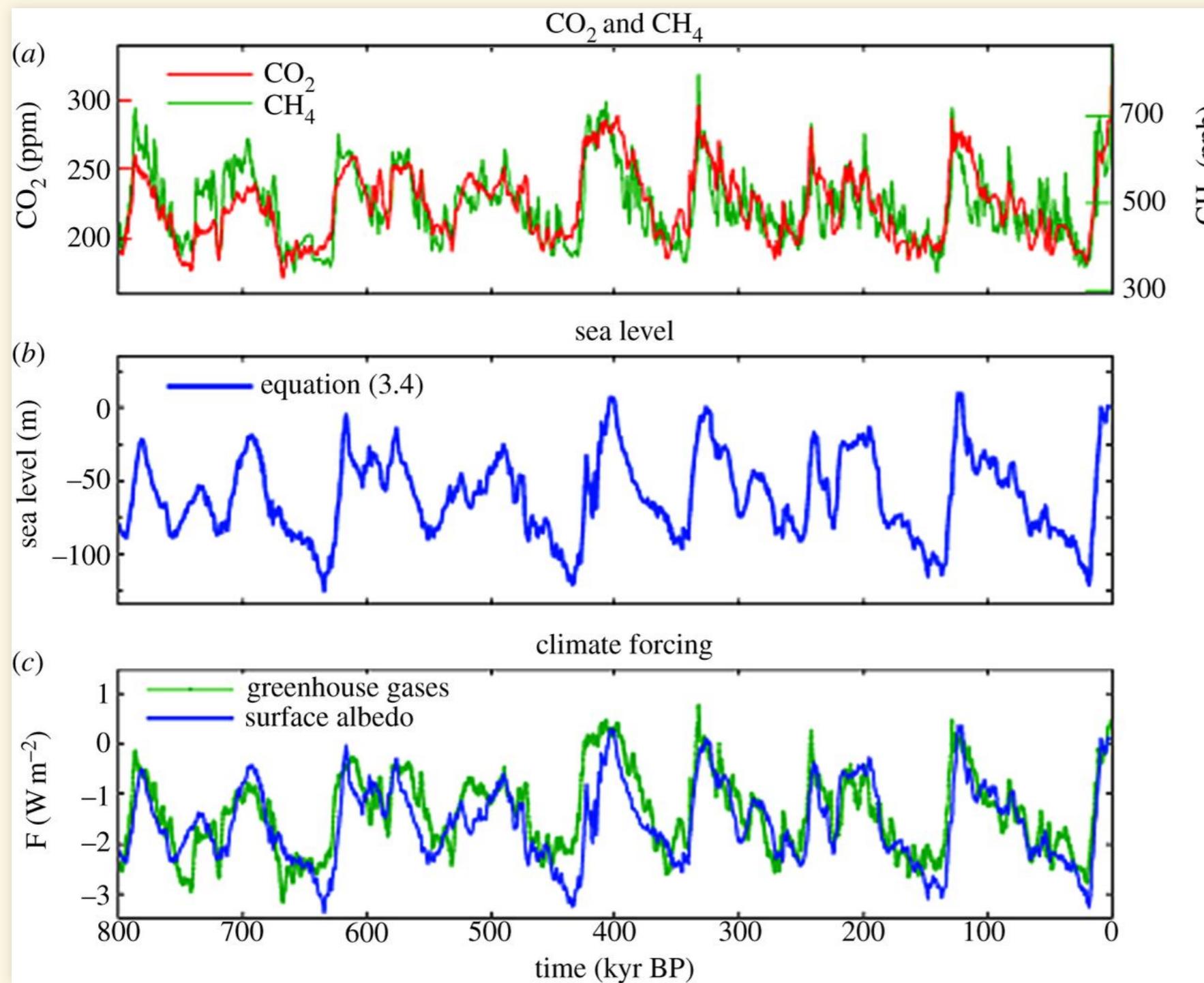


- Problem:
 - Orbital variations in solar intensity are too small to cause the big changes in glaciation
 - There must be positive feedbacks
 - Ice-Albedo and CO_2 feedbacks
 - Orbital variations kick things off, but ...
 - ... positive feedbacks amplify the heating/cooling to produce cycles of ice ages

CO₂ Feedbacks

- What do you do to keep an opened bottle of soda fizzy?
 - **Solubility**
 - More CO₂ dissolves in cold water than warm water
 - As global temperatures cool, more CO₂ can dissolve into the oceans.
- **Currents**
 - Surface oceans saturate with CO₂
 - Deep oceans can hold much more
 - Currents slowly move CO₂ from surface to deep oceans
 - Climate change affects ocean currents that move water between surface and deep oceans.

