Paleoclimate

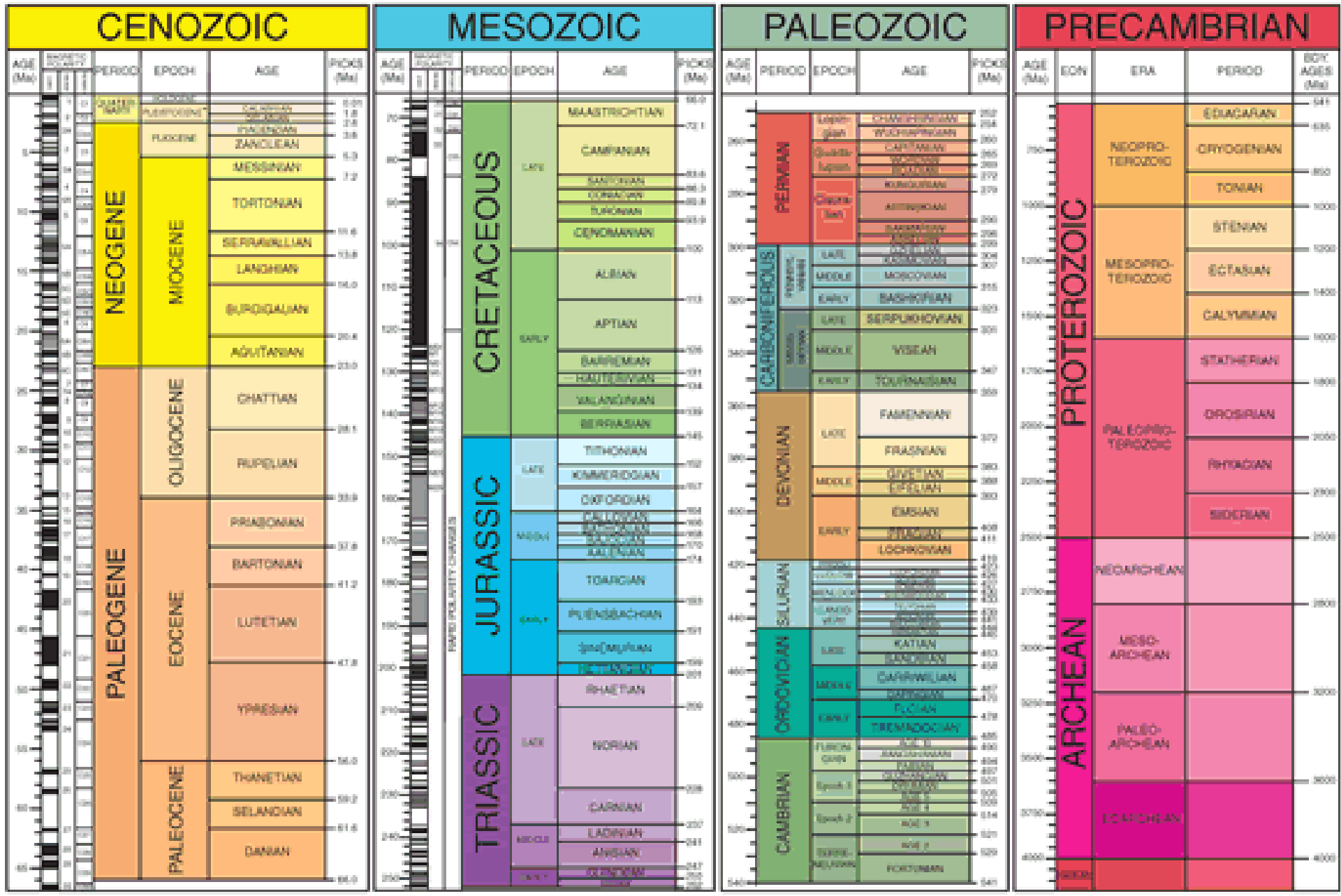
Deep Time

- The Bible

Hutton's Unconformity

Other Approaches

- Josiah Whitney and “Grand Cataclysm” of Yosemite
- Victorian resistance to Enlightenment ideas
- L.A. and the Evangelical movement
- Modern:
  - The Discovery Institute
  - Ken Hamm and the Creation Museum
  - Young Earth/Old Earth Creationism
  - Progressive Creationism & Intelligent Design
  - Michael Behe and “irreducible complexity”


CENOZOIC
MESOZOIC
PALEOZOIC
PRECAMBRIAN
AGE (Ma)
PERIOD
EPOCH
AGE
PICKS (Ma)
NEOGENE
PALEOGENE
QUATERNARY
NEOGENE
PALEOGENE
PLIOCENE
MIOCENE
OLIGOCENE
EOCENE
PALEOCENE
ZANCLEAN
MESSINIAN
TORTONIAN
SERRAVALLIAN
LANGHIAN
BURDIGALIAN
AQUITANIAN
CHATTIAN
RUPELIAN
PRIABONIAN
BARTONIAN
LUTETIAN
YPRESIAN
THANETIAN
SELANDIAN
DANIAN
CRETACEOUS
JURASSIC
TRIASSIC
MAASTRICHTIAN
CAMPANIAN
SANTONIAN
CONIACIAN
TURONIAN
CENOMANIAN
ALBIAN
APTIAN
BARREMIAN
HAUTERIVIAN
VALANGINIAN
BERRIASIAN
TITHONIAN
KIMMERIDGIAN
OXFORDIAN
CALLOVIAN
BATHONIAN
BAJOCIAN
AALENIAN
TOARCIAN
PLIENSBACHIAN
SINEMURIAN
HETTANGIAN
RHAETIAN
NORIAN
CARNIAN
LADINIAN
ANISIAN
PERMIAN
CARBONIFEROUS
DEVONIAN
SILURIAN
ORDOVICIAN
CAMBRIAN
KATIAN
HIRNANTIAN
FAMENNIAN
FRASNIAN
EMSIAN
LOCHKOVIAN
TOURNAISIAN
VISEAN
SERPUKHOVIAN
MOSCOVIAN
BASHKIRIAN
TREMADOCIAN
FORTUNIAN
ARCHEAN
PROTEROZOIC
EON
ERA
PERIOD
BGY AGES (Ma)
NEOARCHEAN
MESO-ARCHEAN
PALEO-ARCHEAN
EOARCHEAN
NEOPRO-TEROZOIC
MESOPRO-TEROZOIC
PALEOPRO-TEROZOIC
EDIACARAN
CRYOGENIAN
TONIAN
STENIAN
ECTASIAN
CALYMMIAN
STATHERIAN
OROSIRIAN
RHYACIAN
SIDERIAN

A Climatologist's Geologic Tools

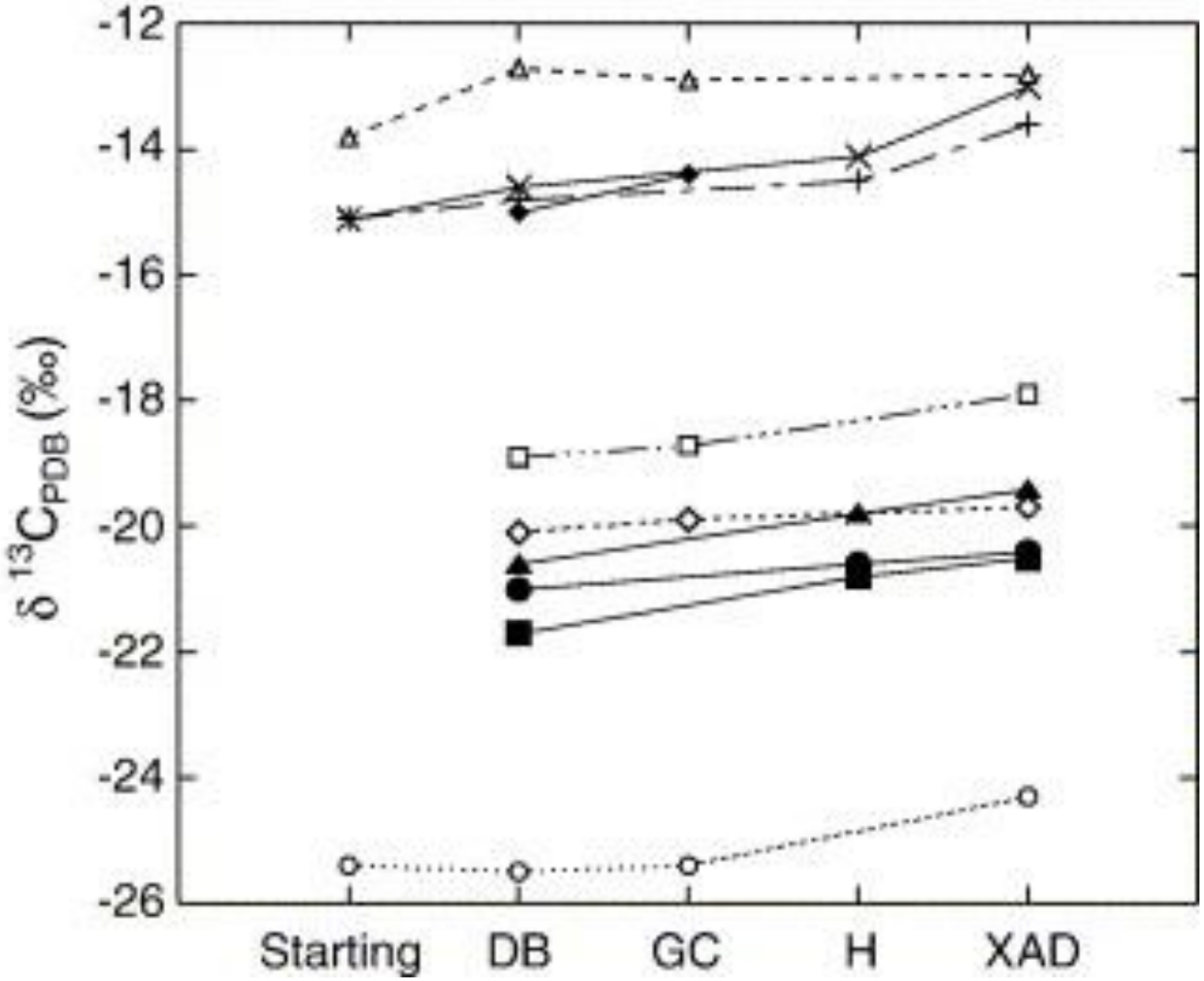
1. Lithology
2. Isotope Chemistry
3. Proxy thermometers
4.Trace Element Substitution

