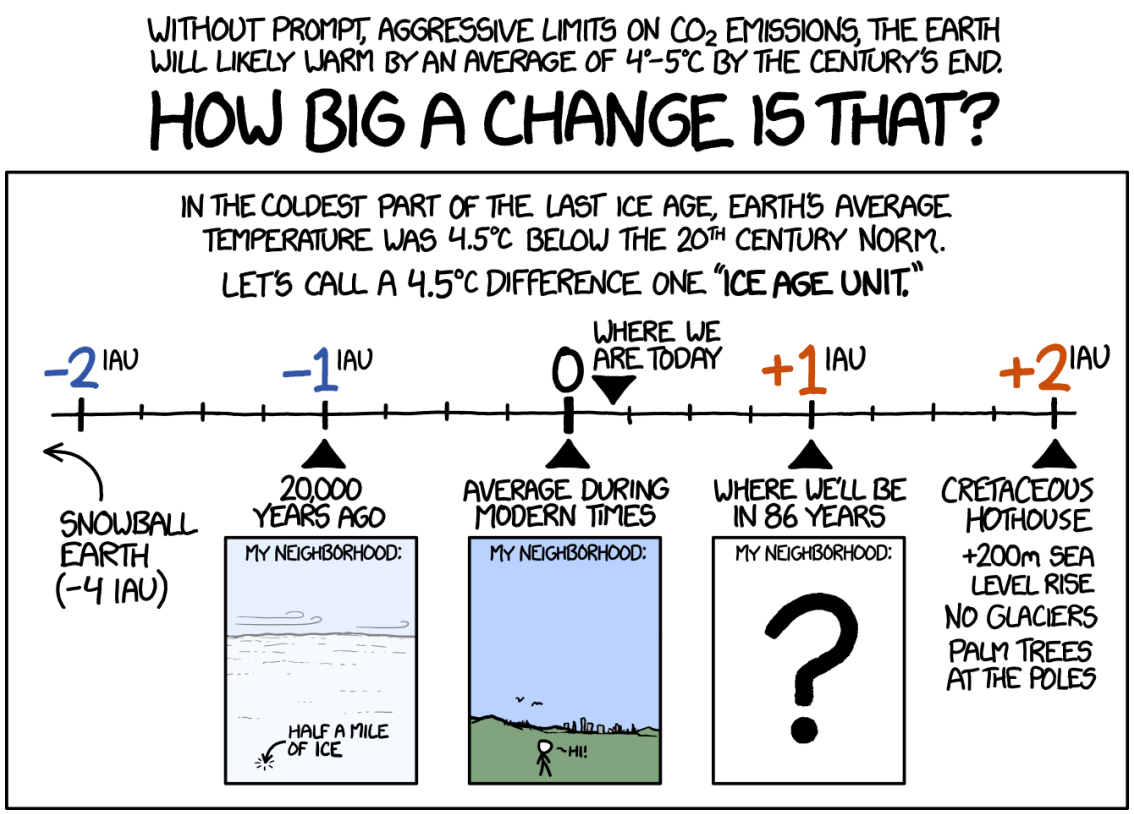

Class 13: Deep Time Paleoclimate

- Greenhouse vs. Icehouse Worlds
- Plate Tectonic Processes & their Effects on Climate
- The Cretaceous Greenhouse World +Dinosaurs!
- Snowball Earth?

Learning Objectives

1. Describe the characteristics of greenhouse vs. icehouse worlds
2. Understand what geologic processes modulate global climate over long time scales
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4. Explain what runaway feedback system may have led to an 'icehouse' world, otherwise known as the Snowball Earth

GEOLOGY 095, 195. Climate: past, present, future

Climate in the News

Climate change

Leading Australian engineers turn their backs on new fossil fuel projects

The Engineers Declare movement pledges to put climate considerations first in evaluating plans

Ben Smee

@BenSmee

Sun 20 Oct 2019 19.56 EDT

602

About 1,000 Australian engineers have signed a declaration calling for projects to be evaluated against climate considerations. Photograph: Raymond Warren/Alamy

Climate in the News

BROWSE Bloomberg Environment Search Environment & Energy News Advanced Search Go Login

Environment & Energy Report

Can Climate 'Test Cases' Move Forward? It's Up to Supreme Court

Oct. 18, 2019, 5:55 AM

- Oil companies face growing number of nuisance claims from local governments
- Proceedings could continue in state courts if Supreme Court doesn't step in

The Supreme Court is set to decide soon whether to greenlight state-court proceedings for several cases in which state and local government officials seek to hold oil companies accountable for their role in climate change.

Ellen M. Gilmer
Reporter

Related Articles

Court Order Opens New Front in SCOTUS

Climate in the News

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Linda Birnbaum in 2011 SCOTT J. FERRELL/CONGRESSIONAL QUARTERLY/GETTY IMAGES

Now retired, top U.S. environmental scientist feels free to speak her mind

By Warren Cornwall | Oct. 17, 2019 , 2:25 PM

Review: The Last 50 Million Years

Temp

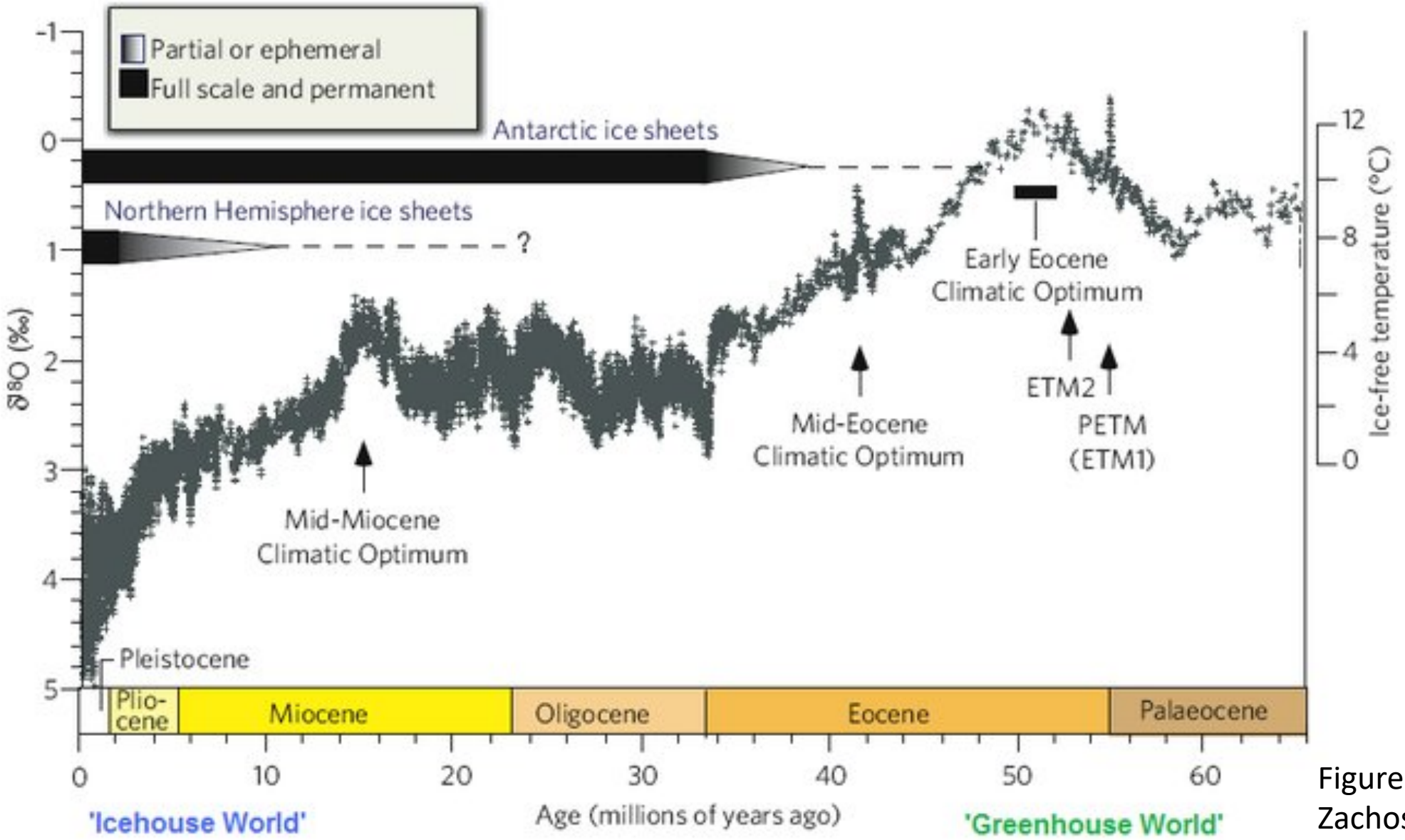
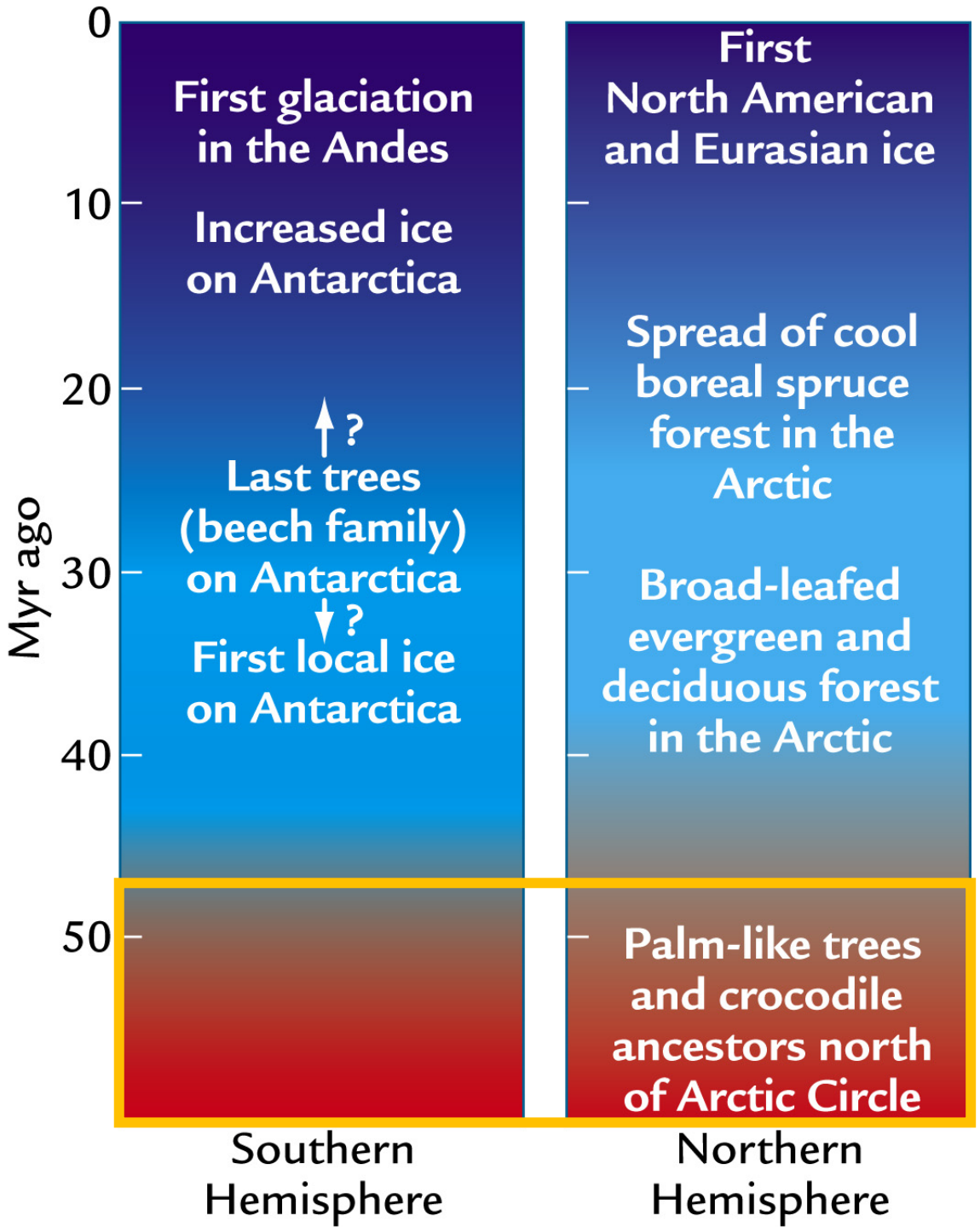
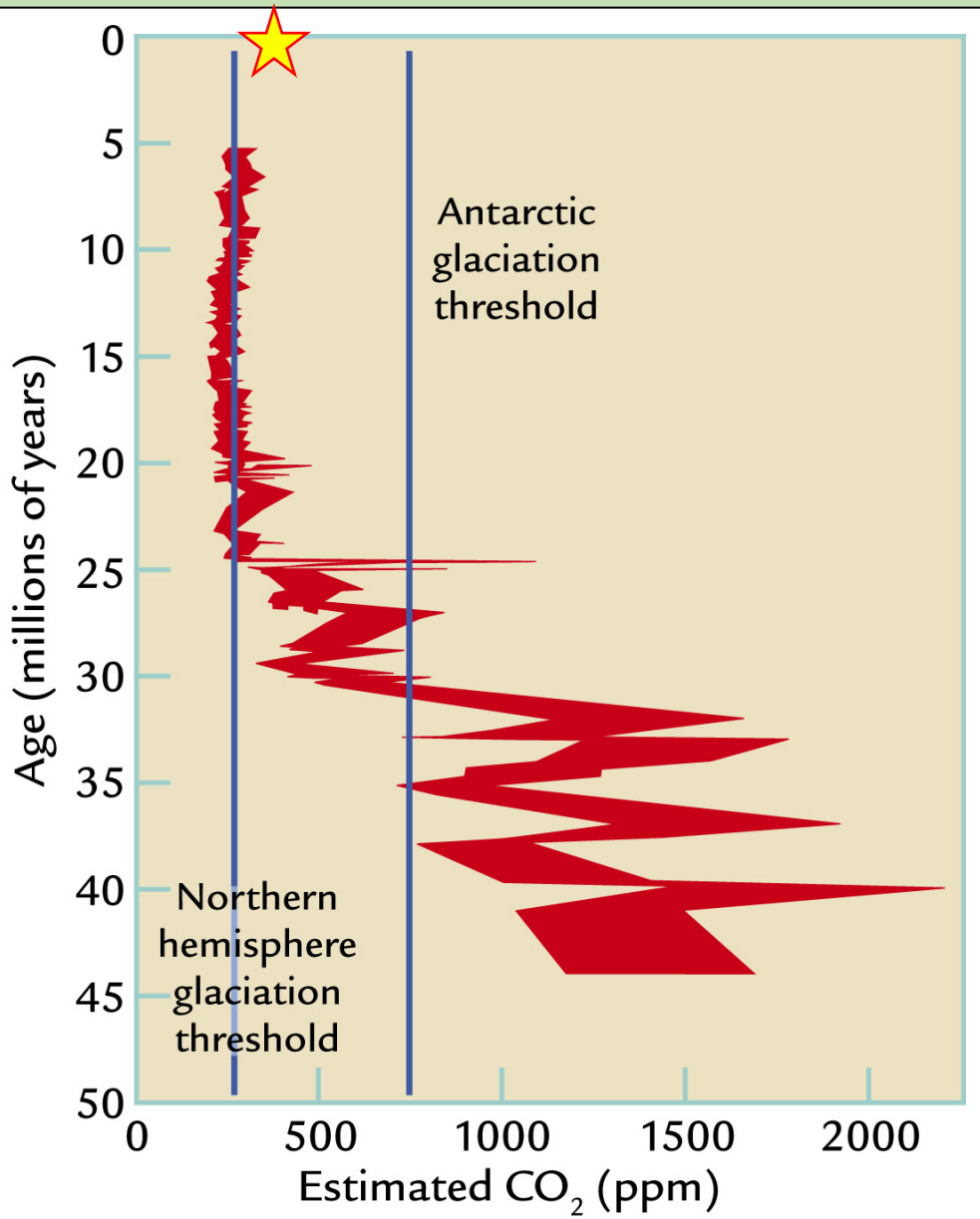