Comparing theory and observation



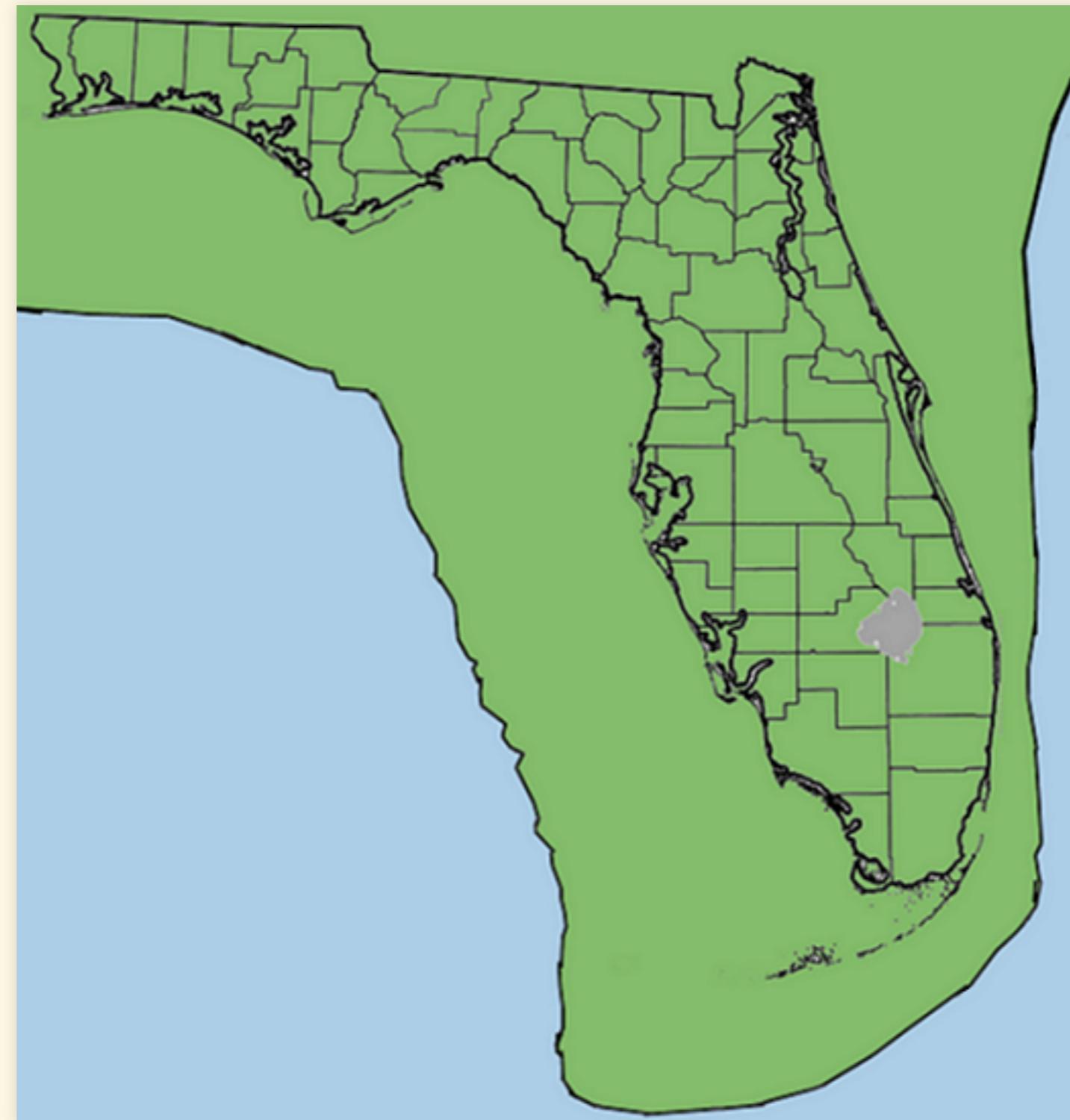
Timeline:

- 1820s: Fourier discovers greenhouse effect
- 1830s: Agassiz discovers past glaciations
- 1840s–60s: Discovery of greenhouse gases (CO_2 and H_2O)
- 1890s: Scientists speculate that natural variations in CO_2 is responsible
- 1930s: Milutin Milankovitch develops orbital-variation theory
- 1970s: Testing the theory:
 - Invention of isotopic analysis
 - Deep-sea cores
 - Scientists can finally figure out the timing of the cycles:
 - When did glaciations begin and end?
 - Beginnings and endings of ice-ages matched Milankovitch's theory