More recent durations only:
5. Dendrochronology
6. Scleroclimatology
7. Stalactite & Stalagmite
8. Ice Core composition
9. Sediment cores

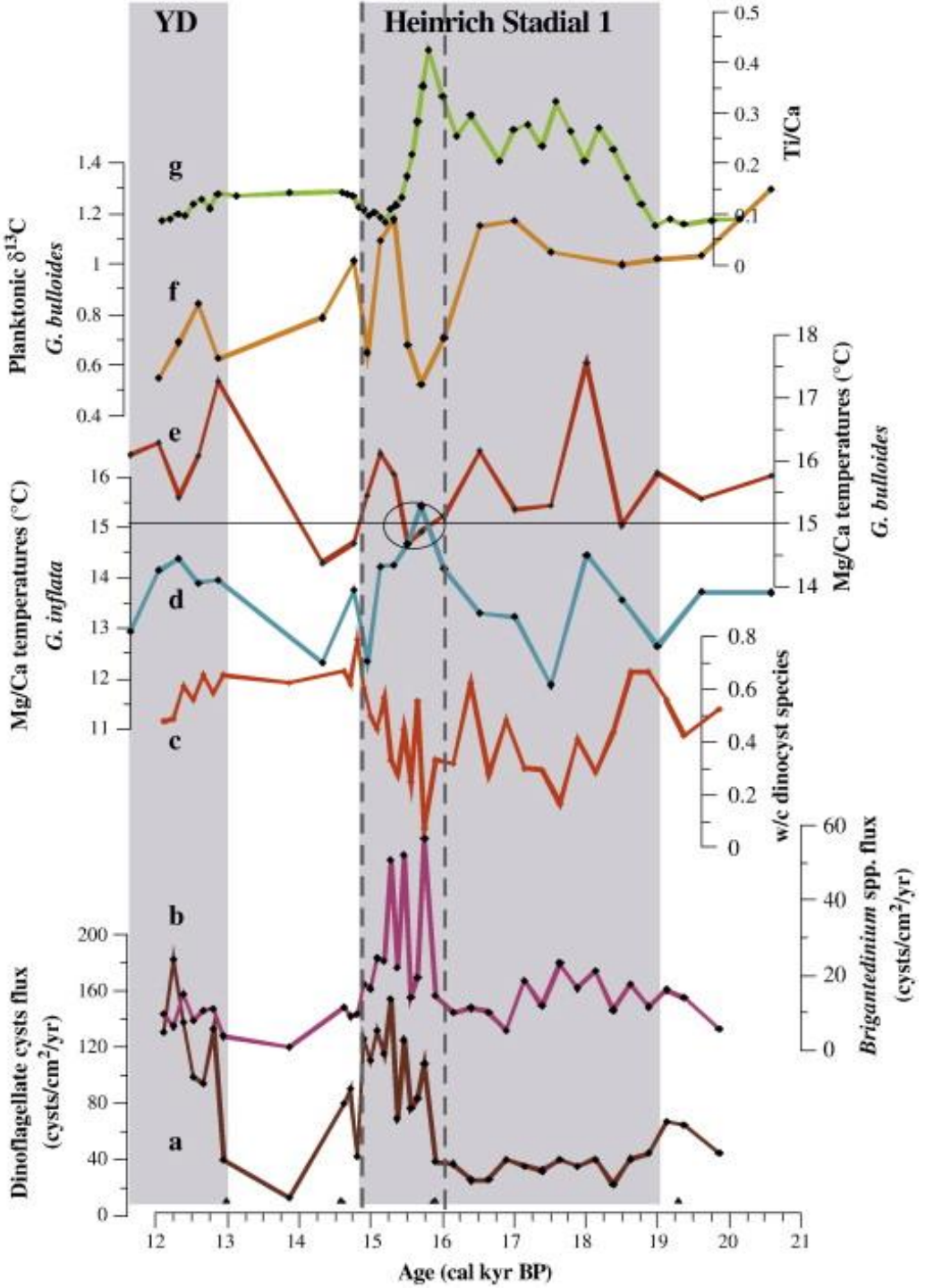
Lithology

- Sedimentary Structures
- Carbon Sequestration
  - Coal
  - Oil Shales
  - Limestone
  - Coccolithophores (DMS emitters, brighter oceans)
- Vulcanism
- Dunes and desert pavement (thermoluminescence, OSL)
- Glaciers (till/moraines)
- dropstones (icebergs)
- Loess
- Ikaites, Calcretes, Evaporites, Tropical laterites

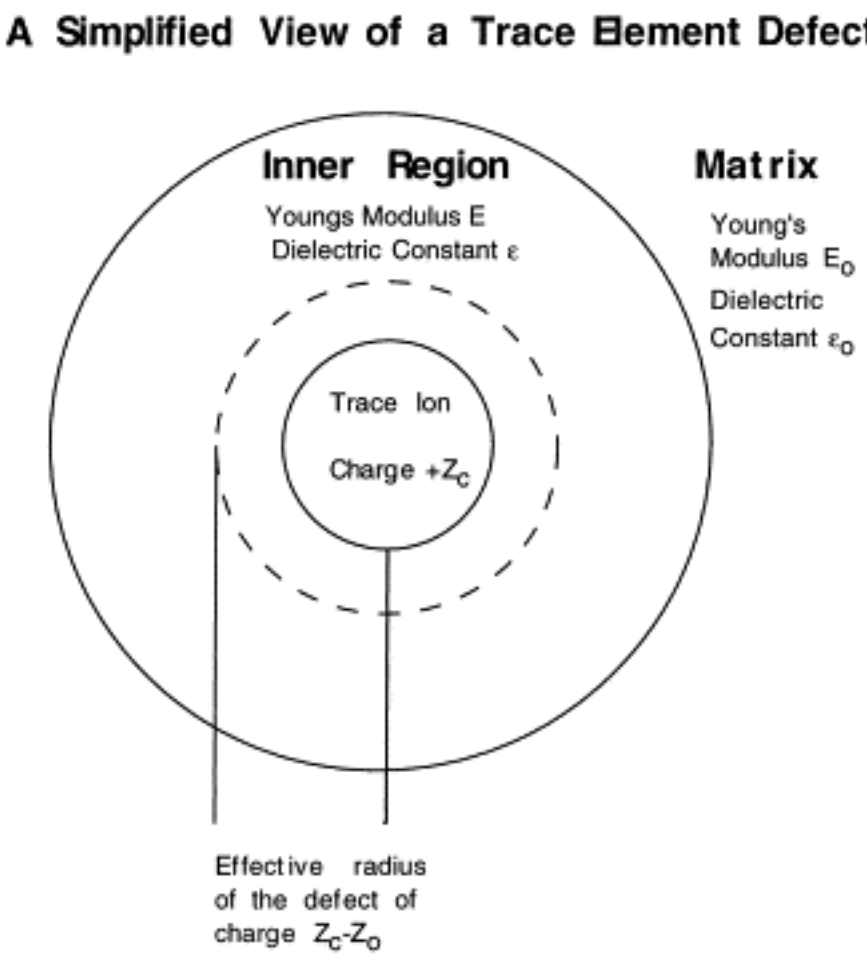
Isotope Chemistry

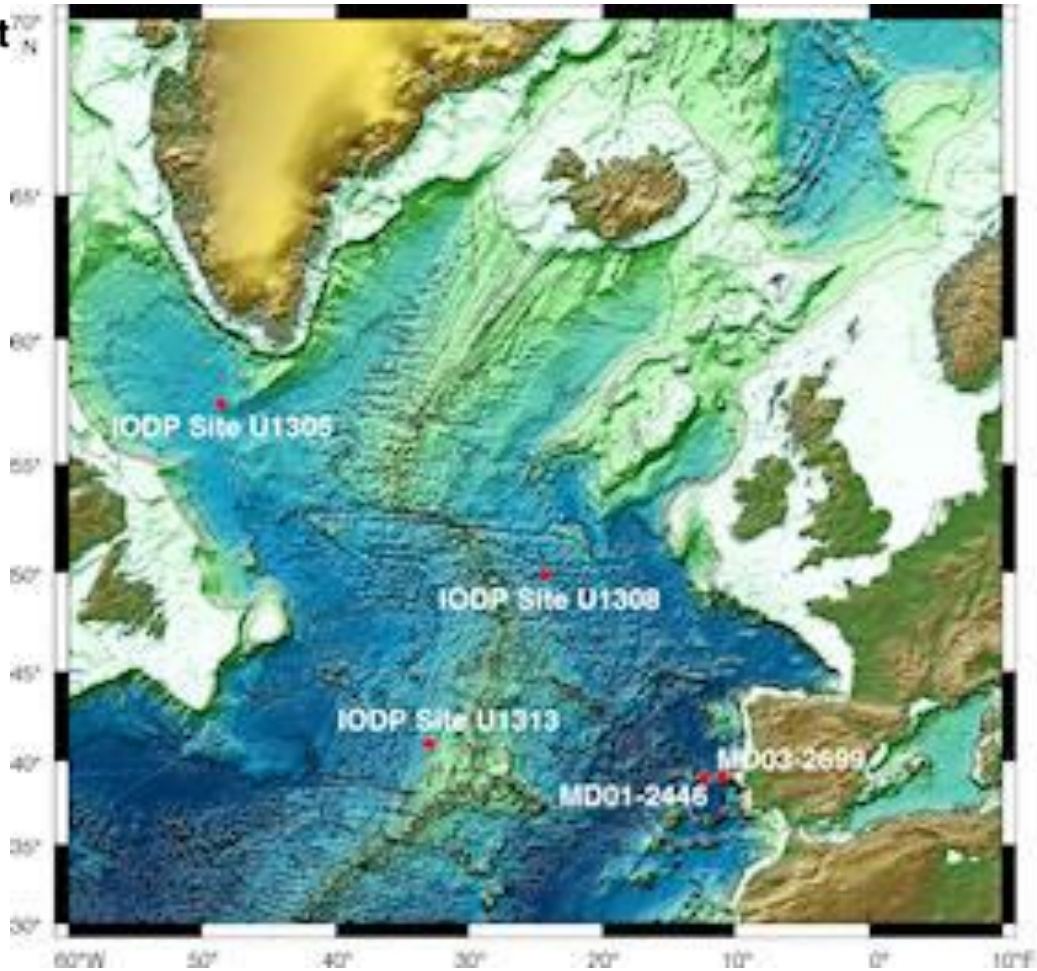


Proxy Thermometers



Trace Element Substitution






first year growth
rainy season
dry season
scar from forest fire

Scleroclimatology (Corals)