Figure from
Zachos et al. (2008)

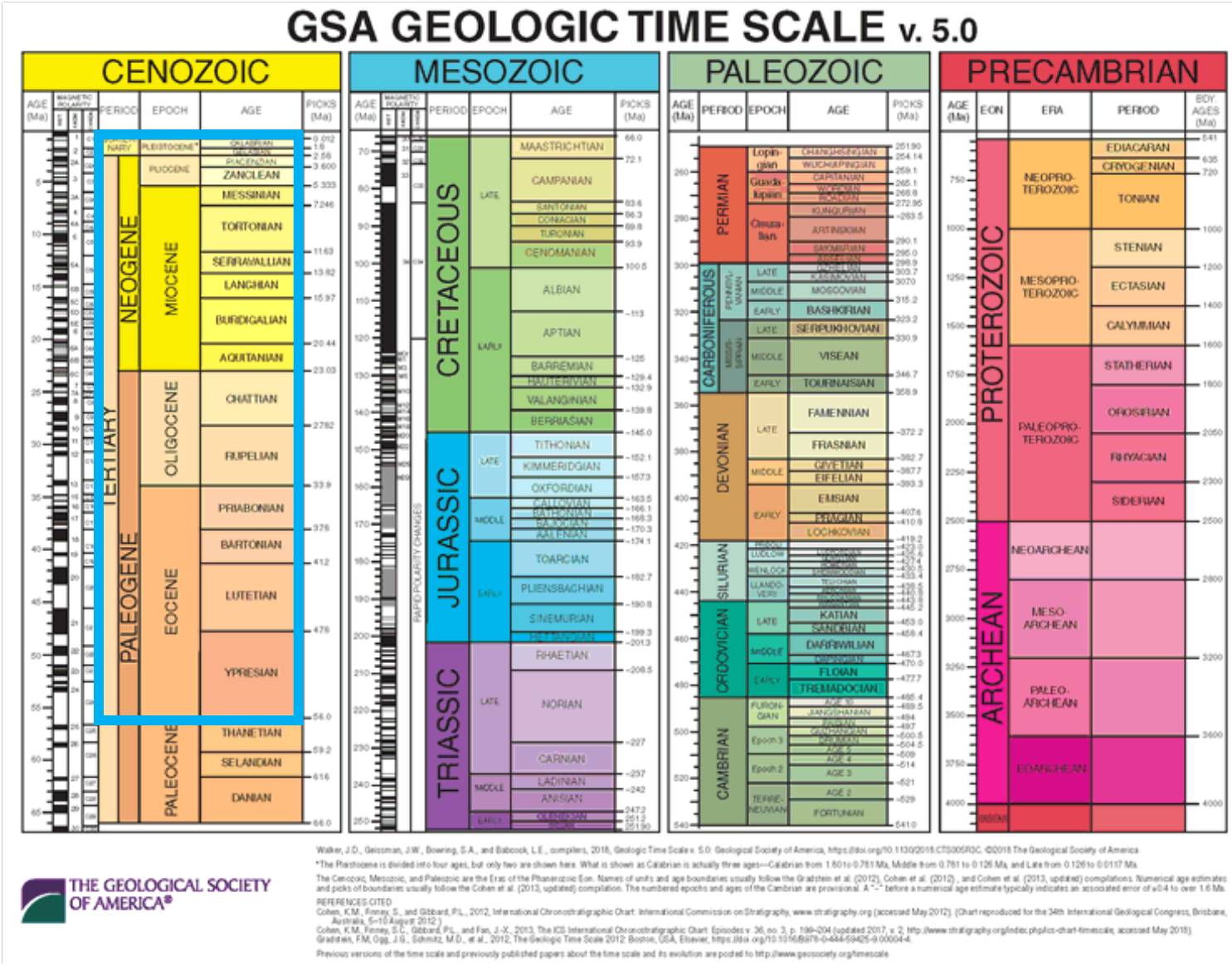

0
10
20
30
40
50
Myr ago
First glaciation in the Andes
Increased ice on Antarctica
?
Last trees (beech family) on Antarctica
?
First local ice on Antarctica
First North American and Eurasian ice
Spread of cool boreal spruce forest in the Arctic
Broad-leafed evergreen and deciduous forest in the Arctic
Palm-like trees and crocodile ancestors north of Arctic Circle
Southern Hemisphere
Northern Hemisphere

What explains the cooling?

- Atmospheric CO_2 lowered *a lot*
- Most likely due to a combination of:
- Reduced Volcanism
- Increased chemical weathering (due to the formation of the Himalayan Mountains)



Today's Class – Deep Time Paleoclimate

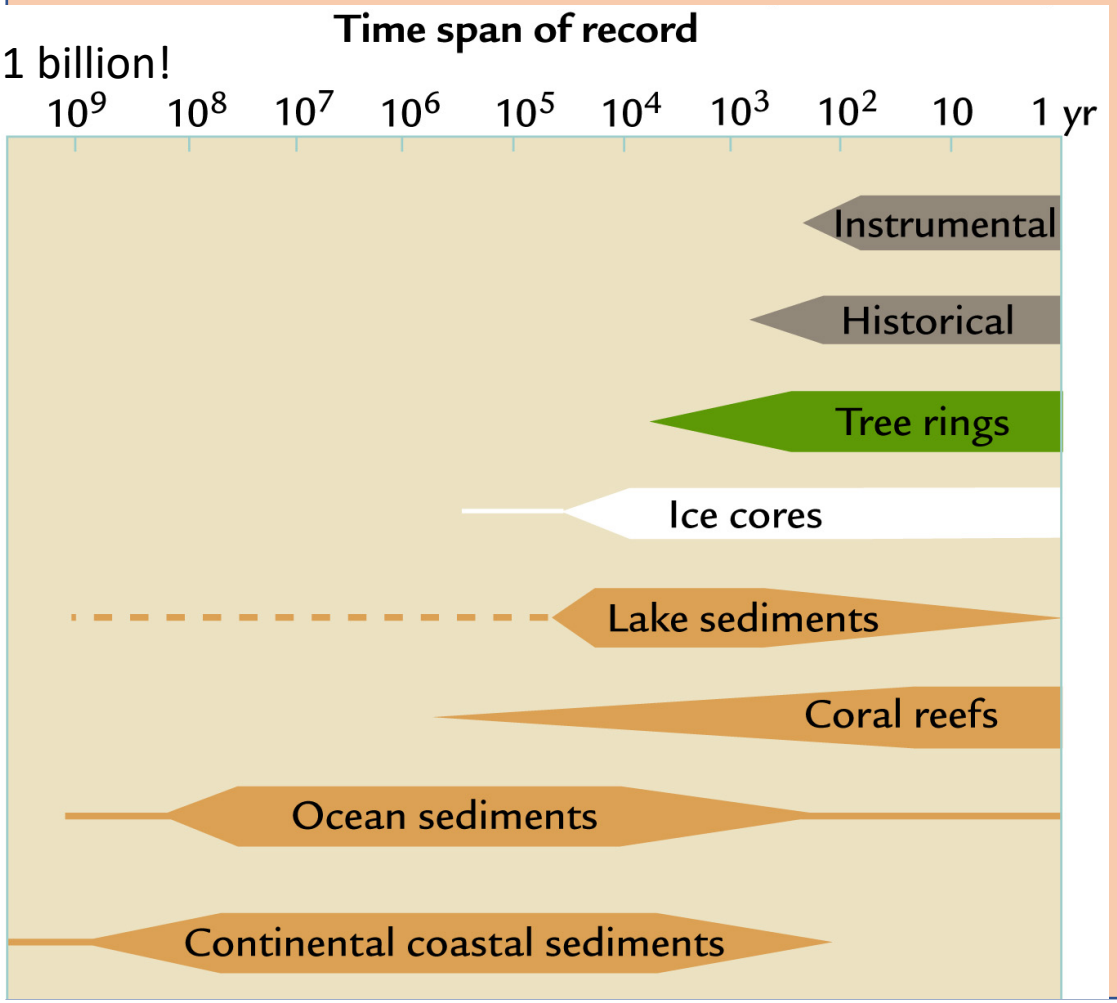


So far we've talked about ~50 million years in the Earth's ~4.5 billion year history…

What happened in the rest of it?

