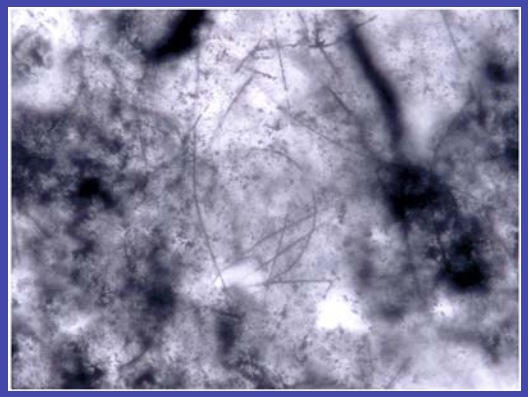


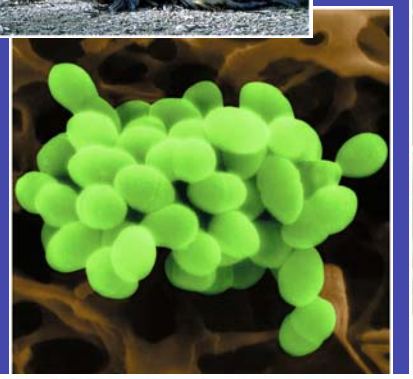






Similarities?

A) Breathing
B) Digestion
C) Cellular structure
D) Warm blooded
E) Living

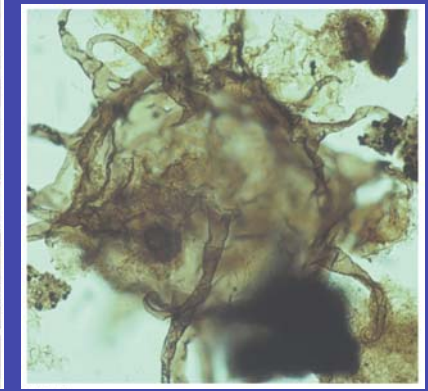