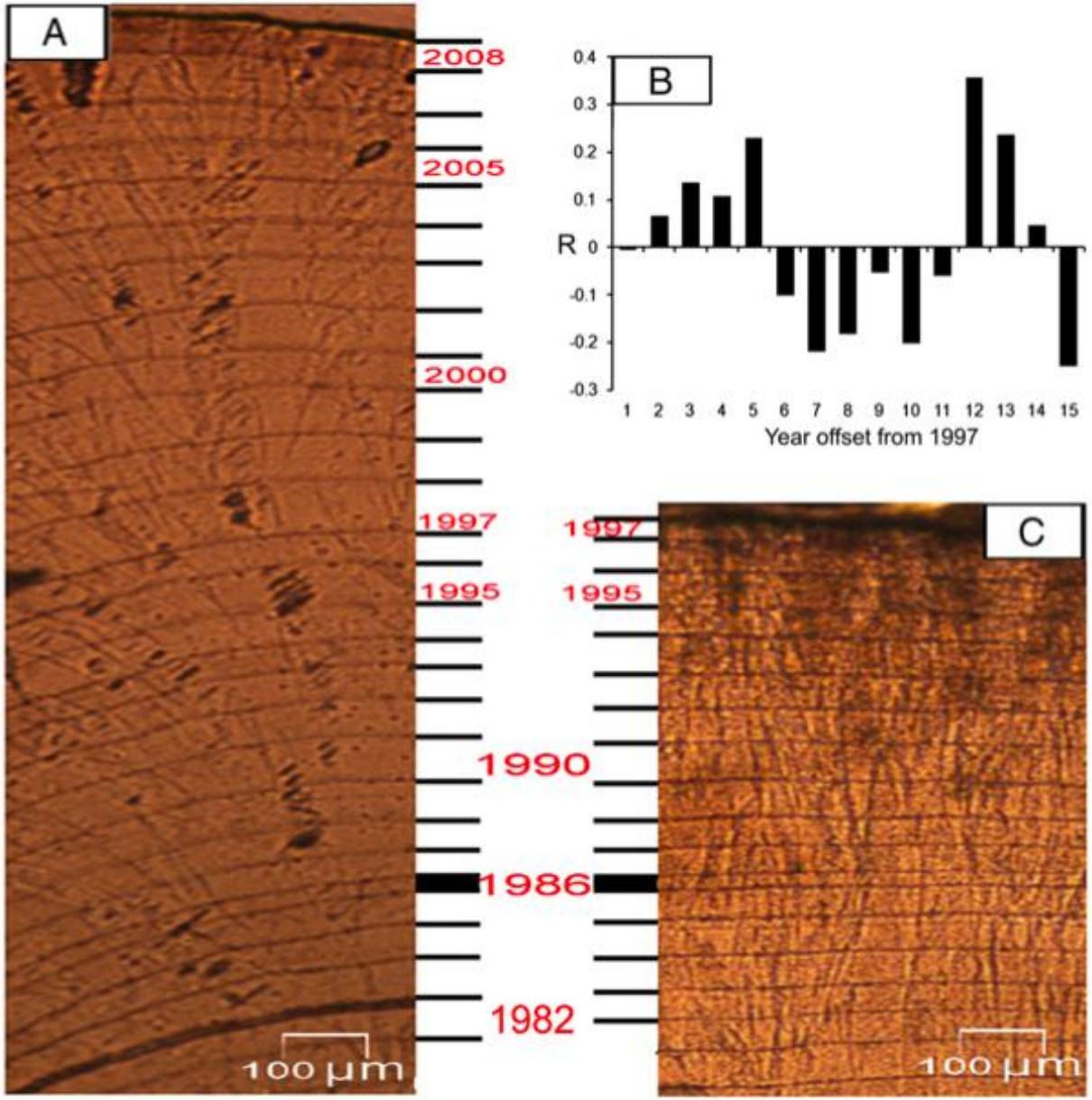
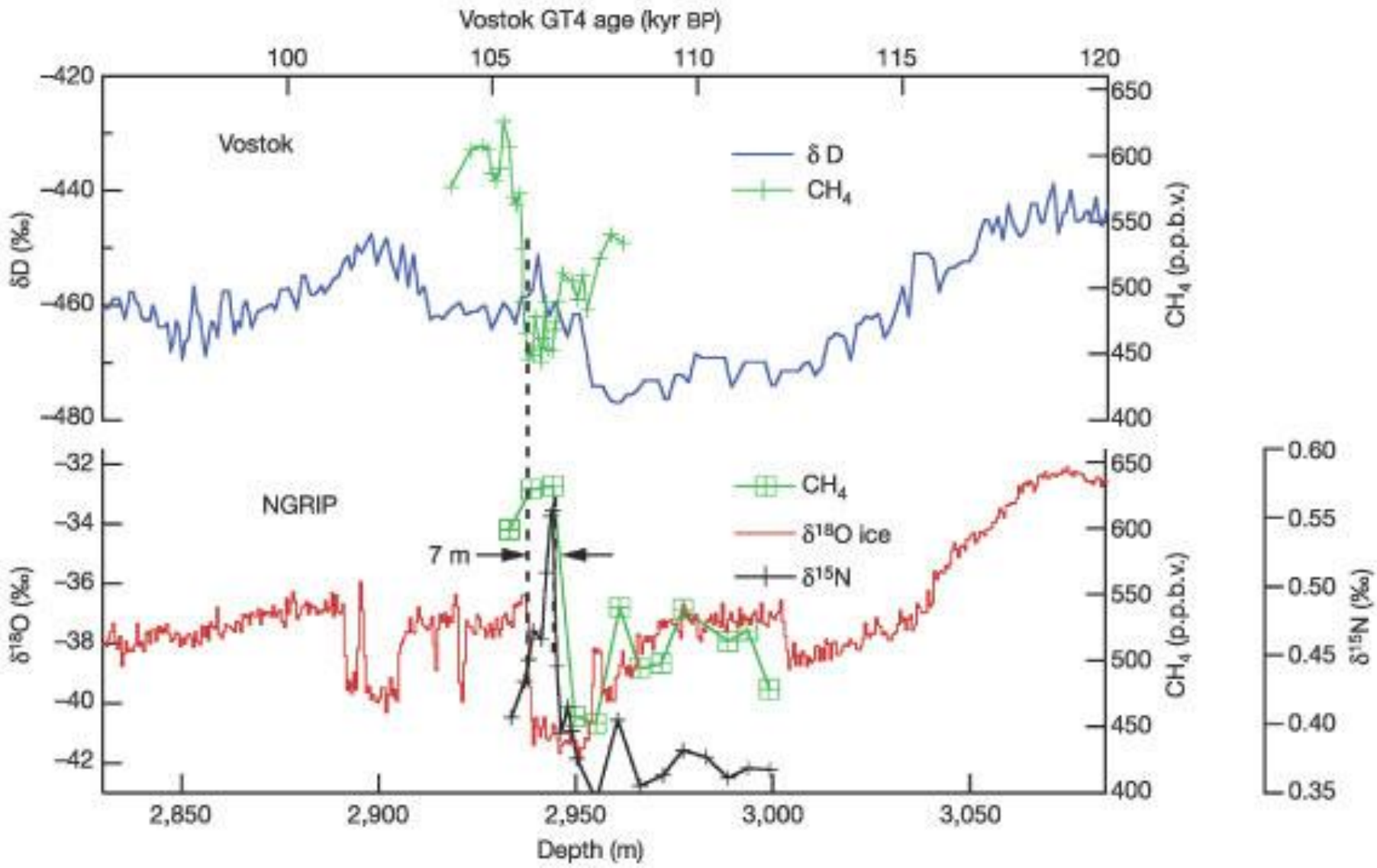


Fig. 6. Photo-mosaic of two photomicrographs of acetate peels of typical shell sections through the hinge of *Glycymeris glycymeris* shells collected in (a) July 2009 (South) and (c) October 1997 (East). Note the very narrow band, common to both images, for 1986. (b) shows correlations between the chronology SGIs at different offsets between 1 and 15 increments.