How Do We Know About Deep Time Paleoclimate?

1. Some Paleoclimate Archives



2. Rocks From the Past—the Geologic Record

3. Life from the Past — The Fossil Record

Today's Class – Deep Time Paleoclimate

Learning Objectives

1. **Describe the characteristics of greenhouse vs. icehouse worlds**
2. Understand what geologic processes modulate global climate over long time scales
3. Identify and explain one hypothesis about the cause(s) of hyperthermal events
4. Explain what runaway feedback system may have led to an 'icehouse' world, otherwise known as the Snowball Earth

Greenhouse vs. Icehouse Climates → CO_2 and Plate Tectonics → Greenhouse World example: the Cretaceous → Icehouse World Example: Snowball Earth

Greenhouse vs. Icehouse Worlds

Greenhouse World— Times when no ice sheets are present on Earth

Icehouse World— Times when ice sheets are present on Earth

Think Pair Share…Greenhouse vs. Icehouse Worlds

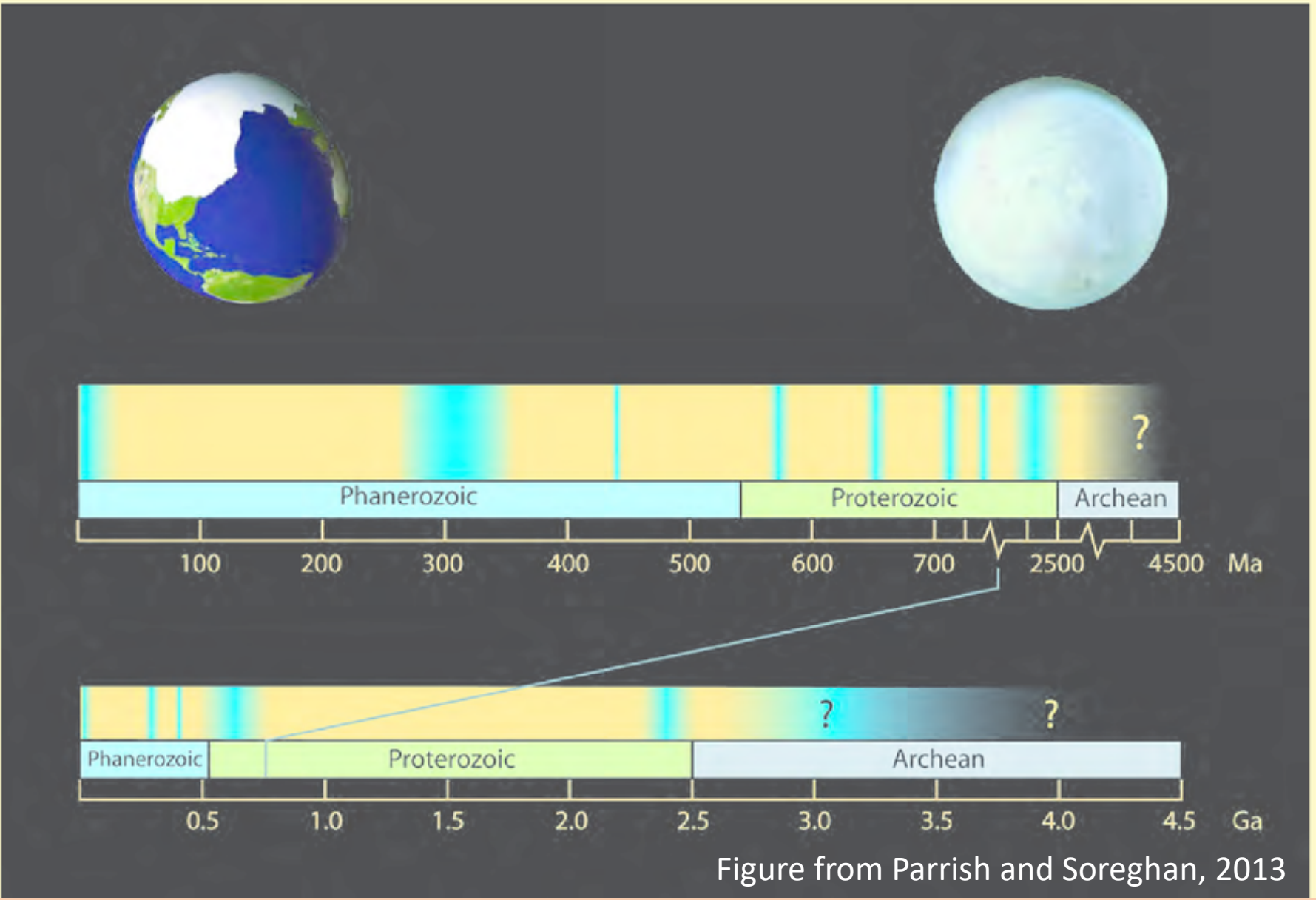


Figure from Parrish and Soreghan, 2013

Blue = icehouse world

Tan = greenhouse world

What observations can you make about the frequency and duration of greenhouse vs. icehouse climate conditions in Earth's history?

Today's Class – Deep Time Paleoclimate

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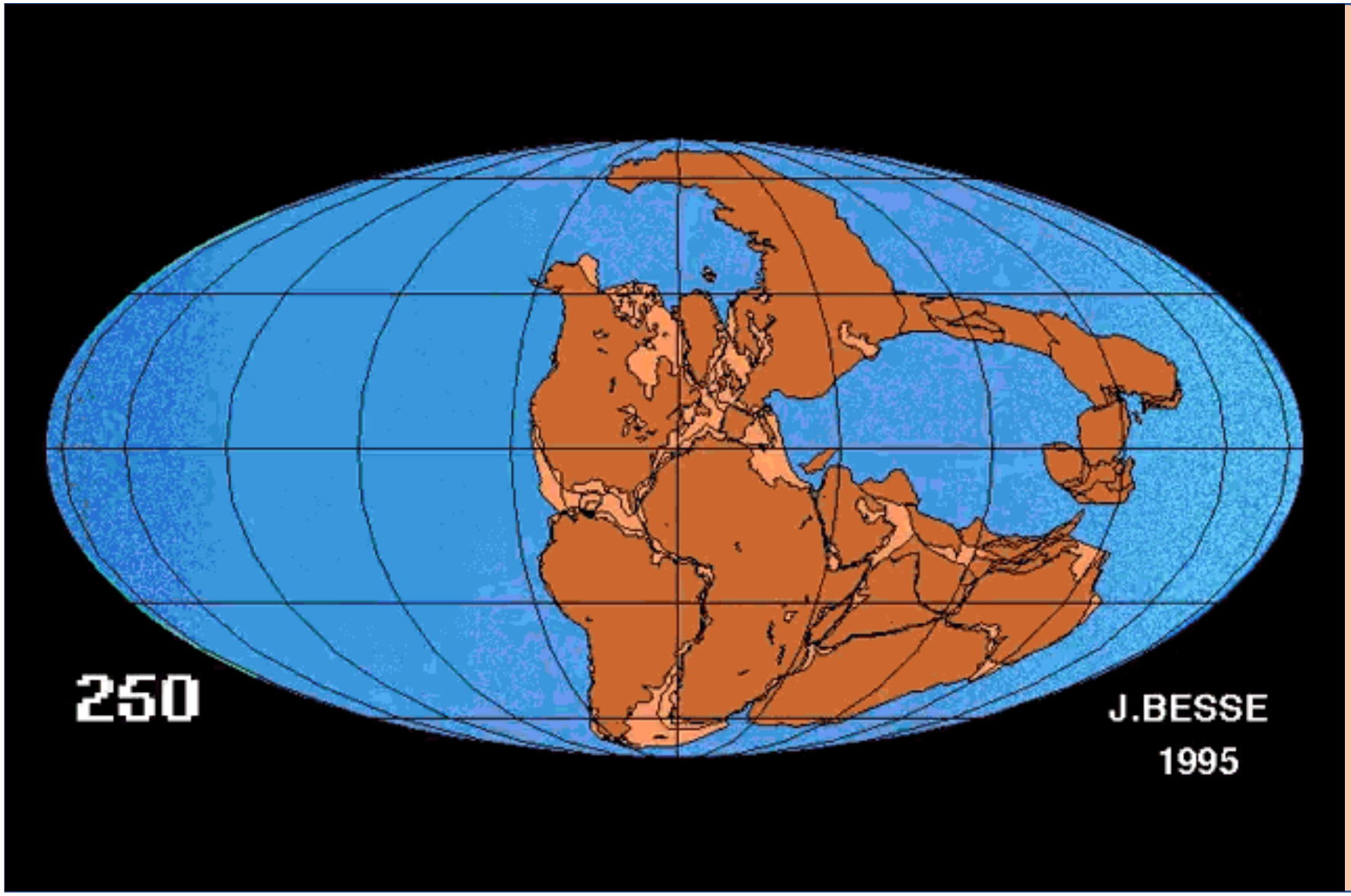
Greenhouse vs. Icehouse Climates → CO_2 and Plate Tectonics → Greenhouse World example: the Cretaceous → Icehouse World Example: Snowball Earth

What Causes Changes in Temperature over Deep Time?

What Causes Changes in CO_2?