Florida Through History

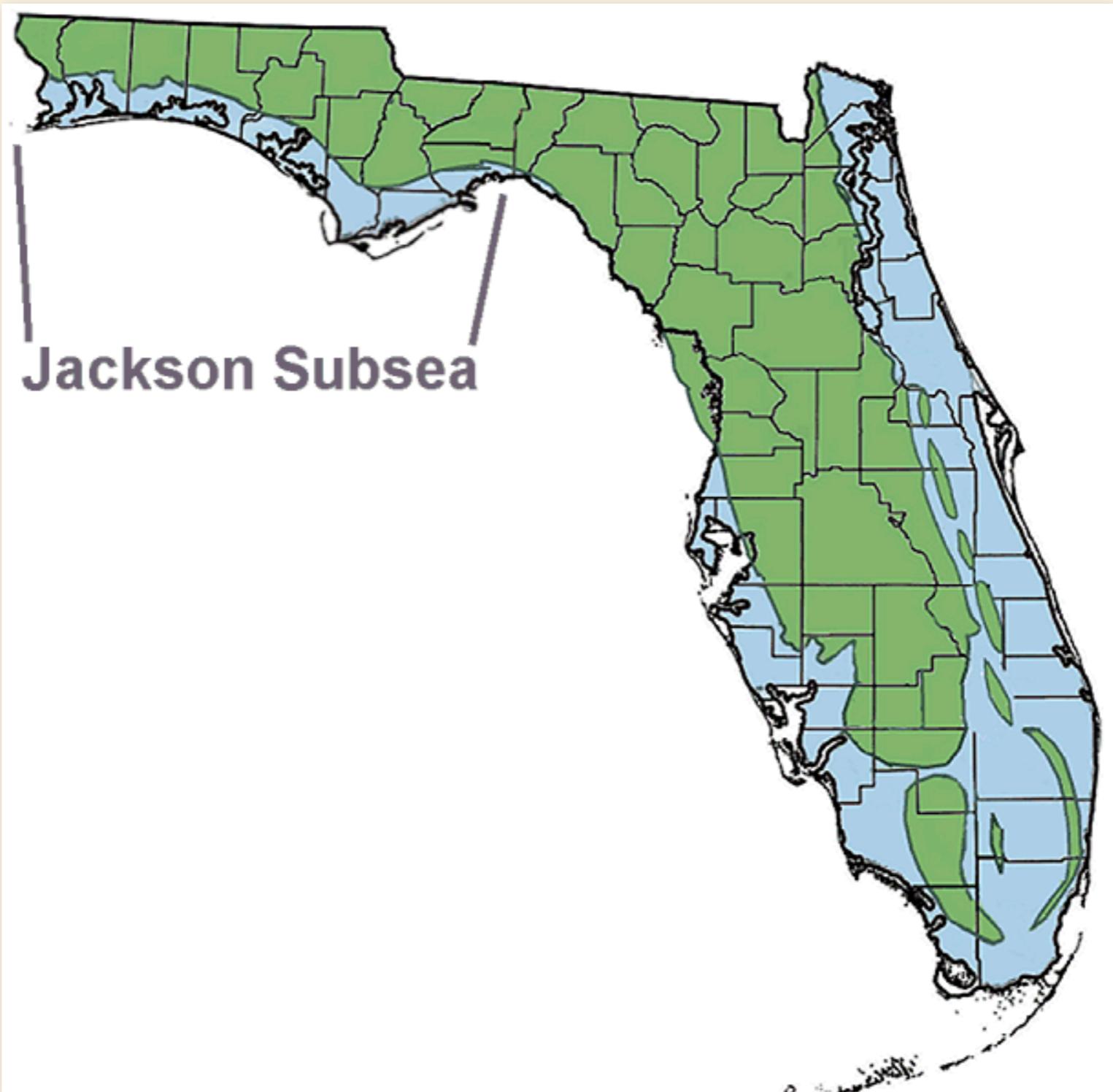
Florida 10,000 years ago

End of last ice age:
Sea level 400 feet lower



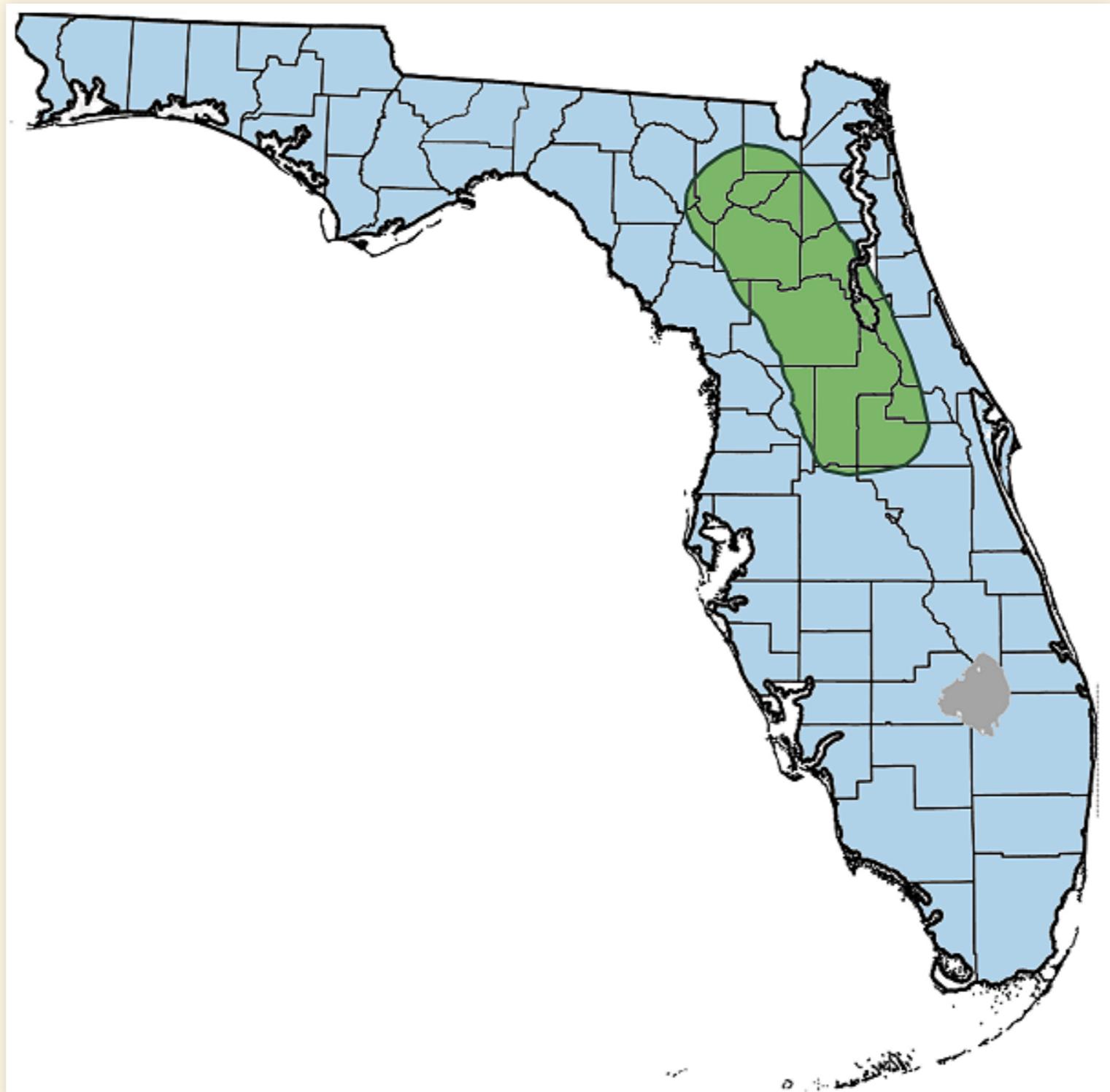
Florida 5 million years ago

Last time CO₂ was at today's levels.
Sea level around 20 meters higher