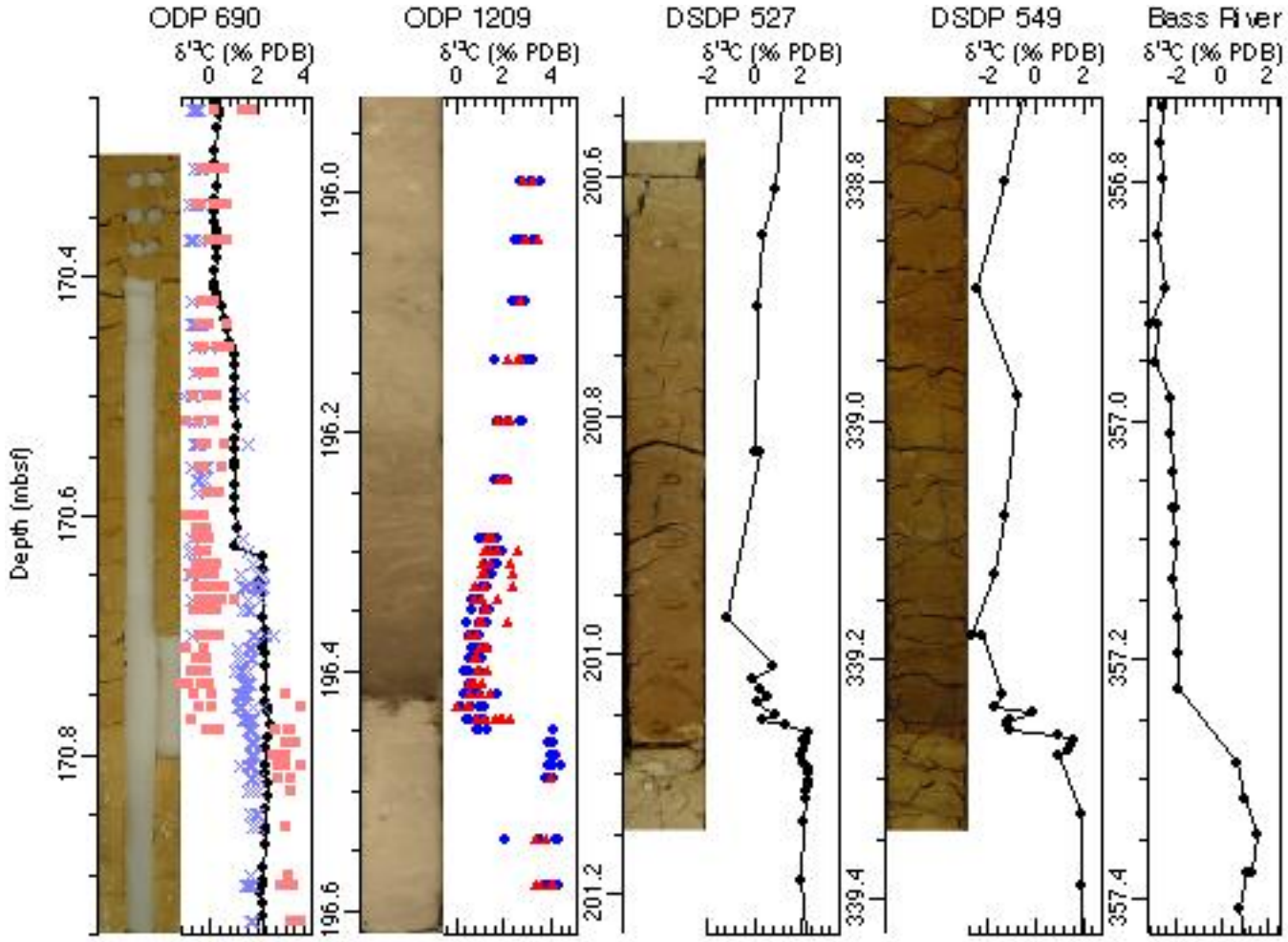
Stalactite and Stalagmite Composition

Very complex

Ice Core Composition



Sediment Cores + Luminescence



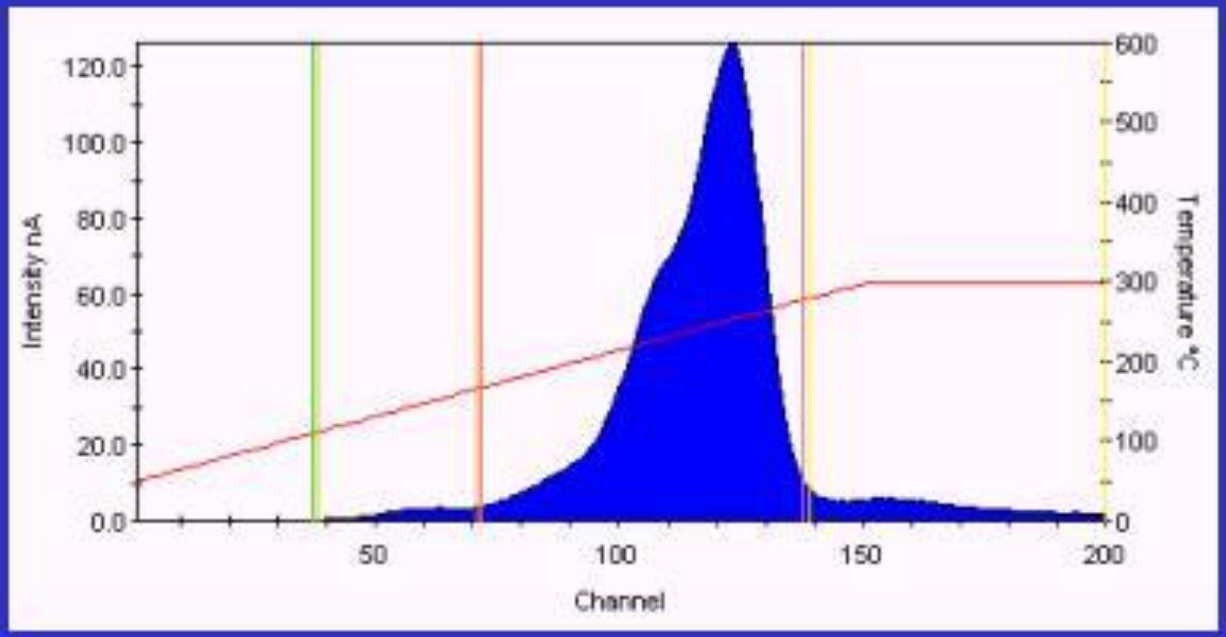
Big advantage: sediment is just about everywhere
Also, lots of biota trapped inside

Why do sediment cores have such worse resolution than ice cores?

1. Much more irregular processes; 2. bioturbation

Thermoluminescence & OSL

- Dosimeters read using Harshaw TLD Model 3500 Thermoluminescence Dosimetry Reader



Sample glow curve produced by WinRems software, interfacing with TLD reader

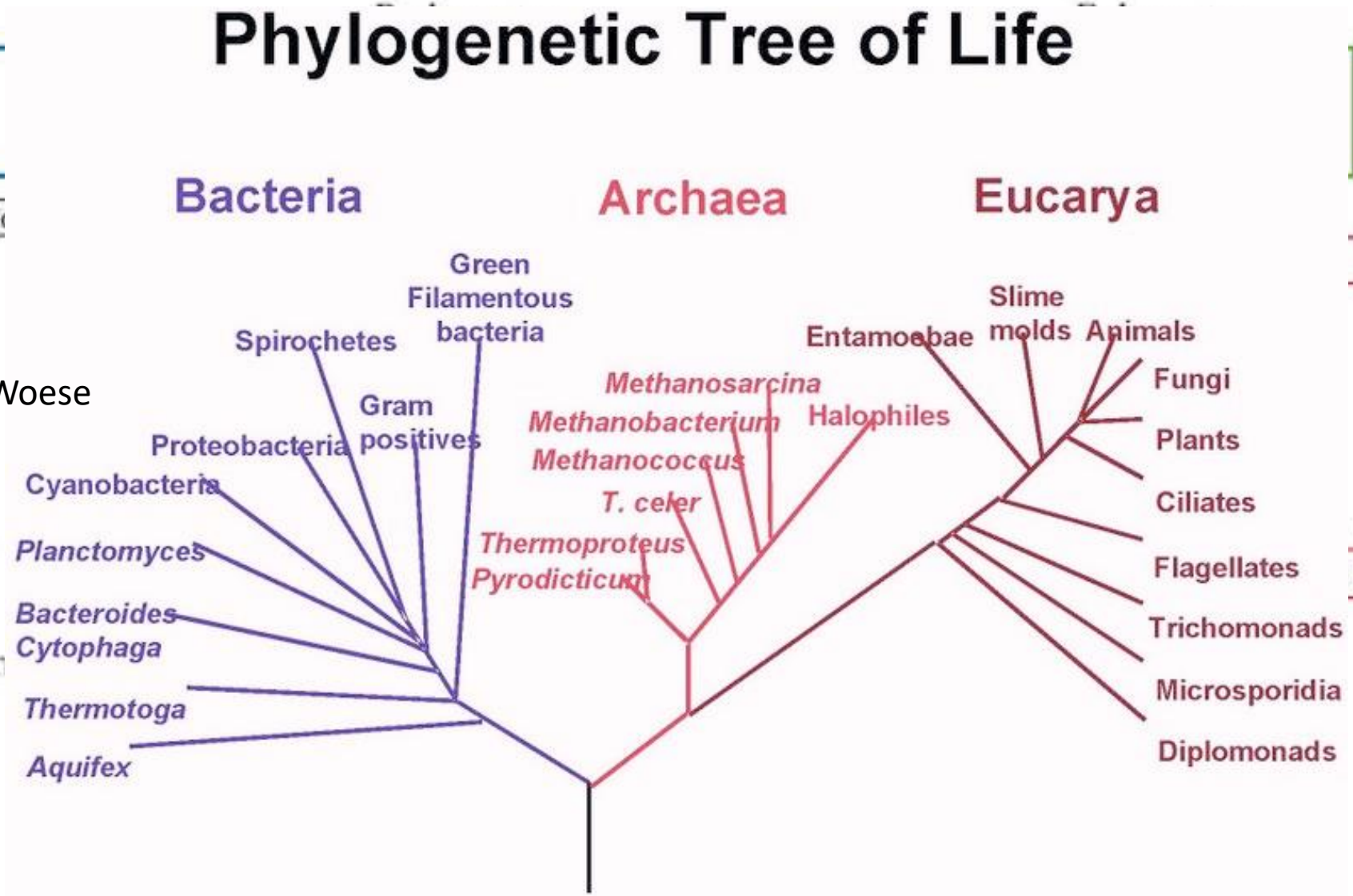
Even MORE obscure tools:

- Dust
- Volcanic Ash
- Sea Salt in ice
- Ice conductivity
- Sulfur processes
- ^{10}Be

Results: So how has climate changed over deep time?