Spreading plates = more volcanism = more CO_2 in the atmosphere

Colliding plates = mountain building = increased chemical weathering = less CO_2 in the atmosphere

Position of the continents also plays a role in climate

Today's Class – Deep Time Paleoclimate

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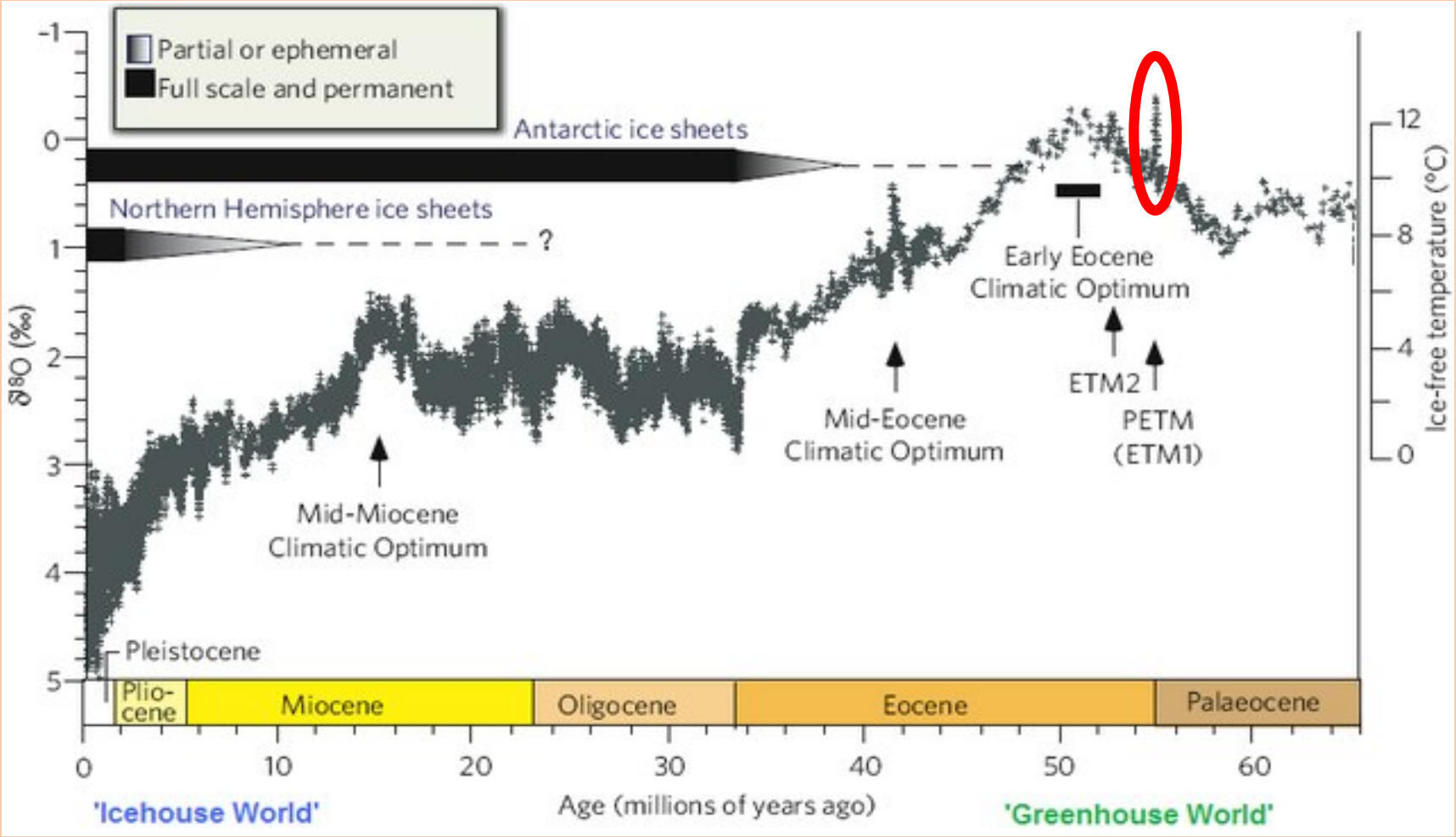
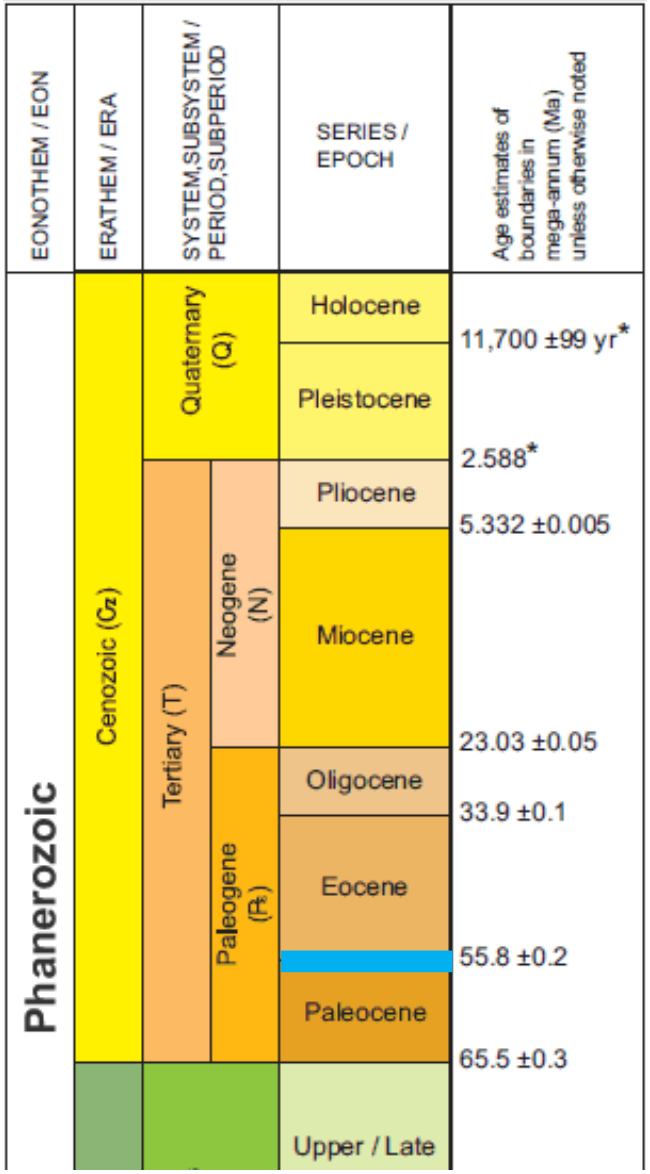
Greenhouse vs. Icehouse Climates → CO_2 and Plate Tectonics → Hyperthermal events → Greenhouse and Icehouse World Examples

Hyperthermals

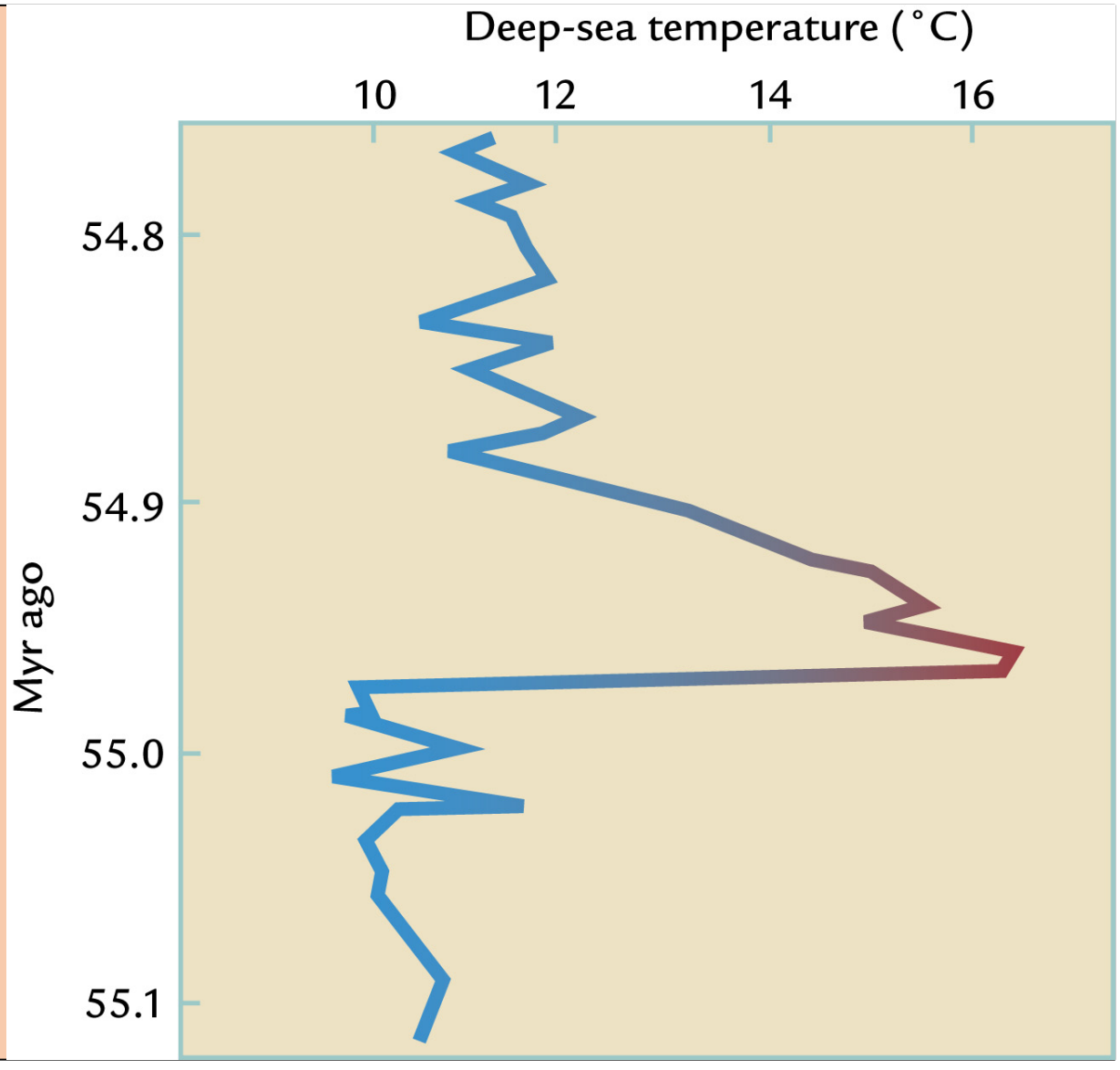


Hyperthermals: Times when the climate is *really* warm!

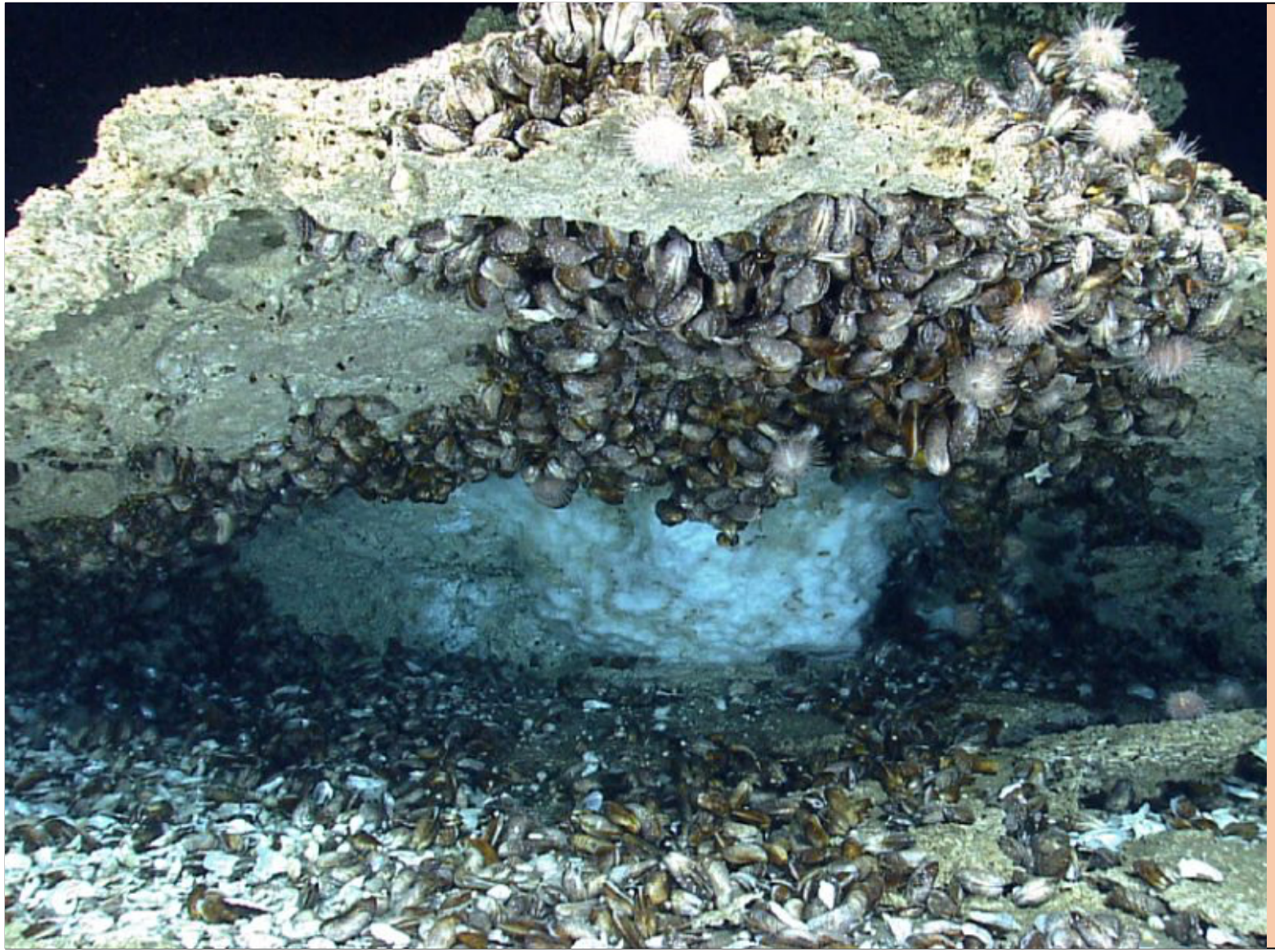
Hyperthermals



The Paleocene-Eocene Thermal Maximum



The PETM—An Analog to Current Warming?