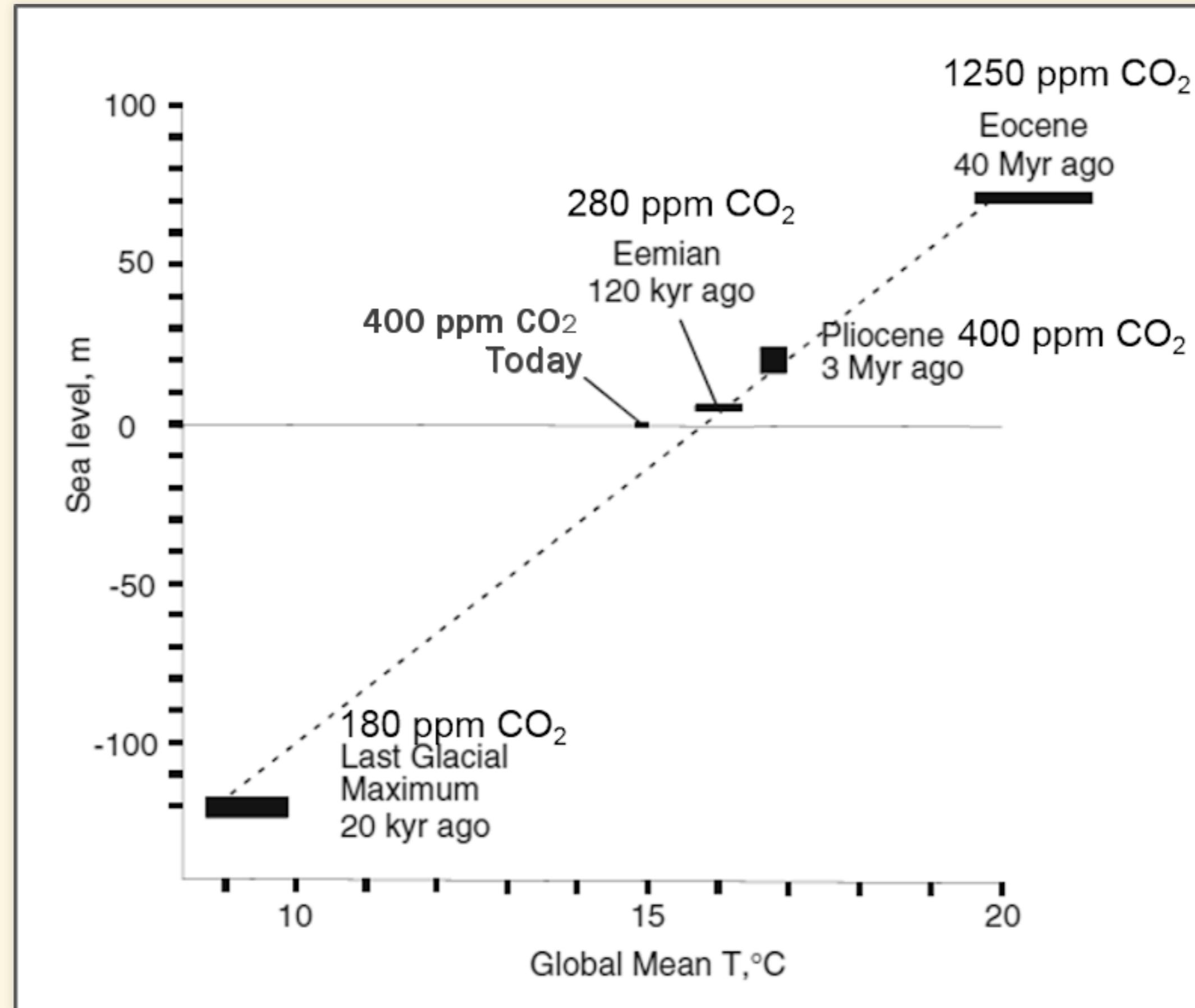


Florida 50 million years ago

Three times present CO₂.
Sea level >70 meters higher



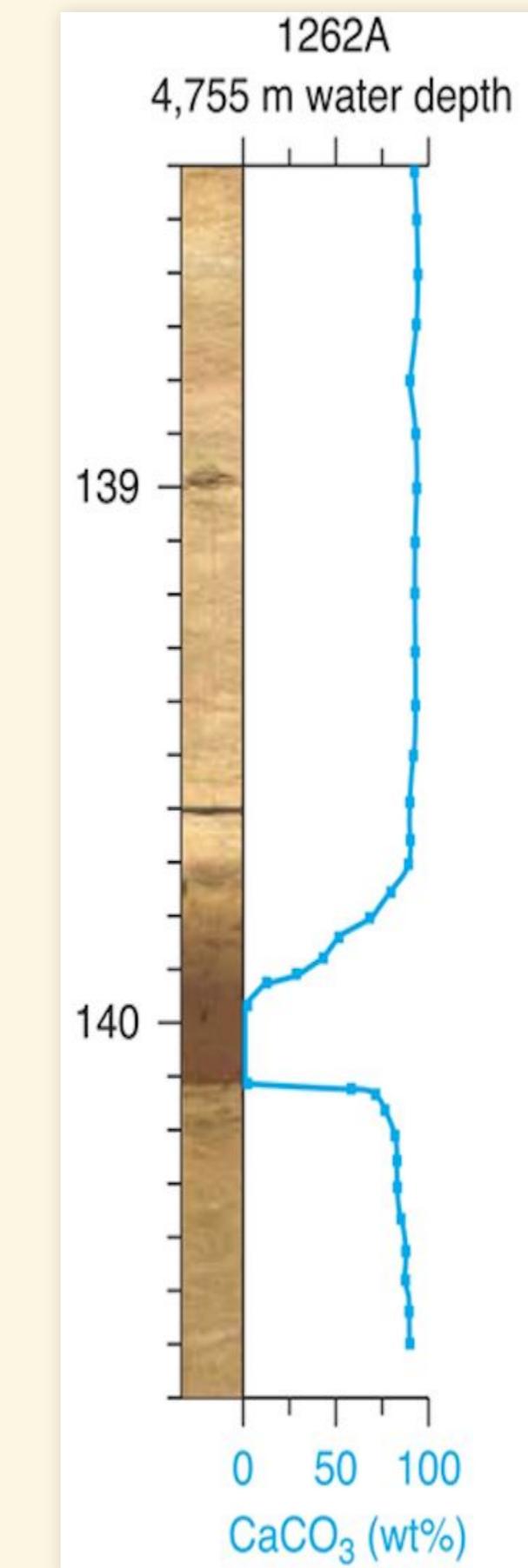
Summary of Past Sea Levels



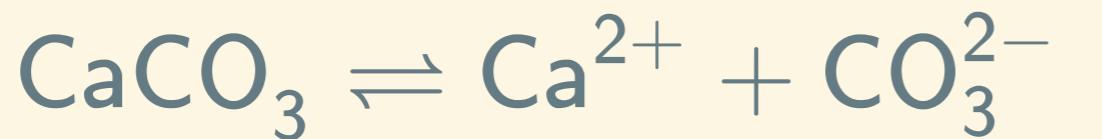
Other Evidence
of Past Climates ...