- Key factors determining trend (warm/cold)
- Climate sensitivity
- Can we use this to make projections?
- Natural vs. Anthropogenic

LIFE



Carl Woese

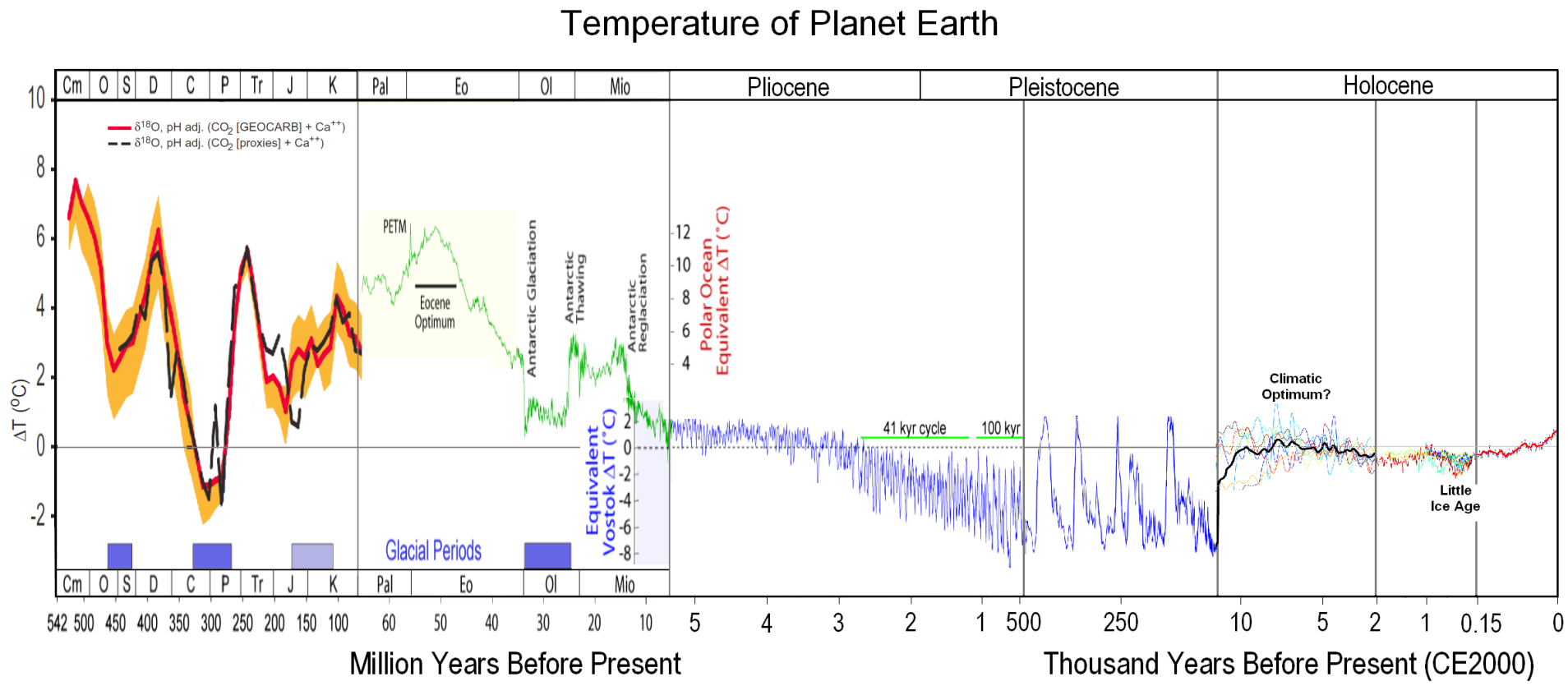
http://www.oceanographerschoice.com/log/wp-content/Evo_large.gif

Proterozoic “Snowball Earth”

- 2.5 Bya (three times!)
- Evidence:
  - Cap carbonates (neoproterozoic)
  - Magnetic patterns & reversals
  - BIFs
  - Tills and other tropical glacial evidence

Warming Earth

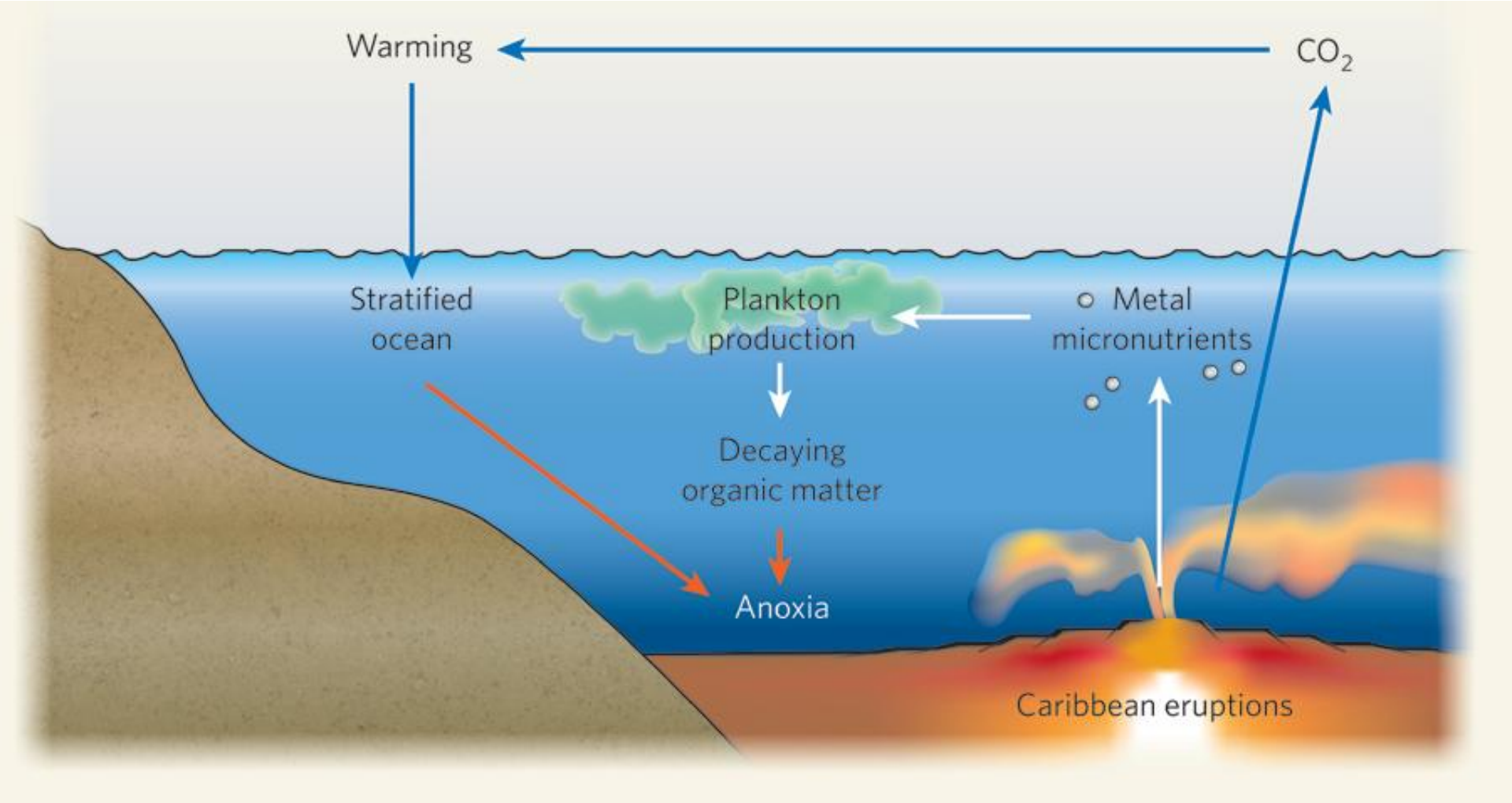
- Cambrian Explosion
- Carboniferous to the…
- Great Permian Extinction (90%)
- The Cretaceous Hothouse



from Wikipedia(!)

Oceanic Anoxic Events (Cretaceous)

Thermohaline shutdown (no Antarctica)



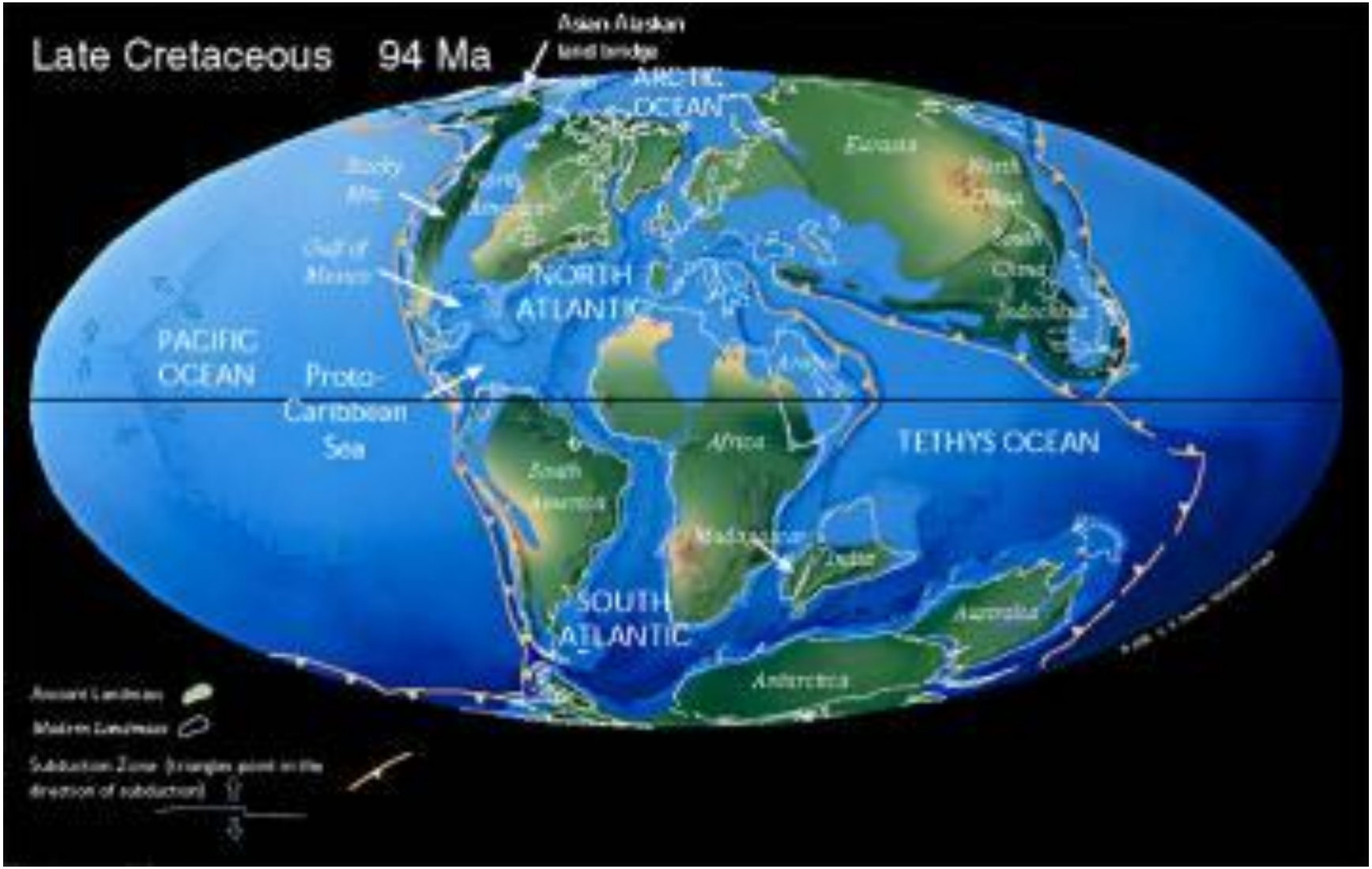
So did temperatures rise rapidly? Plankton mitigation