- The release of methane from the deep ocean is something scientists are concerned about with human-induced warming

Today's Class – Deep Time Paleoclimate

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Greenhouse vs. Icehouse Climates → CO_2 and Plate Tectonics → Hyperthermal events → Greenhouse and Icehouse World Examples

Another Warm Time—the Cretaceous

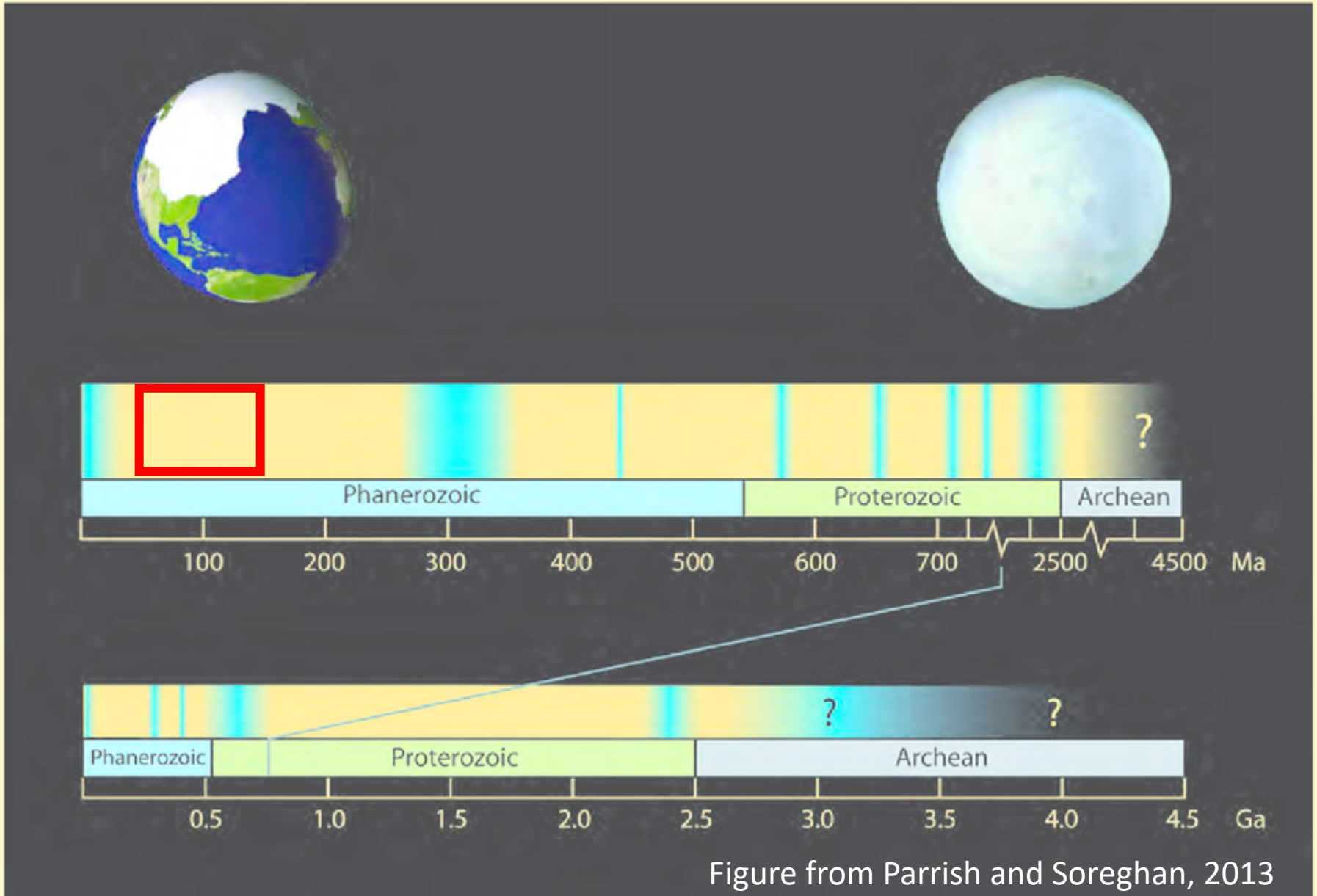
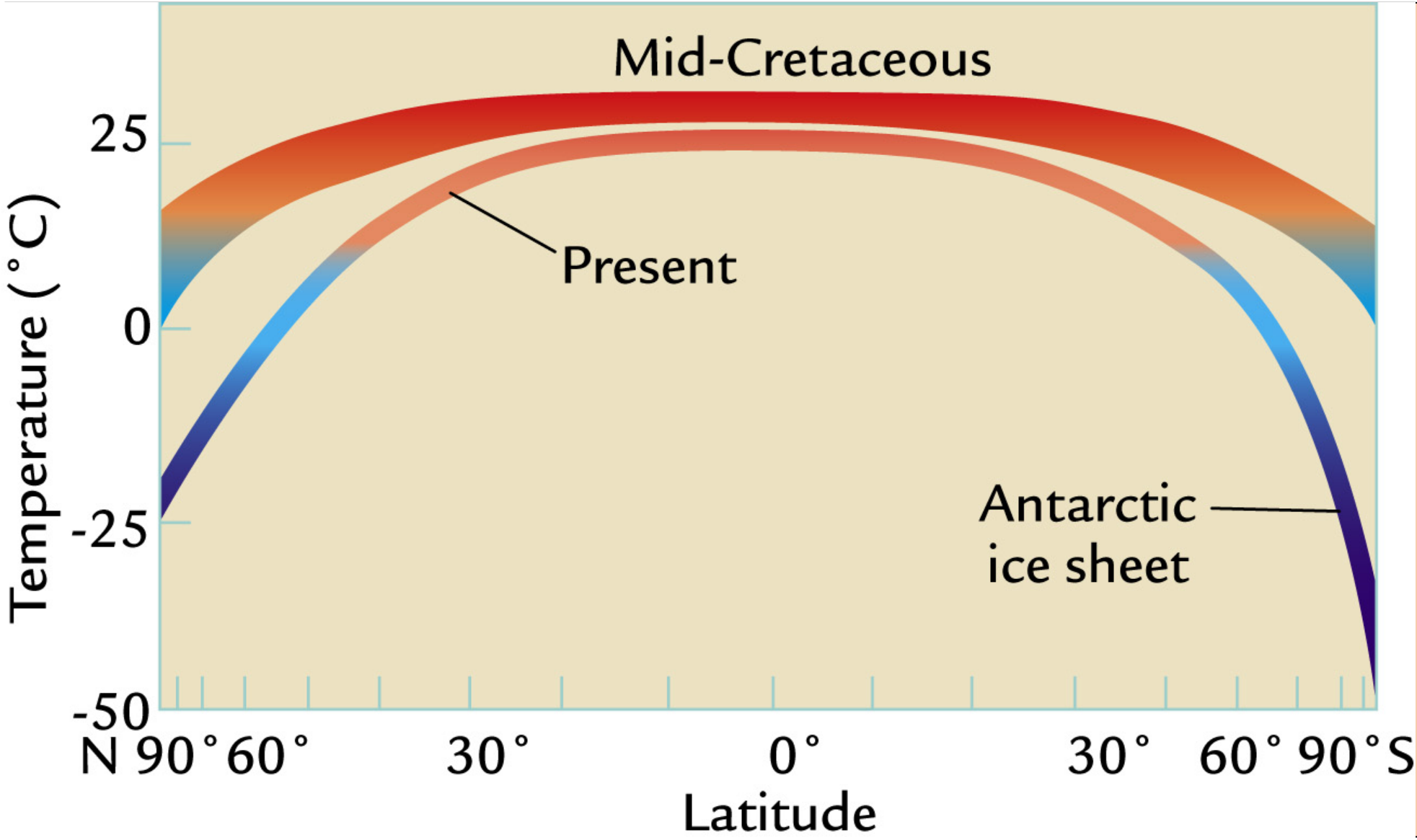