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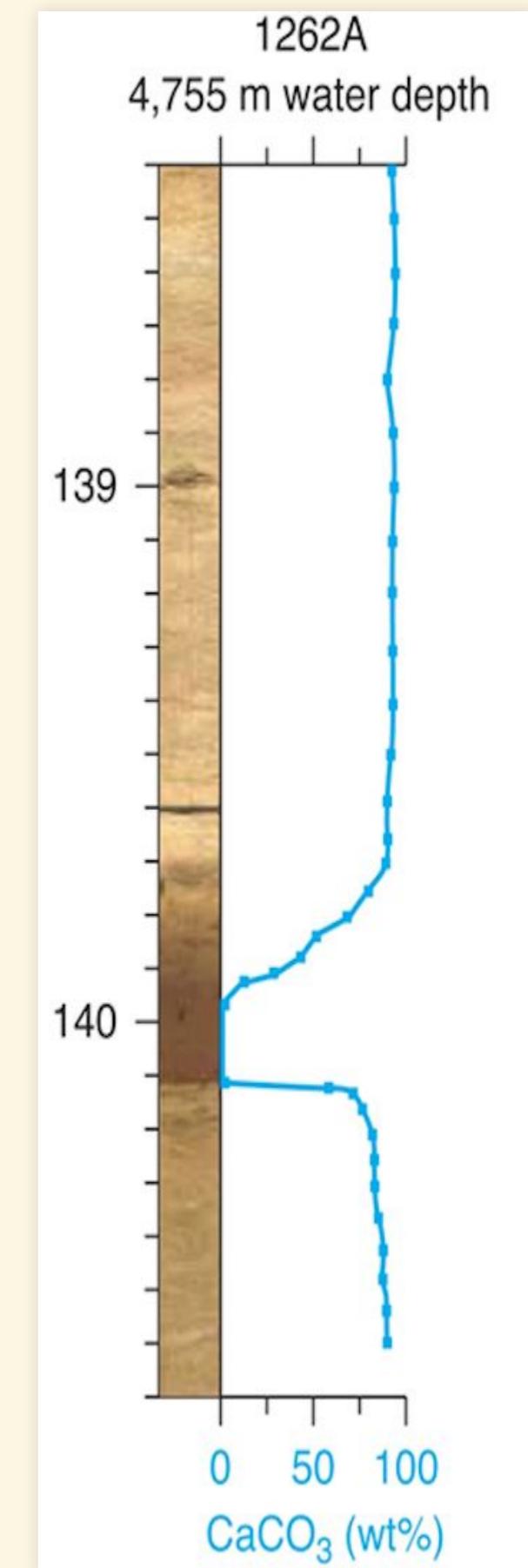
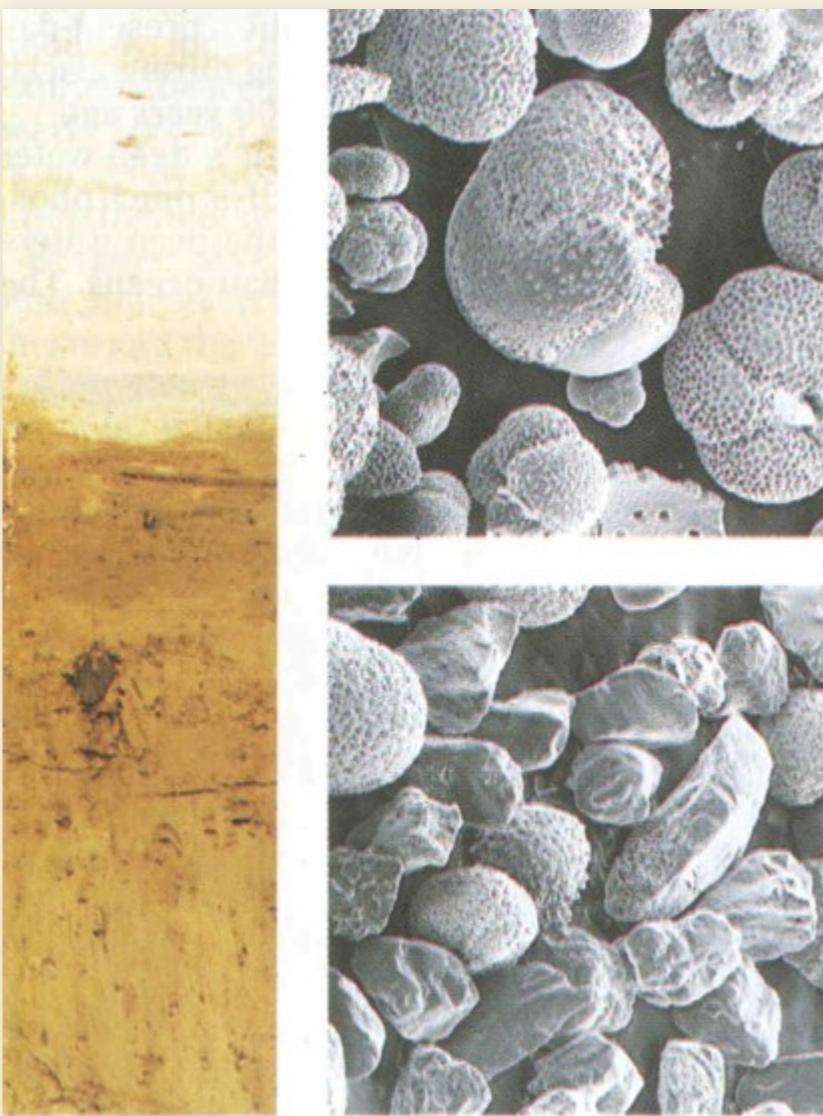
- Sediments tell us about history:
 - Bottom → top = oldest → youngest
- White carbonate sediments
- Red clay layer:
 - ~55 million years ago
 - Almost no carbonates
- What does red layer tell us?