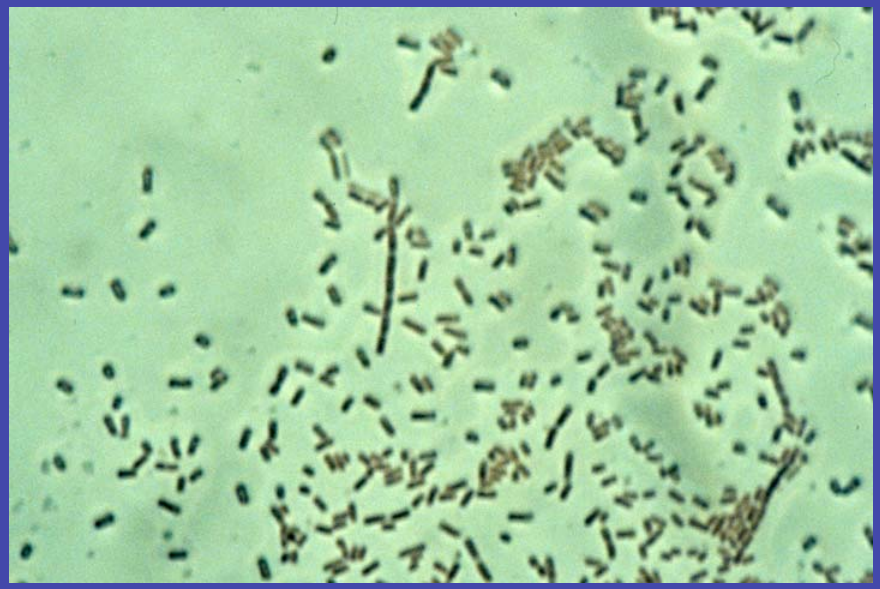


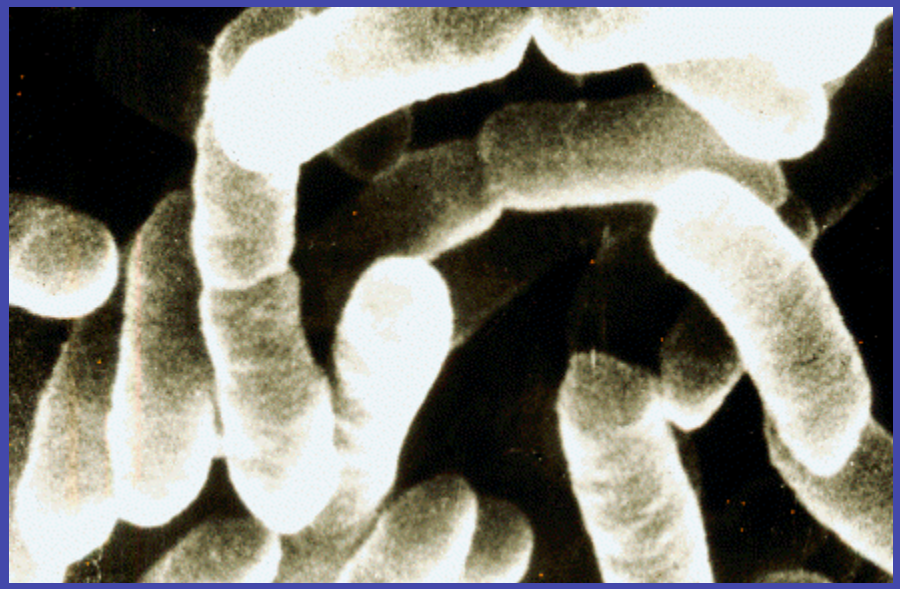




What defines

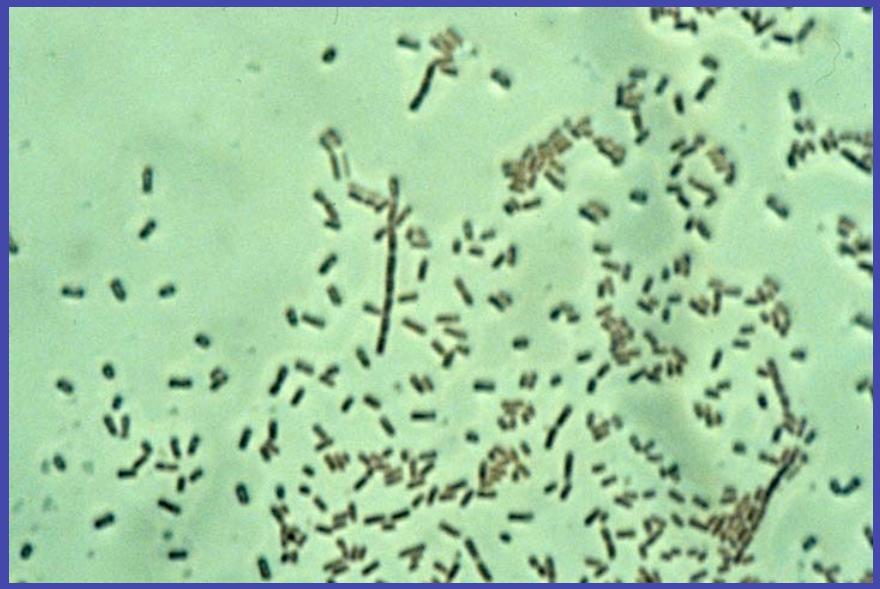
LIFE?





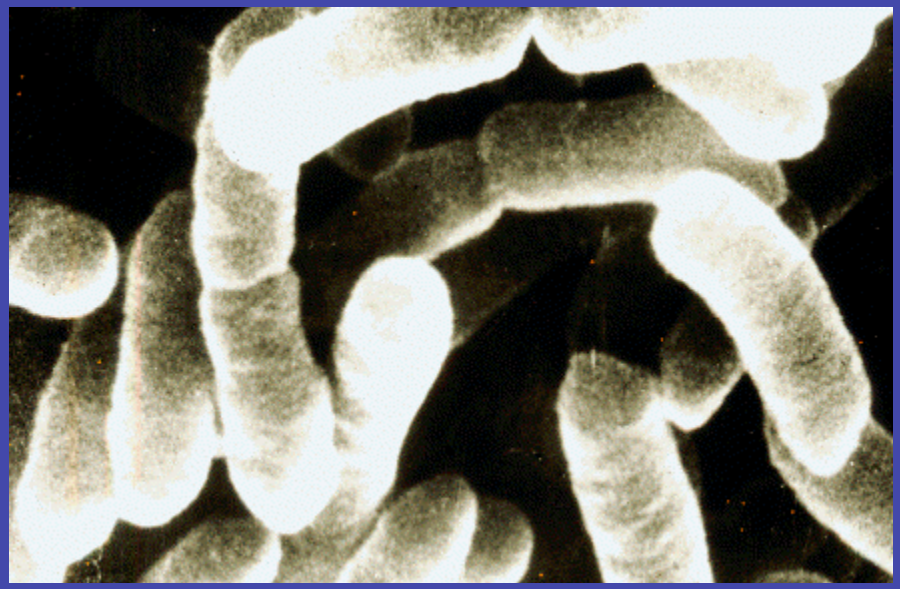
What defines

LIFE?