Figure from Parrish and Soreghan, 2013

The Cretaceous

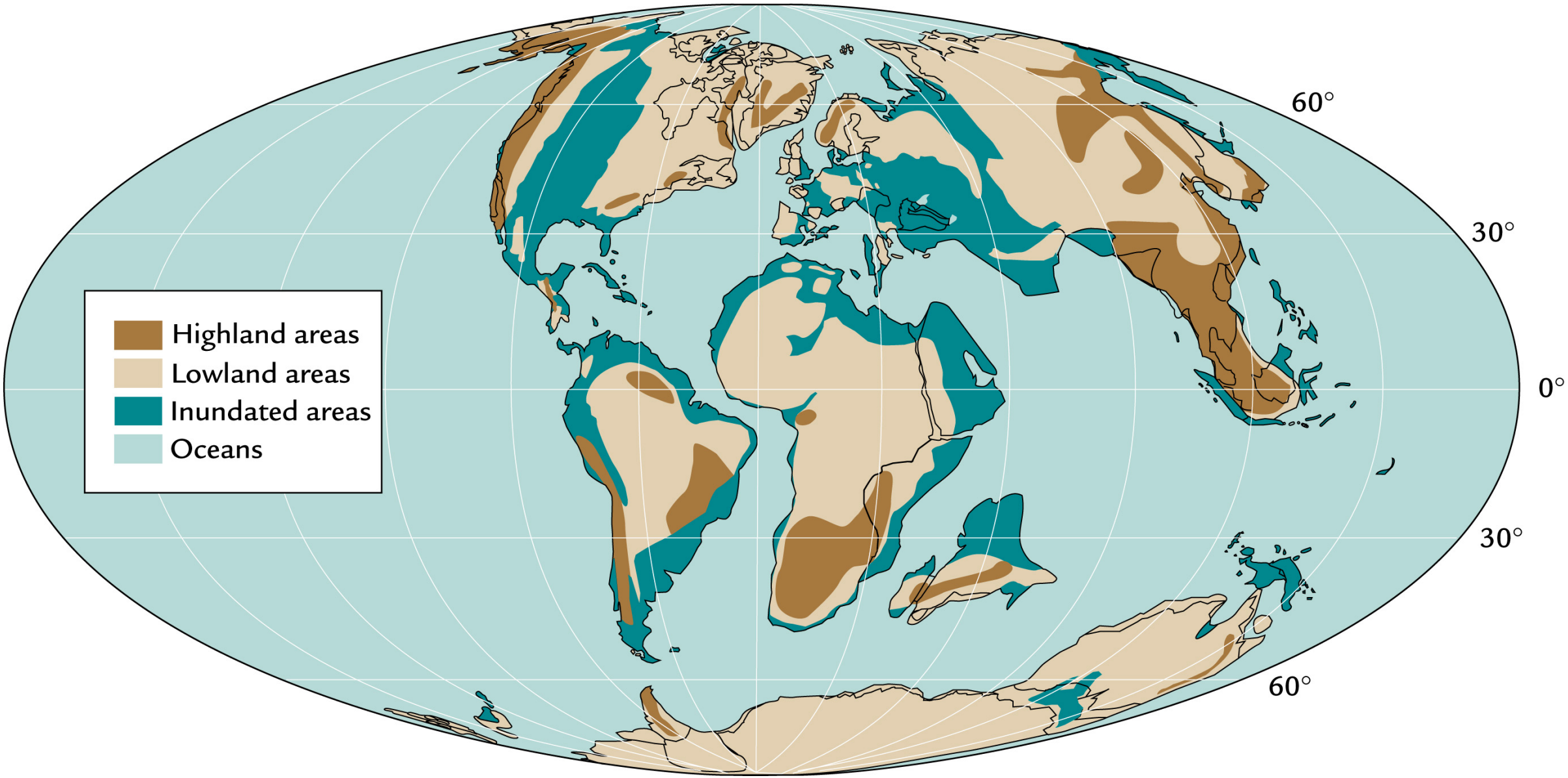
The Cretaceous



CO_2 levels were 4x higher than preindustrial levels

Polar temperatures were much warmer—no ice sheets

The Cretaceous



Today's Class – Deep Time Paleoclimate

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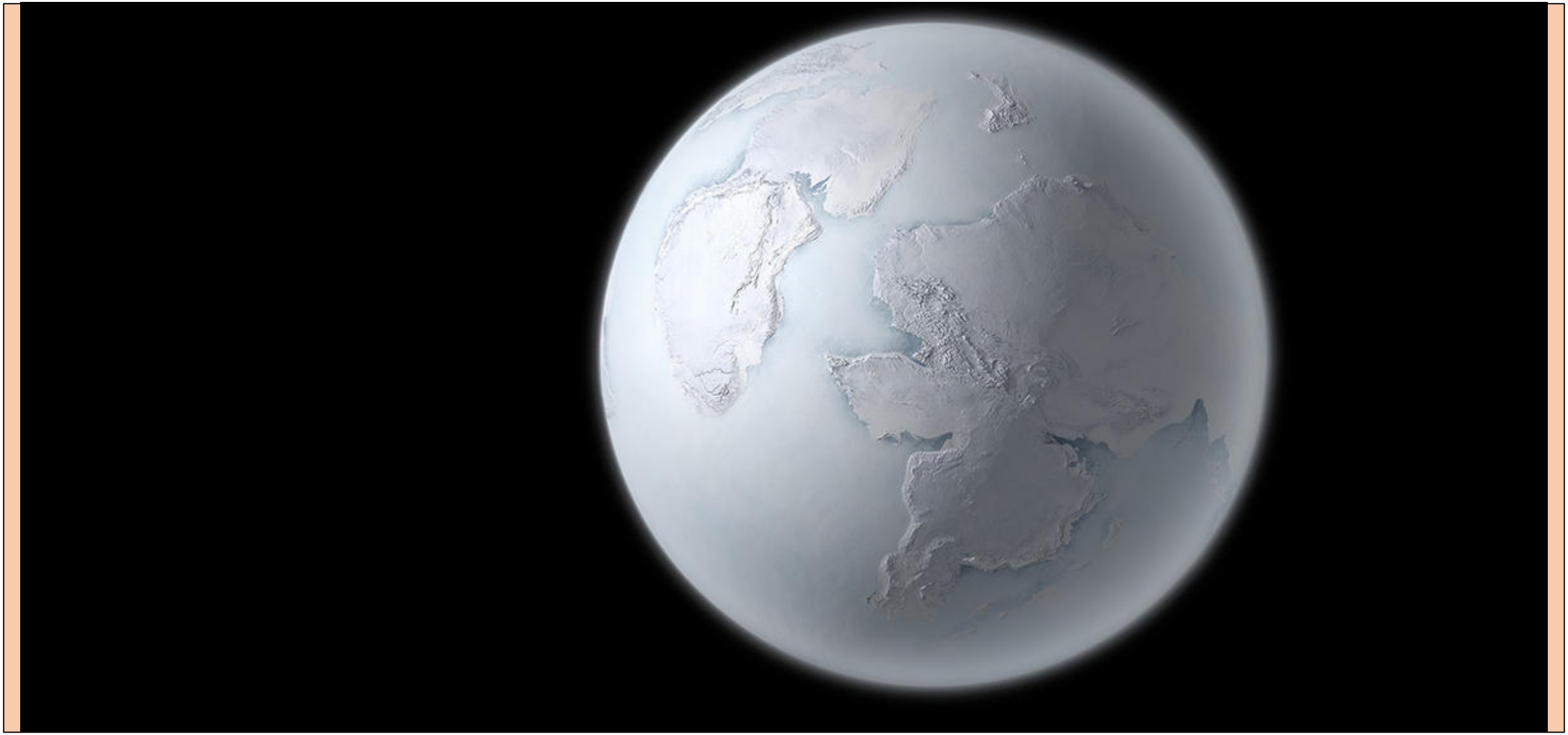
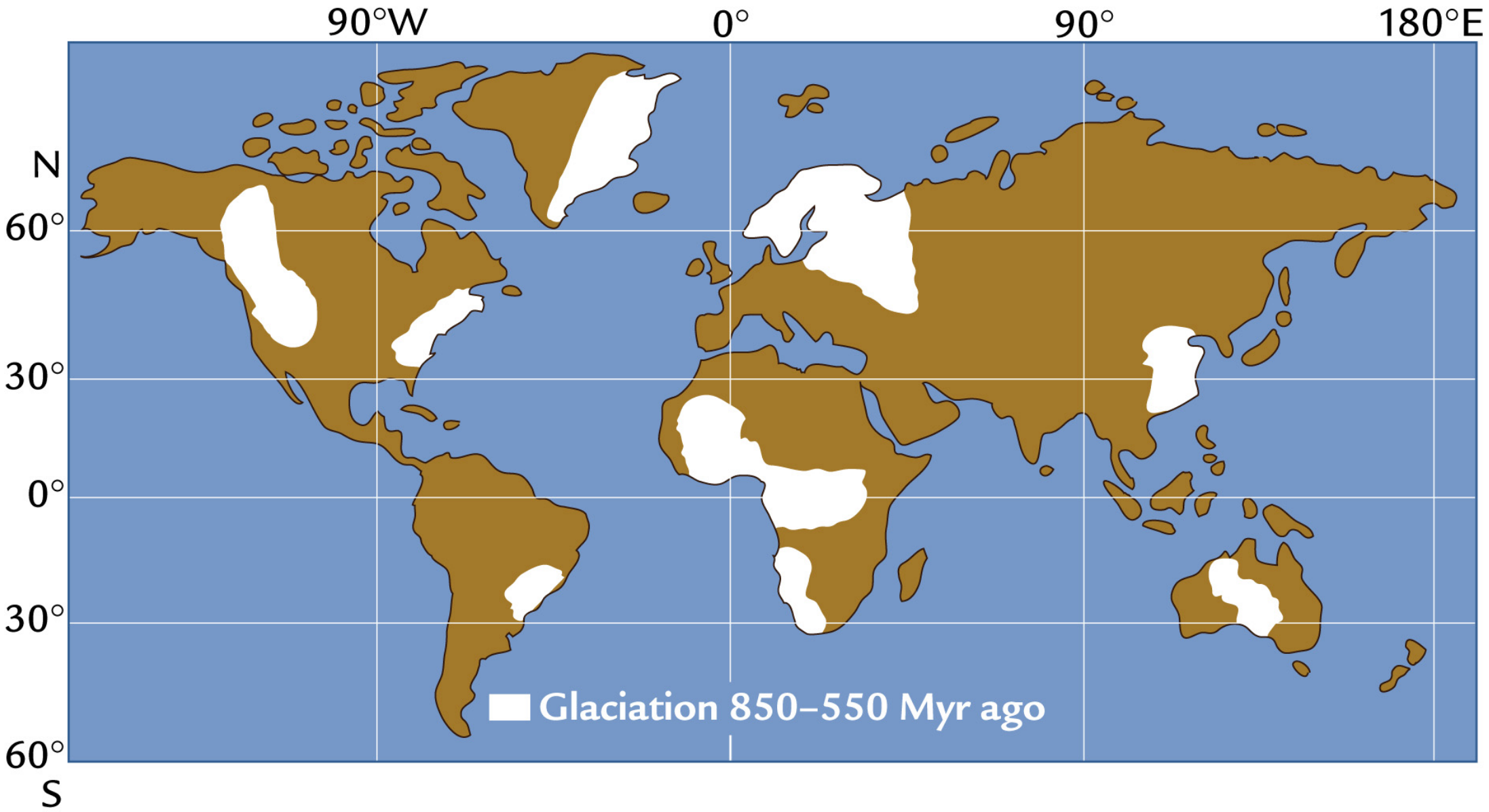
Greenhouse vs. Icehouse Climates → CO_2 and Plate Tectonics → Hyperthermal events → Greenhouse and Icehouse World Examples