Cretaceous is the best historical reference for current CO2 levels

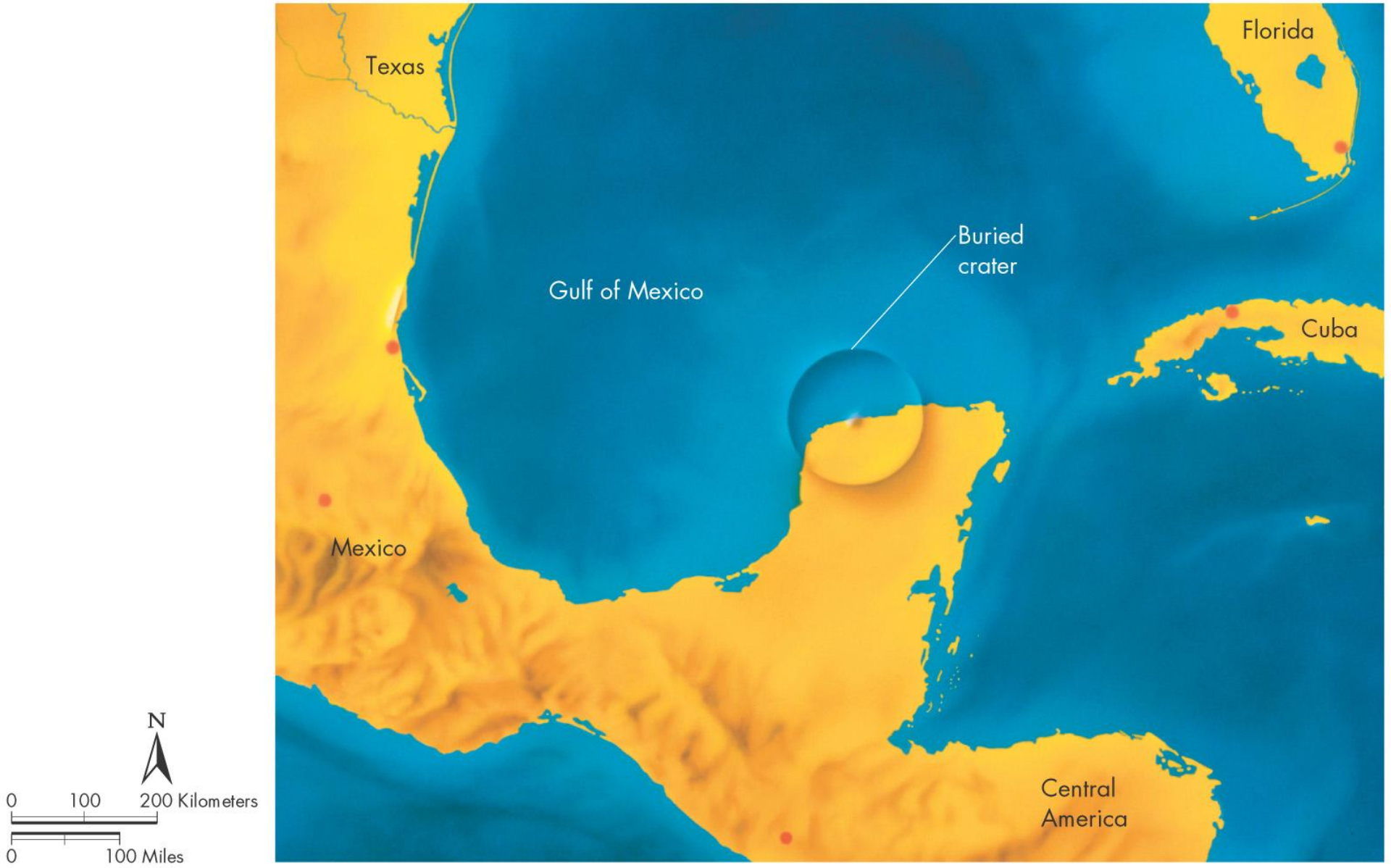
The K-Pg (or K-T) Extinction

- Kretaceous-Paleogene

Cretaceous Continents



300,000 years off (Markus Harting)



Alternative theories?

K-Pg: 65 million years ago

- Chicxulub crater timing is off by a lot
- Giant Forest fires? Doug Robertson at CIRES and the “Global Firestorm” hypothesis
- Sedimentation rates: Paul Renne (UC-Berkeley) and the meteor hypothesis revisited (maybe a comet?)

Gymnosperms and Angiosperms

- About 100 million years ago
- Why is this important?
- Dinosaur indigestion –flowers killedthe dinosaurs?

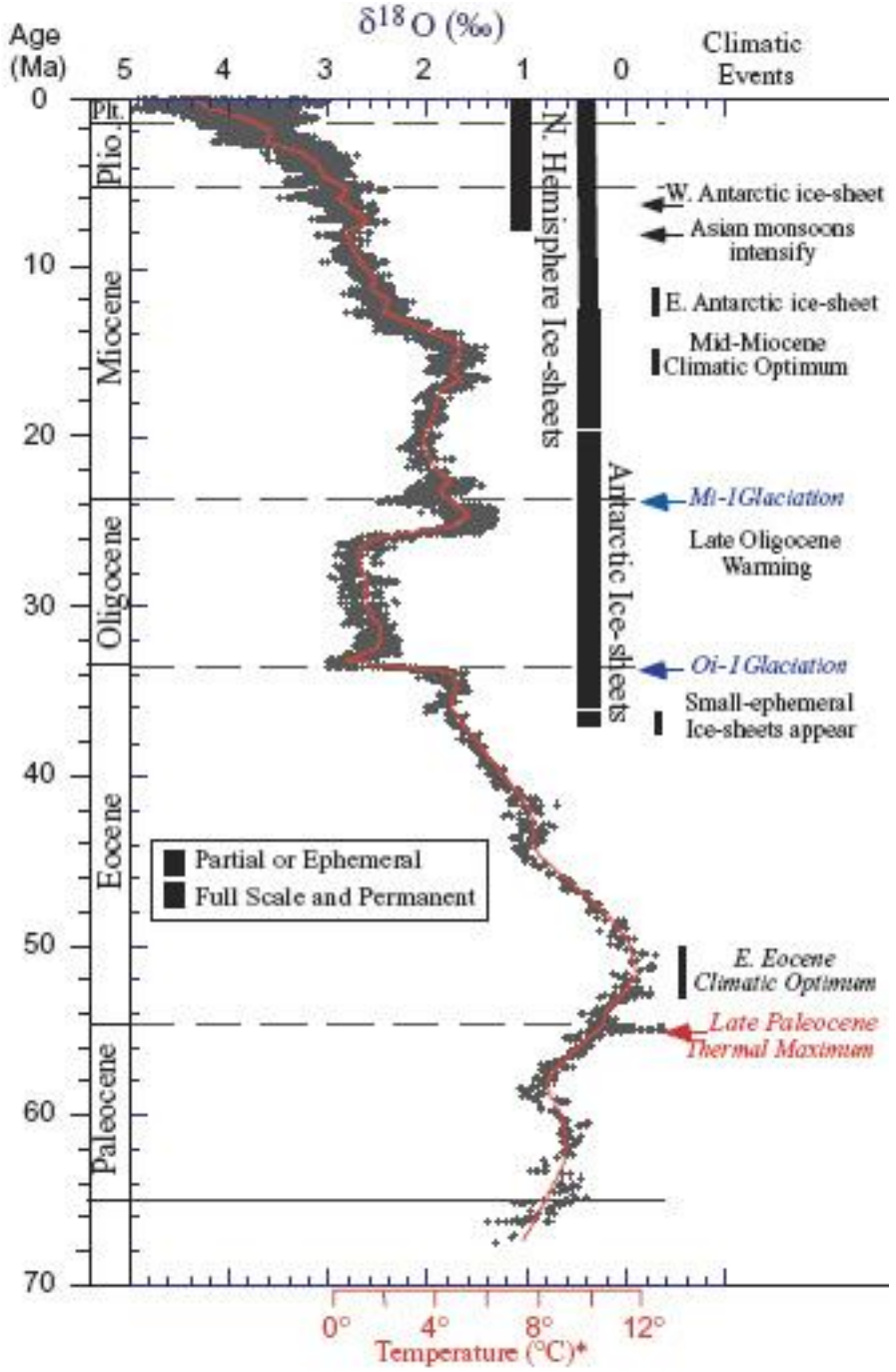
The Cenozoic

Eon	Era	Period		Epoch	Start Date (mya)
Phanerozoic	Cenozoic	Quaternary		Holocene	0.01
				Pleistocene	1.64
		Tertiary	Neogene	Pliocene	5.2
				Miocene	23.3
			Paleogene	Oligocene	35.4
				Eocene	56.5
				Paleocene	65