Other Evidence of Past Climates...



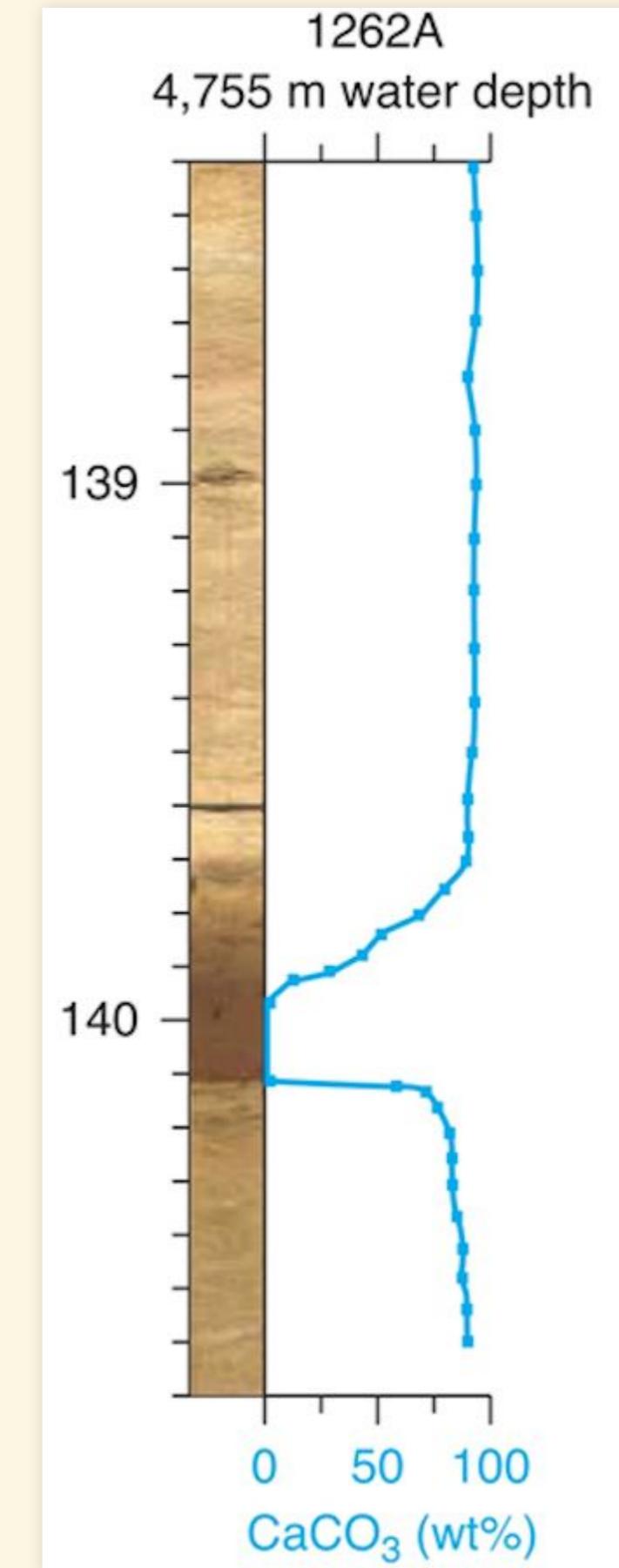
- Alkaline Ocean:
 - High CO_3^{2-} : Reaction runs \leftarrow
 - Carbonates survive on sea floor
- Acid Ocean:
 - Low CO_3^{2-} : Reaction runs \Rightarrow
 - Carbonates dissolve
 - Only clay is left
- Red clay layer \Rightarrow ocean acidification
 - Large burst of CO_2 into atmosphere.



Other Evidence of Past Climates...



- Just below red clay layer, $\delta^{13}\text{C}$ drops suddenly.
- What does that tell us?
- Lower ^{13}C means rise in CO_2 came from organic source.