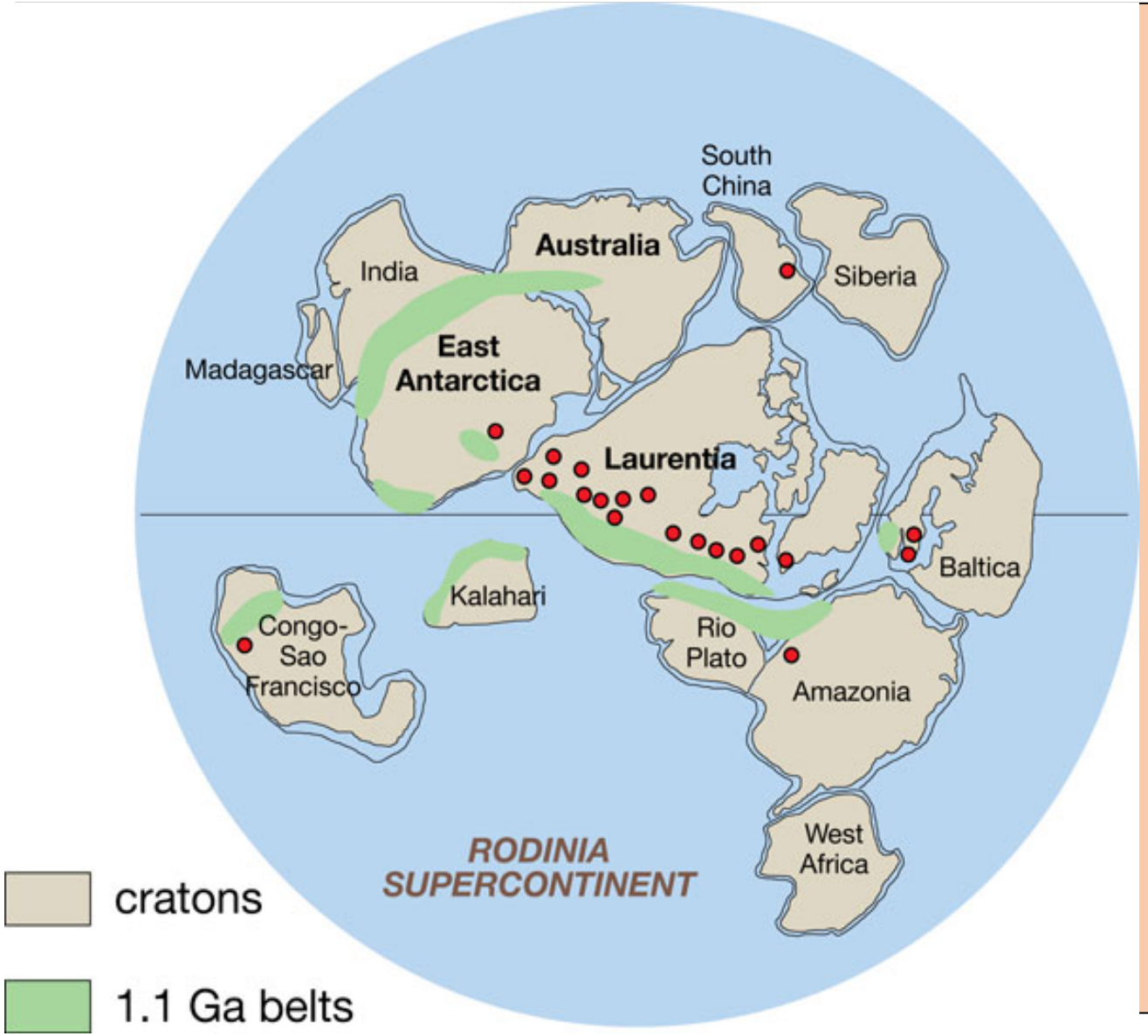
Snowball Earth



Snowball Earth



Snowball Earth



Continents were clustered at the Equator

High rainfall at the equator fell on the continents, causing an immense amount of chemical weathering

Chemical weathering removed a lot of CO_2 from the atmosphere, causing initial cooling

Snowball Earth

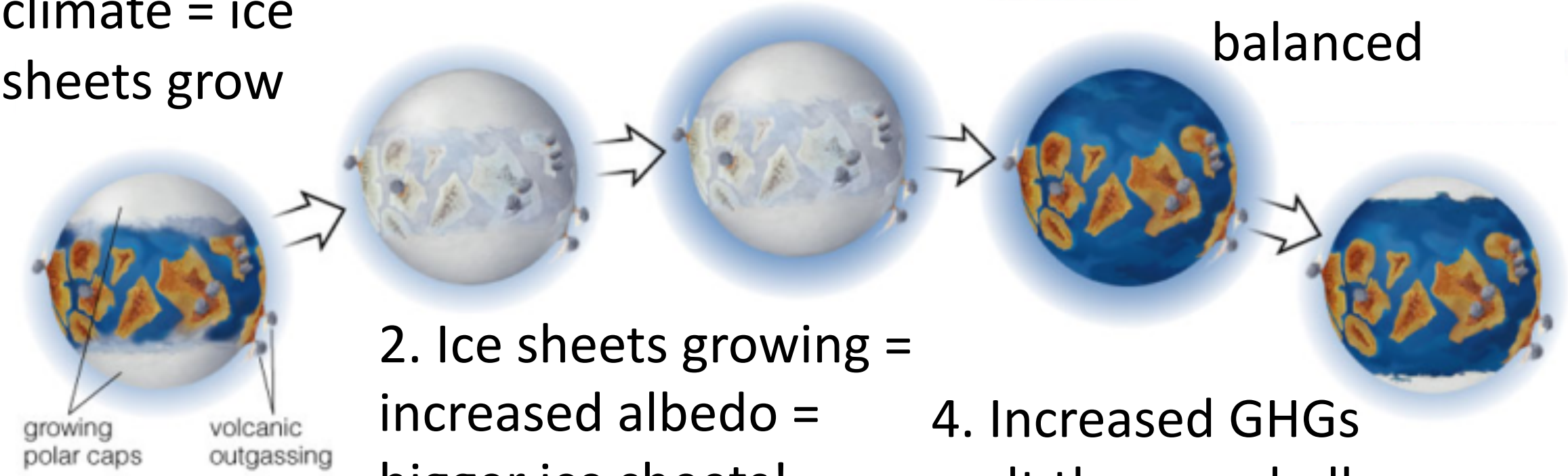
1. Cooler climate = ice sheets grow

2. Ice sheets growing = increased albedo = bigger ice sheets!

3. Ocean stops storing new carbon, CO_2 builds up in atmosphere

4. Increased GHGs melt the snowball

5. Ocean carbon transport resumes, climate is re-balanced

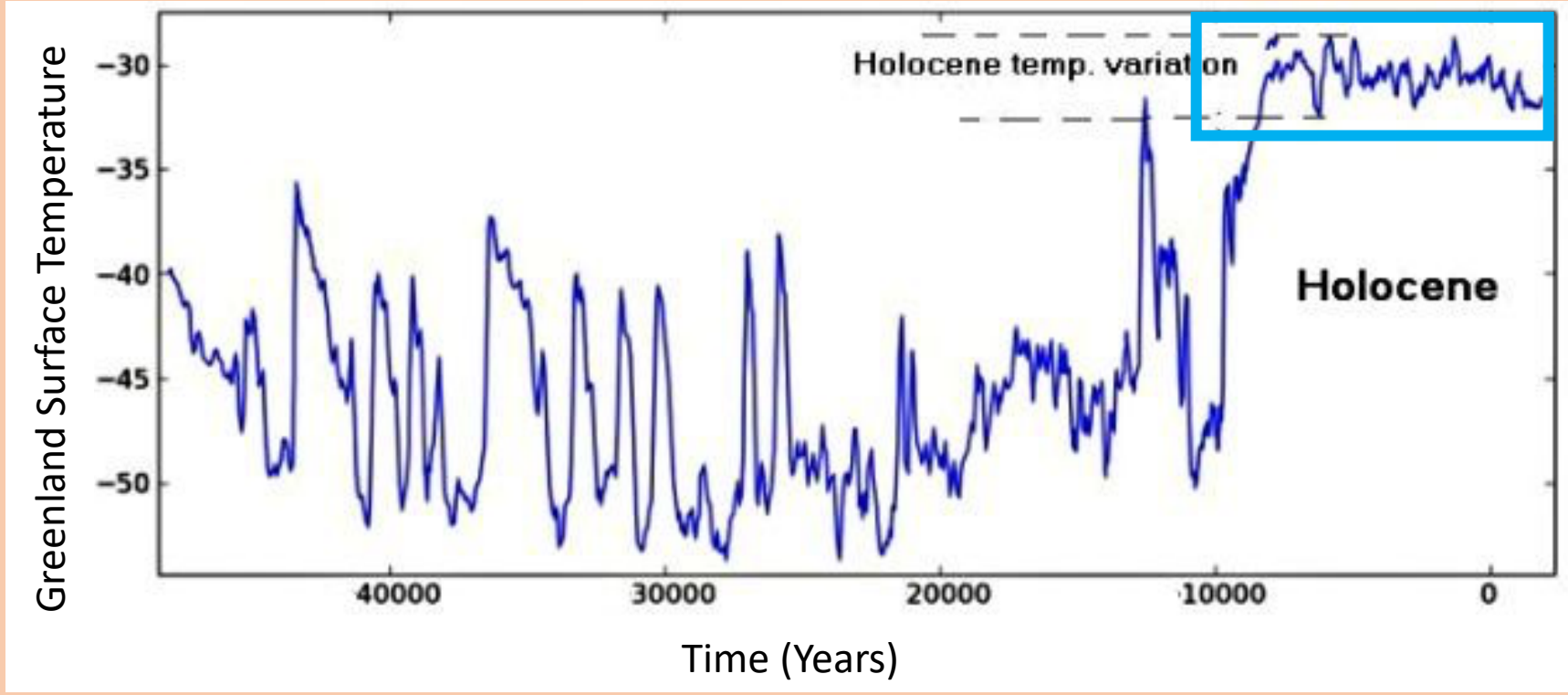


Summary: Deep Time Paleoclimate

- The Earth's climate has shifted between greenhouse and icehouse conditions numerous times in its history
- Changes in temperature over long timescales are caused by plate tectonic processes that increase or decrease CO_2 in the atmosphere
- Extreme changes in the amount of CO_2 in the atmosphere have caused both extremely warm and extremely cold climate conditions
- Studying these past warm periods can help us learn about changes that may occur as a result of human-caused warming

Review— The Holocene

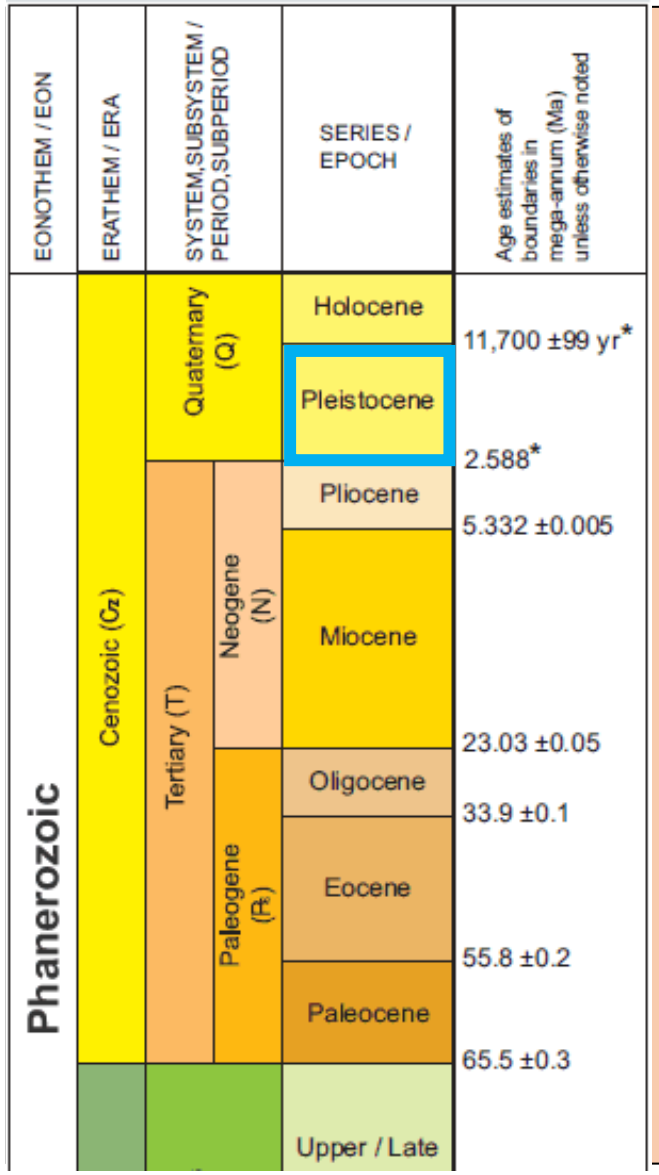
EONOTHEM / EON	ERATHEM / ERA	SYSTEM,SUBSYSTEM / PERIOD,SUBPERIOD	SERIES / EPOCH	Age estimates of boundaries in mega-annum (Ma) unless otherwise noted
Phanerozoic	Cenozoic (Cz)	Quaternary (Q)	Holocene	11,700 ±99 yr*
			Pleistocene	2.588*
		Tertiary (T) / Neogene (N)	Pliocene	5.332 ±0.005
			Miocene	23.03 ±0.05
		Tertiary (T) / Paleogene (R)	Oligocene	33.9 ±0.1
			Eocene	55.8 ±0.2
			Paleocene	65.5 ±0.3
			Upper / Late	