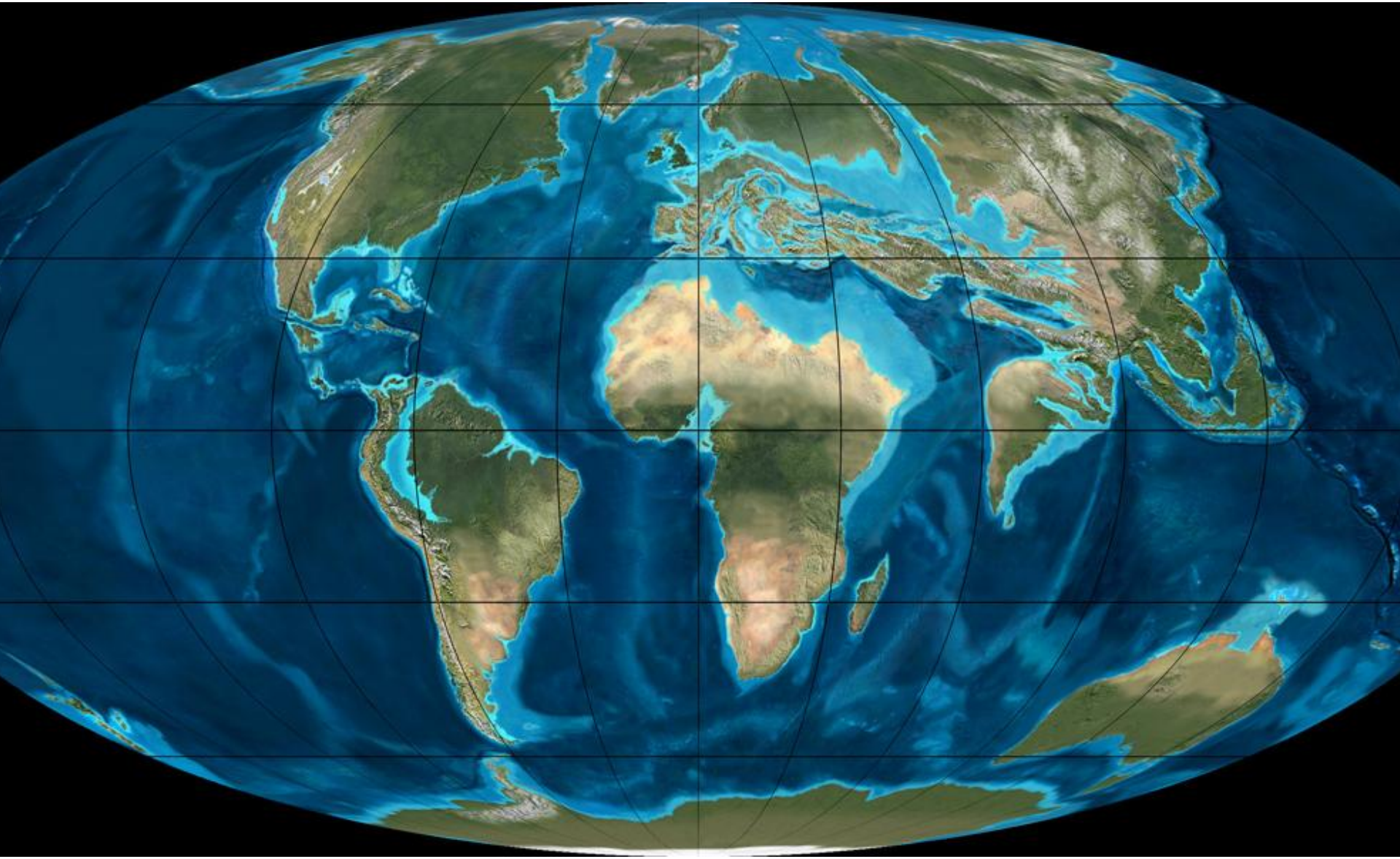
Paleocene-Eocene Thermal Maximum

Eo: dawn
Here come the mammals

Where are the leftover dinosaurs?
What evidence?

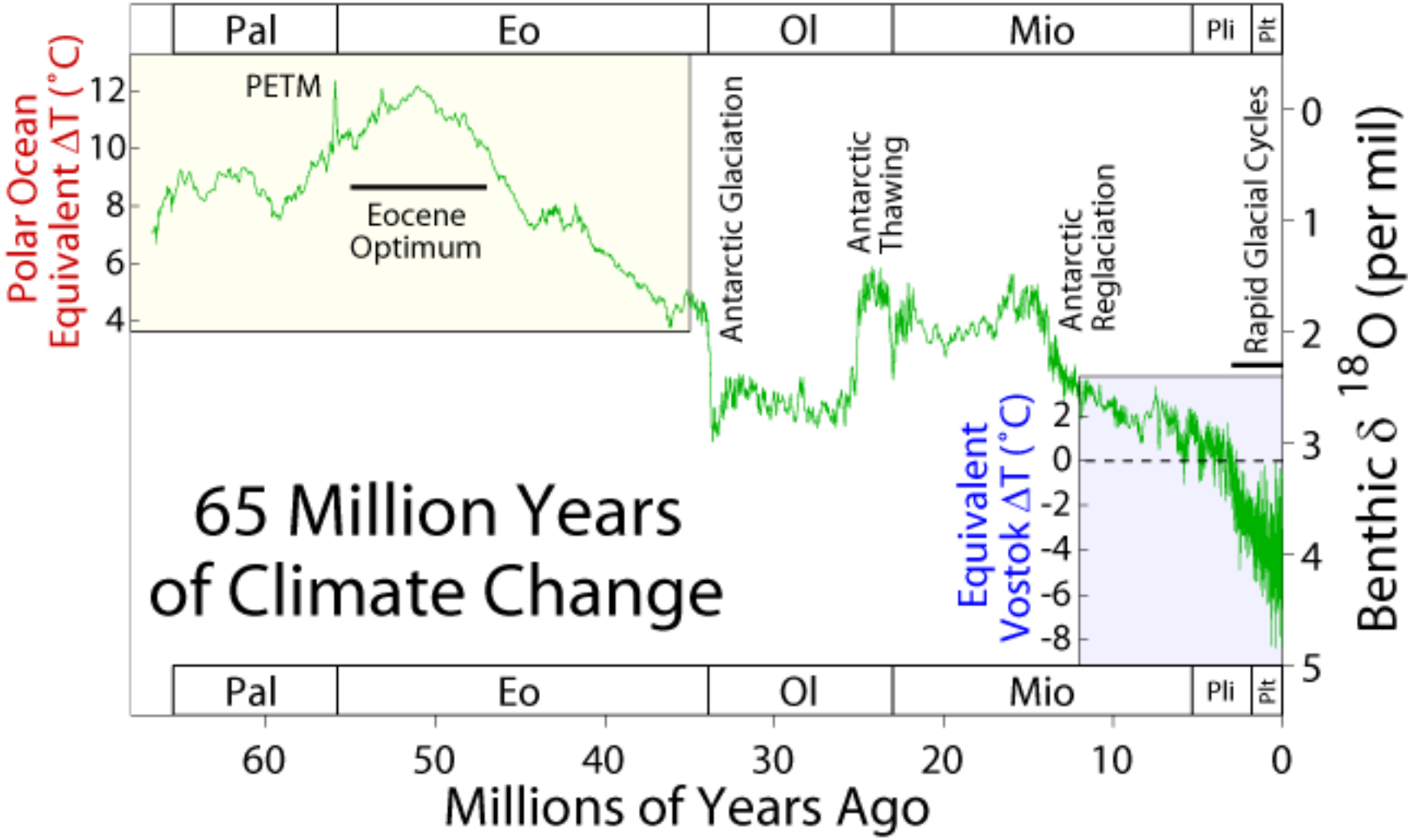


Middle Eocene



PETA/PETM

6°C in 20,000 years; huge carbon increase in atm



What caused the warmup to the Eocene Optimum?

- Sea levels?
- Another Ocean Anoxic Event?
- Carbonate compensation depth changed?
- Changes in weathering rates?
- Different ecosystem structures?

What about the Eocene optimum?

- Ice-albedo feedback linked to warm state
- Warmer poles, but NO
- Higher climate sensitiv
  - Missing feedbacks?
  - Methane Hydrates ->
- The breakup of Gondw
  - The Antarctic current
- Climate models have fa
  process maybe are ver

Into the icehouse of the late Cenozoic

- Warmer conditions– what about the water cycle?
- Maybe Azolla sinking in the Arctic?
- Massive burial of methane, coal and oil in the oceans and continental shelves (anoxic conditions helped)
- mid-ocean ridges subsided (MORBs)
- CO_2 reduction appears to be the main driver
- The ice-albedo feedback kicks in

Late Cenozoic glaciation (Oligocene)