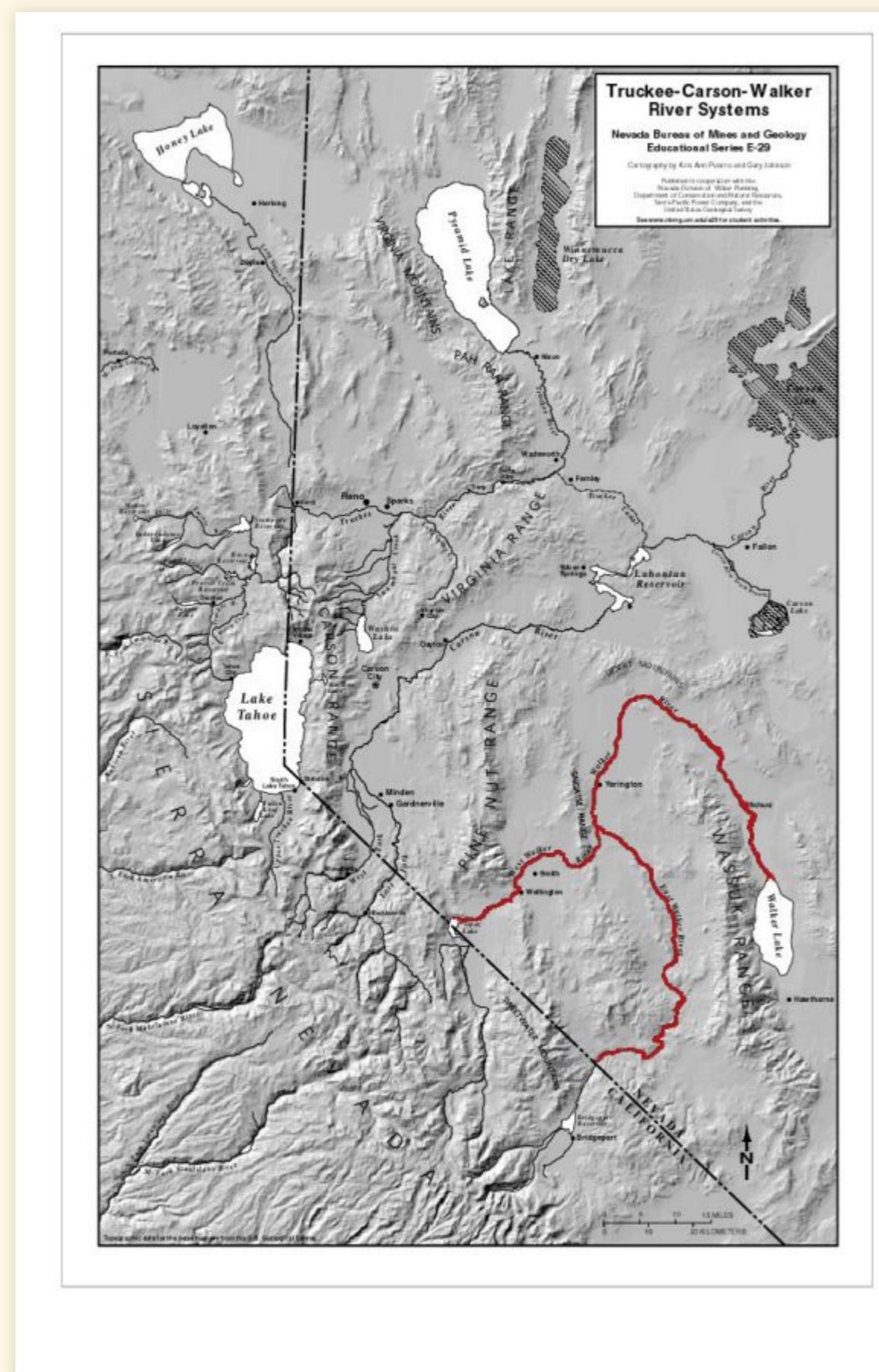


Paleocene-Eocene Thermal Maximum

- 55 million years ago
- 1500–4500 GT carbon added to atmosphere in 1000 years
 - Compare:
 - 600 GT in atmosphere in 1700s,
 - 884 GT today
 - Known fossil fuels: ~5000 GT
- Temperature rose 5–9°C (9–16°F)
 - Ocean at North Pole was about 23° C (73° F).
 - Breadfruit & other tropical trees grew in Canada
- Lasted ~120,000 years
 - Transition to cooler temperatures took ~40,000 years
- Eocene → ⋯ → Pliocene → Pleistocene
 - Gradual cooling for 50 million years
 - Ice age glaciation of North America, Europe begins ~2.8 MYA