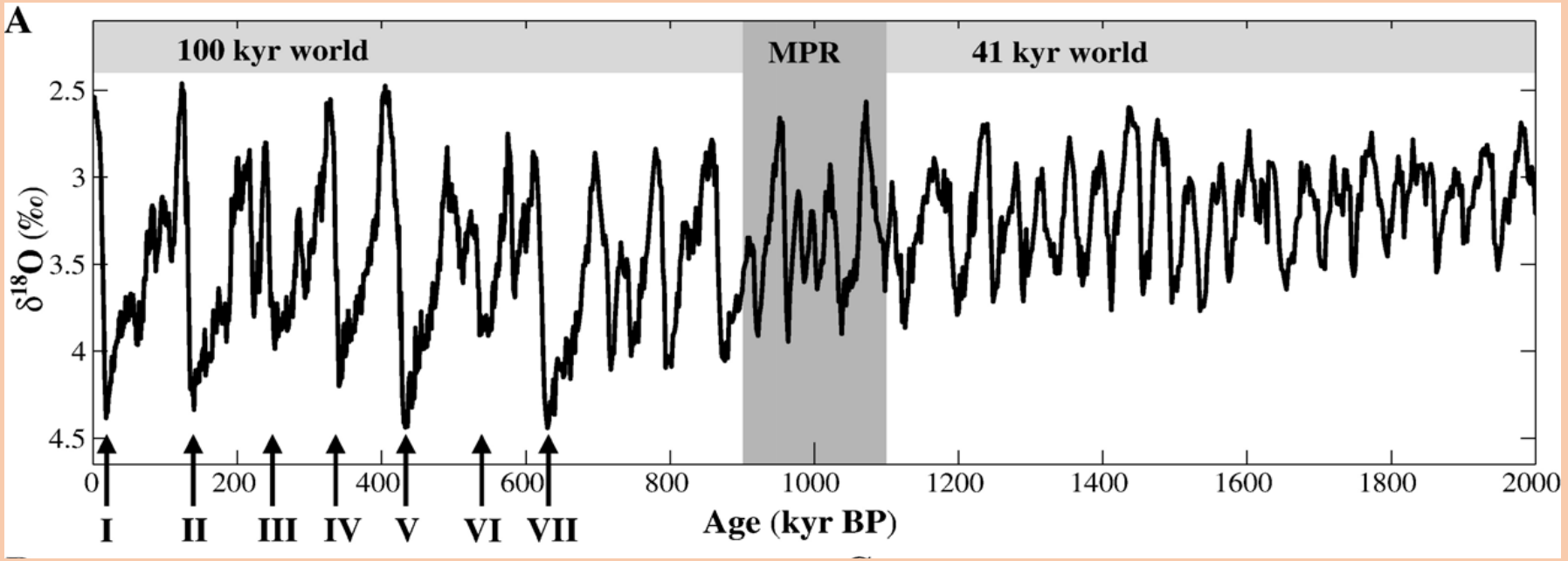


Holocene: 11,700 years ago to present

Characterized by stable temperatures, sea levels, and CO_2

Review— The Pleistocene





Pleistocene: 11,700-2.6 million years ago

Characterized by ‘sawtooth’ pattern of temperatures, slow build up to glaciers and rapid retreat

Review– The Last 50 million Years

EONOTHEM / EON	ERATHEM / ERA	SYSTEM,SUBSYSTEM / PERIOD,SUBPERIOD	SERIES / EPOCH	Age estimates of boundaries in mega-annum (Ma) unless otherwise noted
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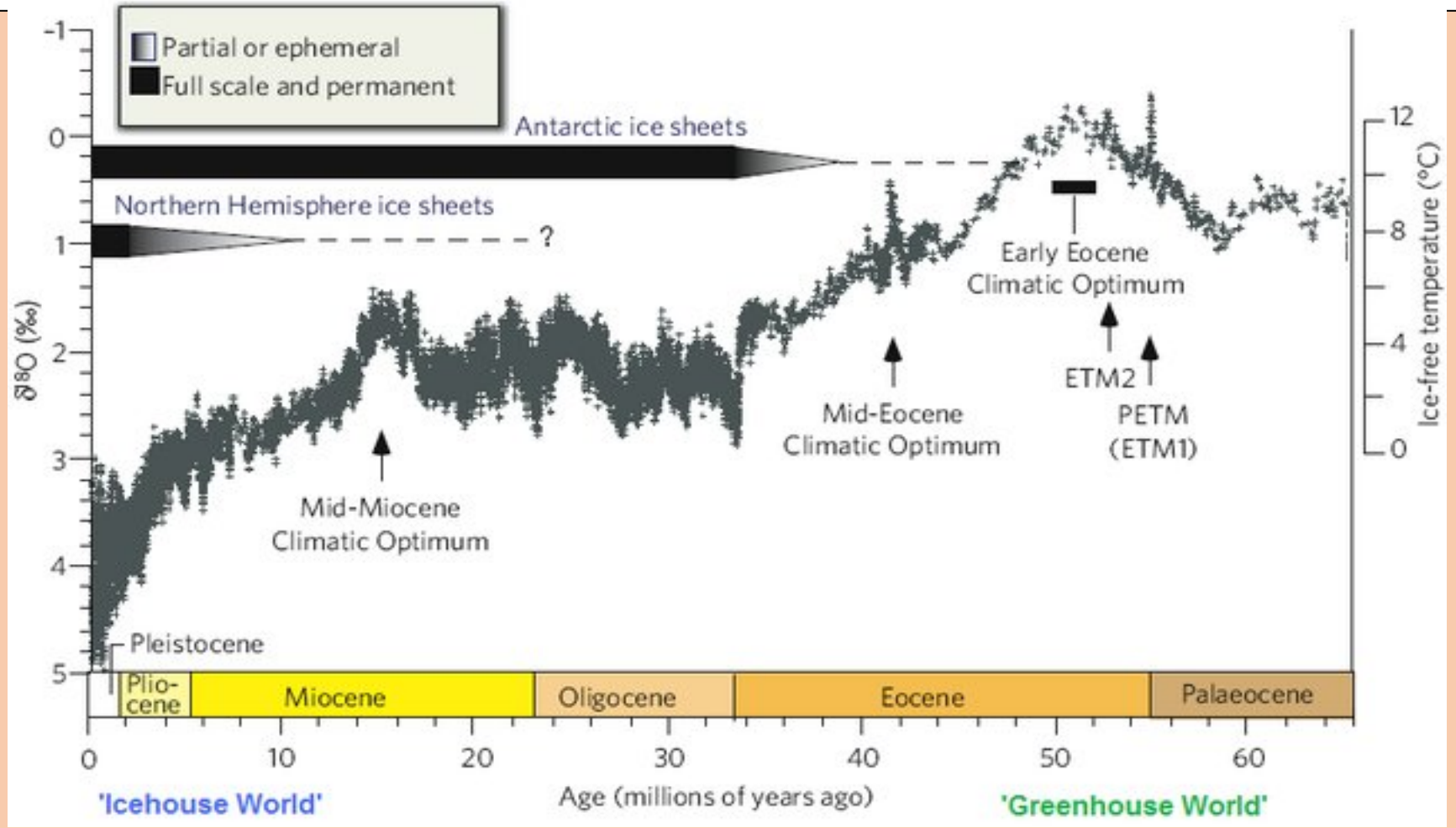

2.5-50 million years ago: Climate is overall much warmer than the Pleistocene and the Holocene

Review– Deep Time

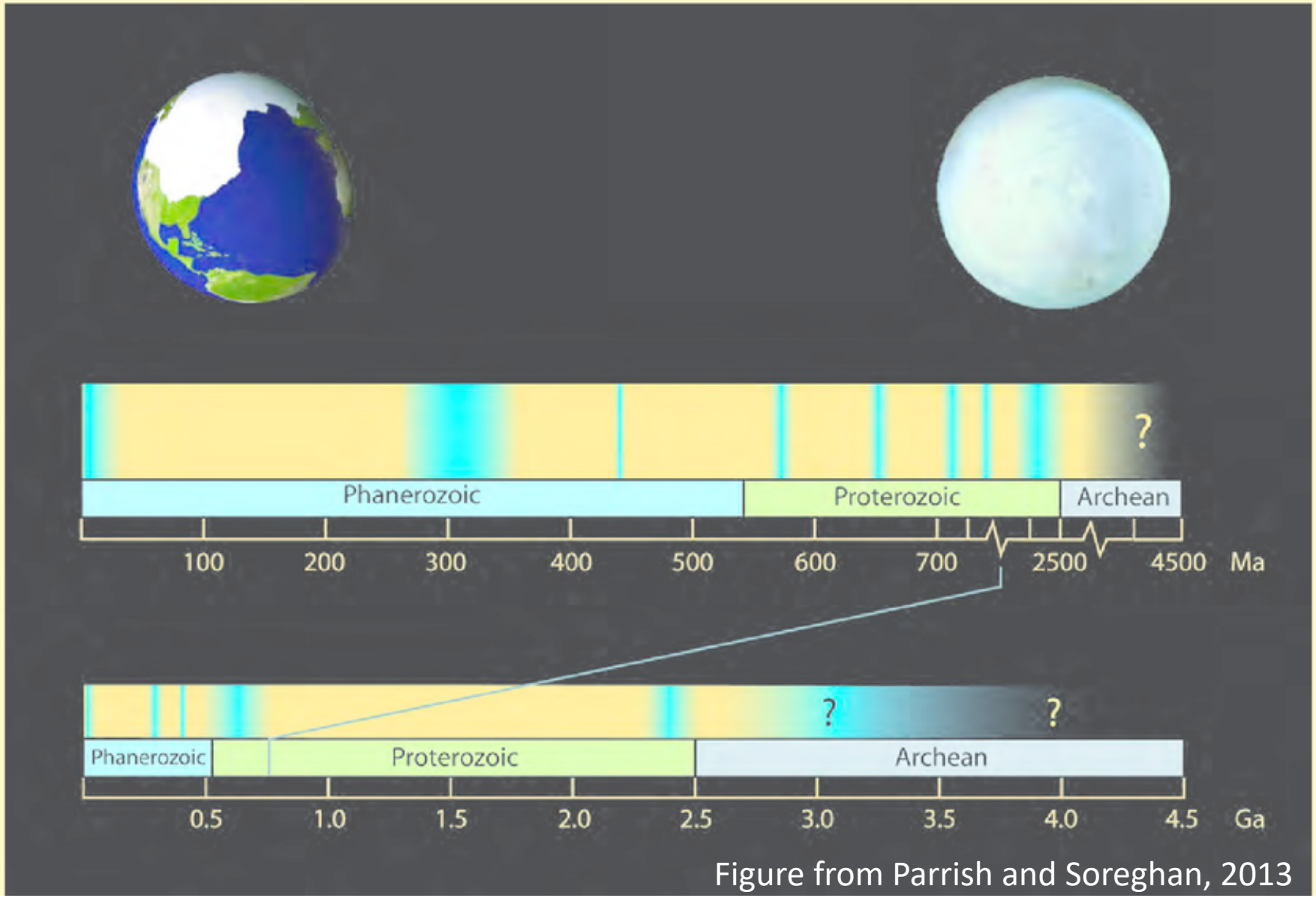

Figure from Parrish and Soreghan, 2013

Over long timescales, Earth has fluctuated between Greenhouse and Icehouse conditions

Changes driven by plate tectonics

Review Session Time

- Exam is the same format as last time– 1 essay, short answer questions.
- Not cumulative, just paleoclimate.
- Has to be taken during class time.
- Still open book and open note.
- On your honor not to give or receive help from anyone.

- This is your time, ask us questions!