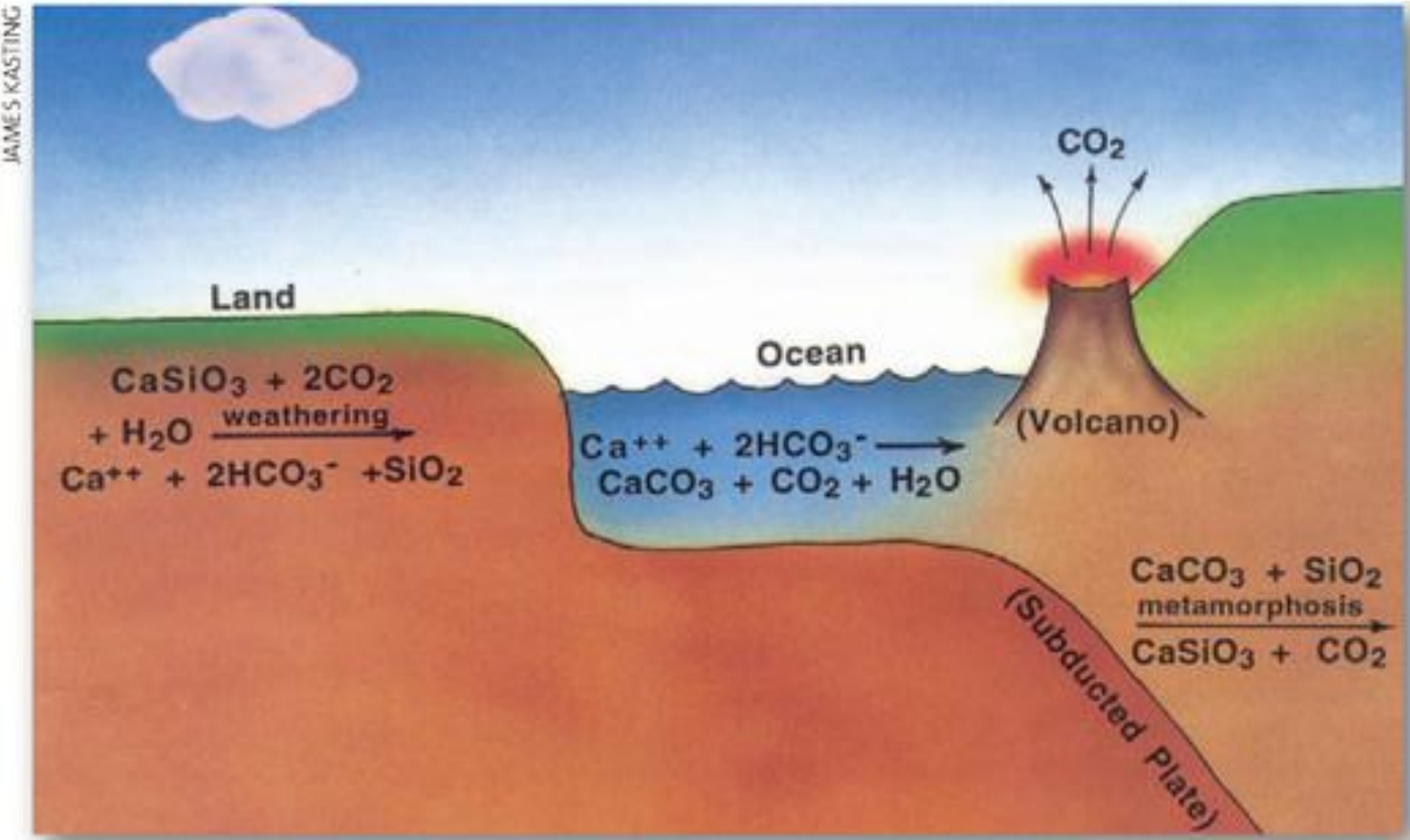
- Drop in vulcanism
- Burial of heat in the ocean (thermohaline circ)
- Himalayan uplift? (Maureen Raymo)
  - Driven by increased consumption of CO_2

Why do ice ages start?

Can we blame Antarctica?

Soil CO_2 from silicate and clay weathering

$$H_2O + CO_2 <=> H^+ + HCO_3^- <=> H_2CO_3$$



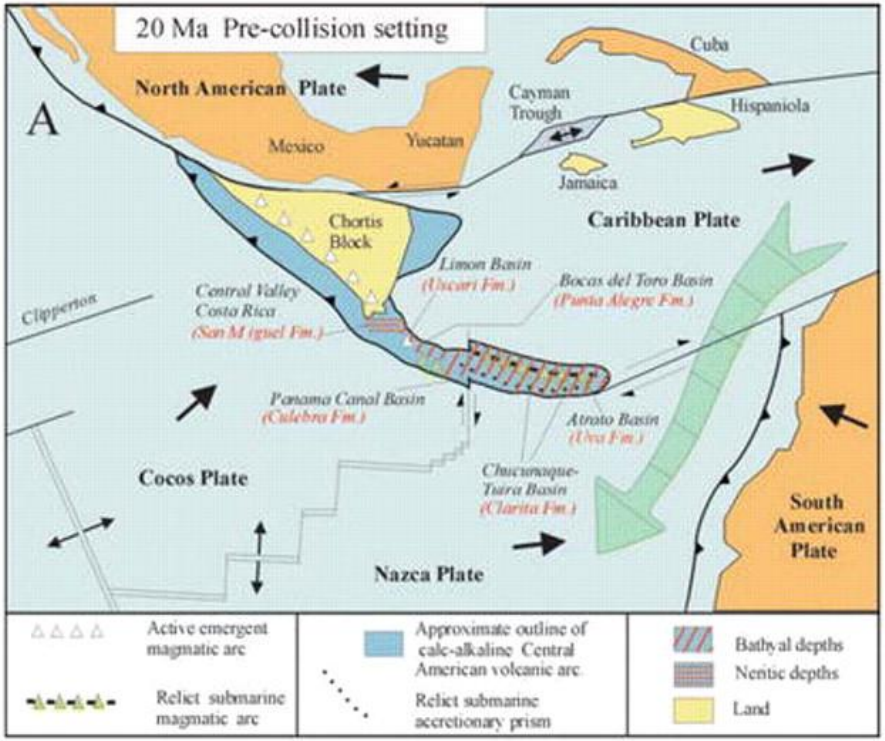
Miocene

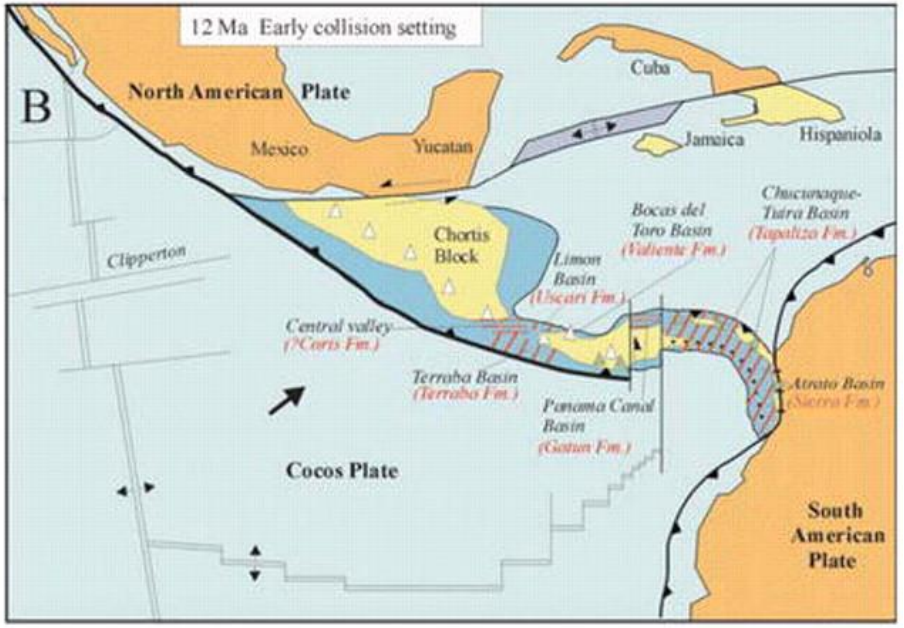
- A bit of a warm-up, but still glaciers
- Beginning of NADW

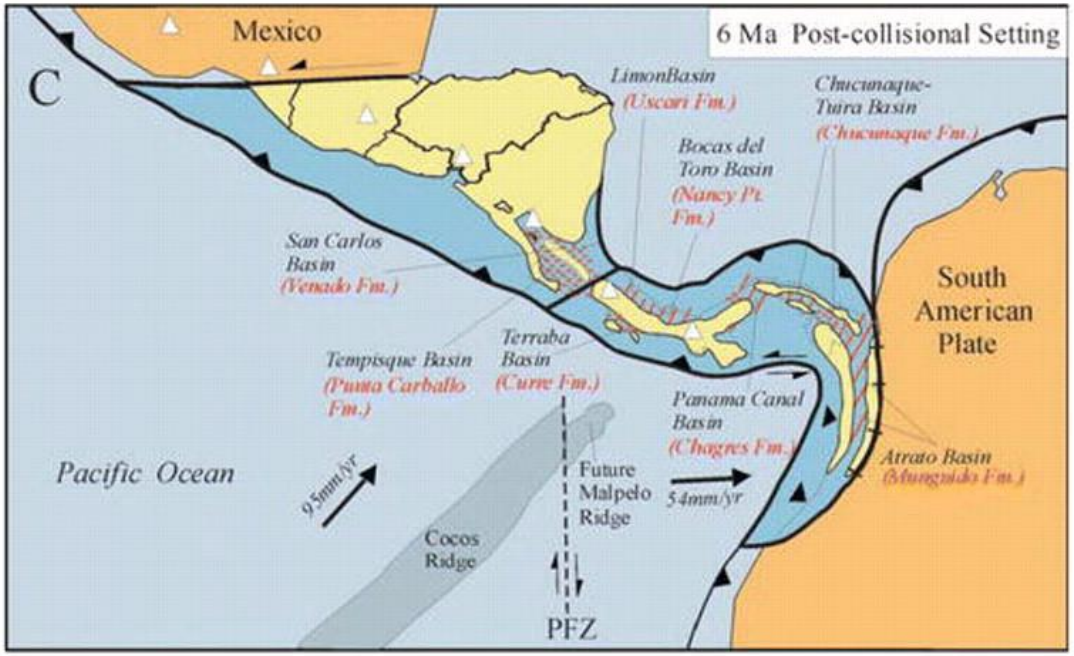
Big Cooling:

More mountain building

Arctic and Antarctic heat flows to the poles boosted burial of organic matter







Isthmus of Panama closes

Grasslands appear;
Permanent El Nino;
The North Atlantic Current

Palynology

Palynology (Gr, *palynos*, dust)

= The study of pollen and spores

Why study?

- Use as characters in phylogenetic analysis
- Use in plant identification
  - Extant plants
  - Fossil plants
    - paleopalynology
    - past plant communities, climate, biogeography, migration

What are they?

Spore - haploid cell derived from sporganium via meiosis

Pollen - immature, endosporic male gametophyte derived from male spores (microspores) in Seed Plants