Climate in the Last Millennium

Walker River



Relict Tree Stumps



Relict Tree Stumps



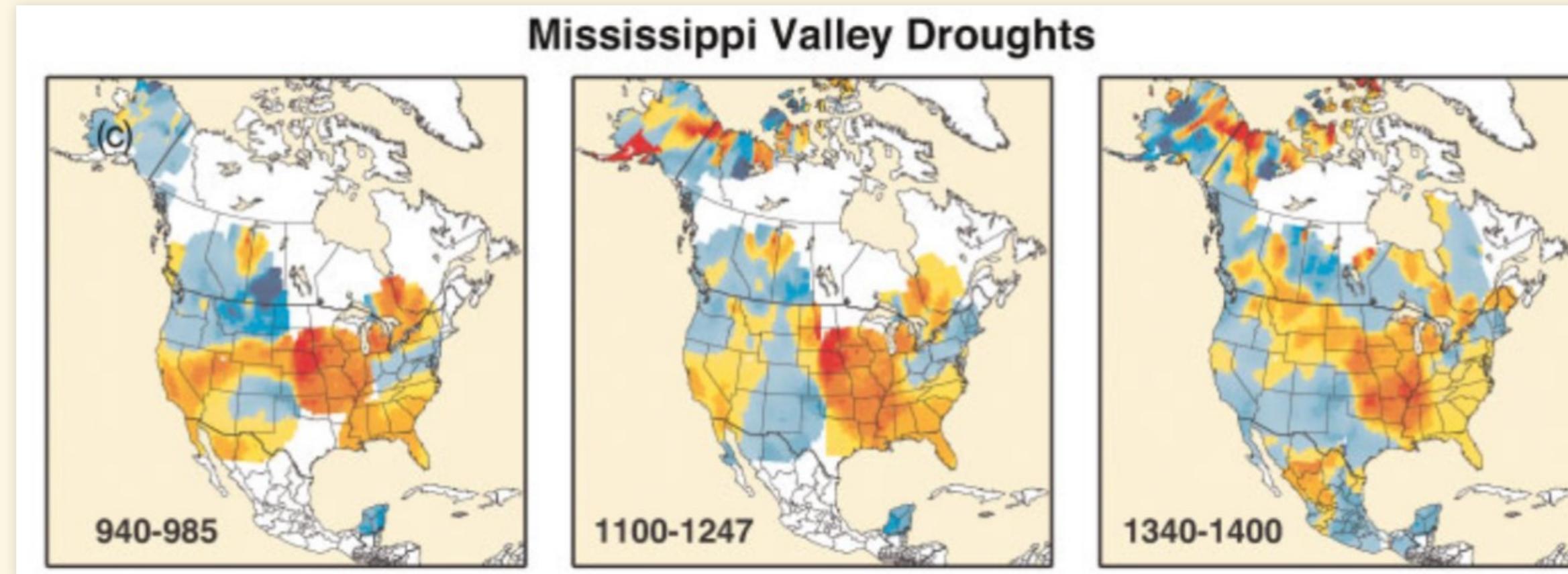
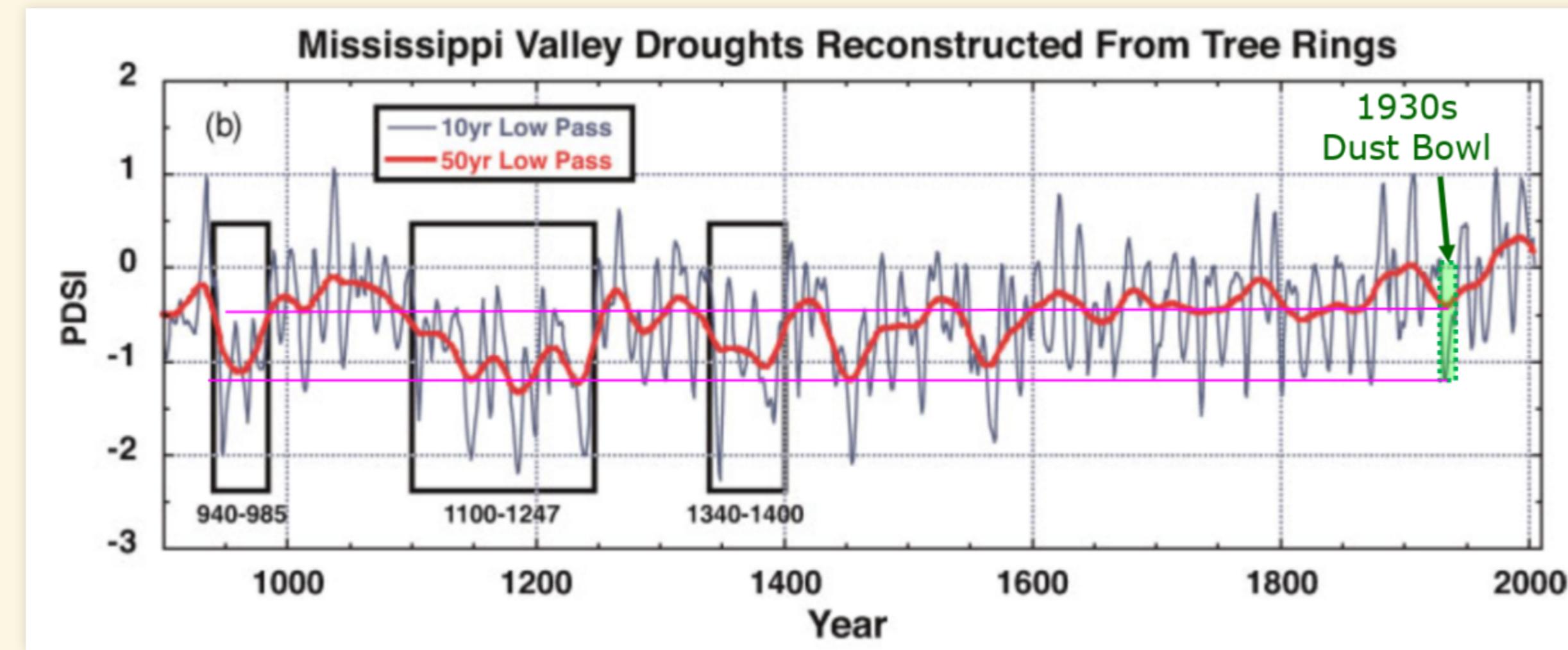
Lake Tanaya, Yosemite



Chaco Canyon



Reconstructing Megadroughts



Dust Bowl vs. Megadroughts

- 1930s “Dust Bowl”
 - 6 years
 - 25% reduction in rainfall in plains states
 - Hundreds of thousands of refugees
- Medieval Megadroughts:
 - Multiple droughts
 - 60 years or longer (up to 240)
 - 40% reduction of rainfall in plains states
- New research (2022):
 - Current drought in the Southwest is the most severe since the medieval megadroughts.