Bacteria

Self-replicating



Virus

Only under special circumstances









What defines

LIFE?

1) Self-replicating
2) Self-regulating
(Homeostasis)
(Metabolism)
3) Organization
4) Growth
5) Adaptation
6) Response to Stimuli



Why is Earth UNIQUE?

A) The right size

B) Right temperature

C) Water is liquid

D) Seasonality

E) Polar ice caps



Why is Earth UNIQUE?

A) The right size

B) Right temperature

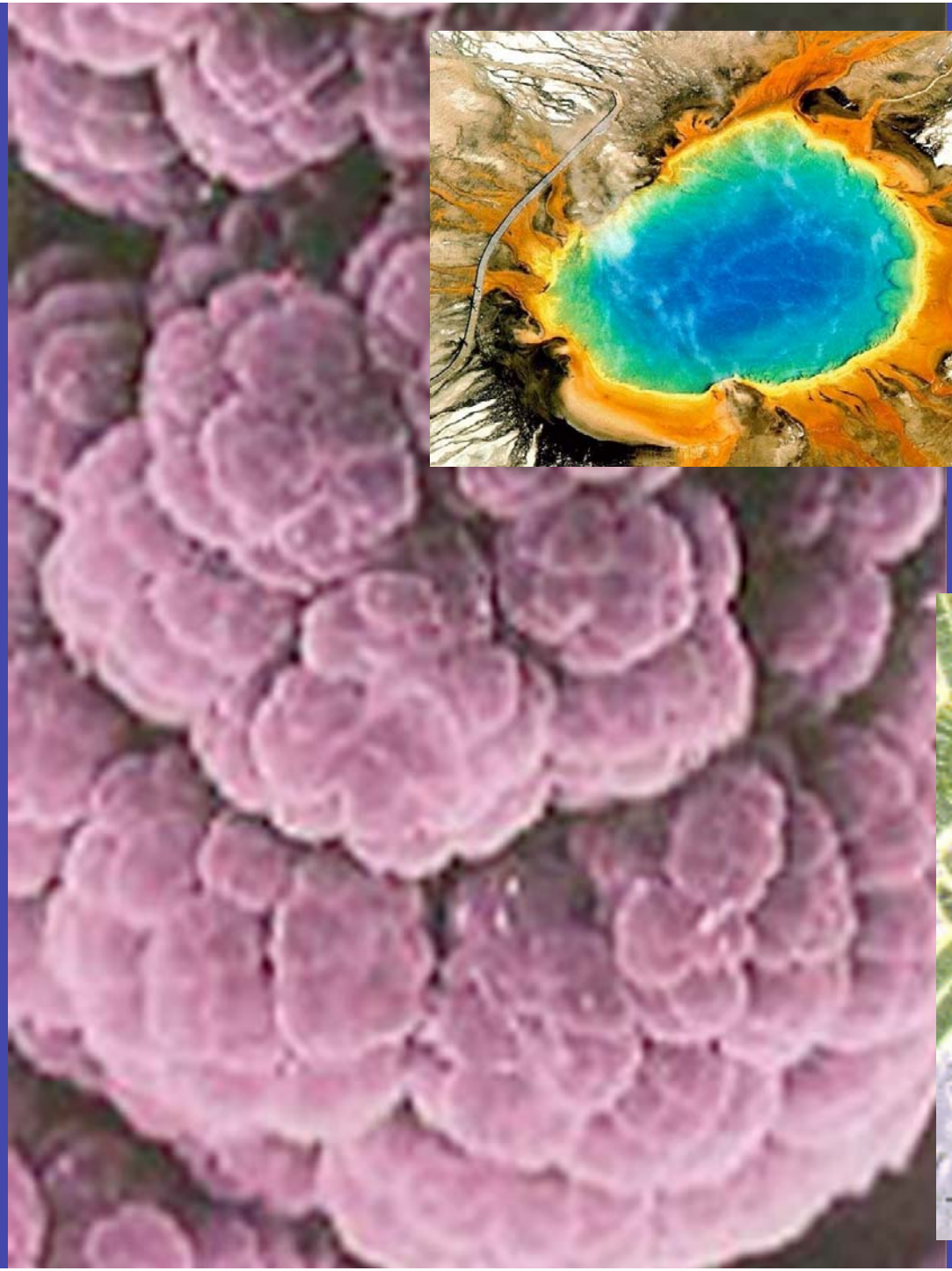
C) Water is liquid

These traits allow Earth to host LIFE

Where did life originate?

How do we know?


Where did life originate?
How do we know?



Archaebacteria tolerate extreme environments:

<u>HIGH</u>

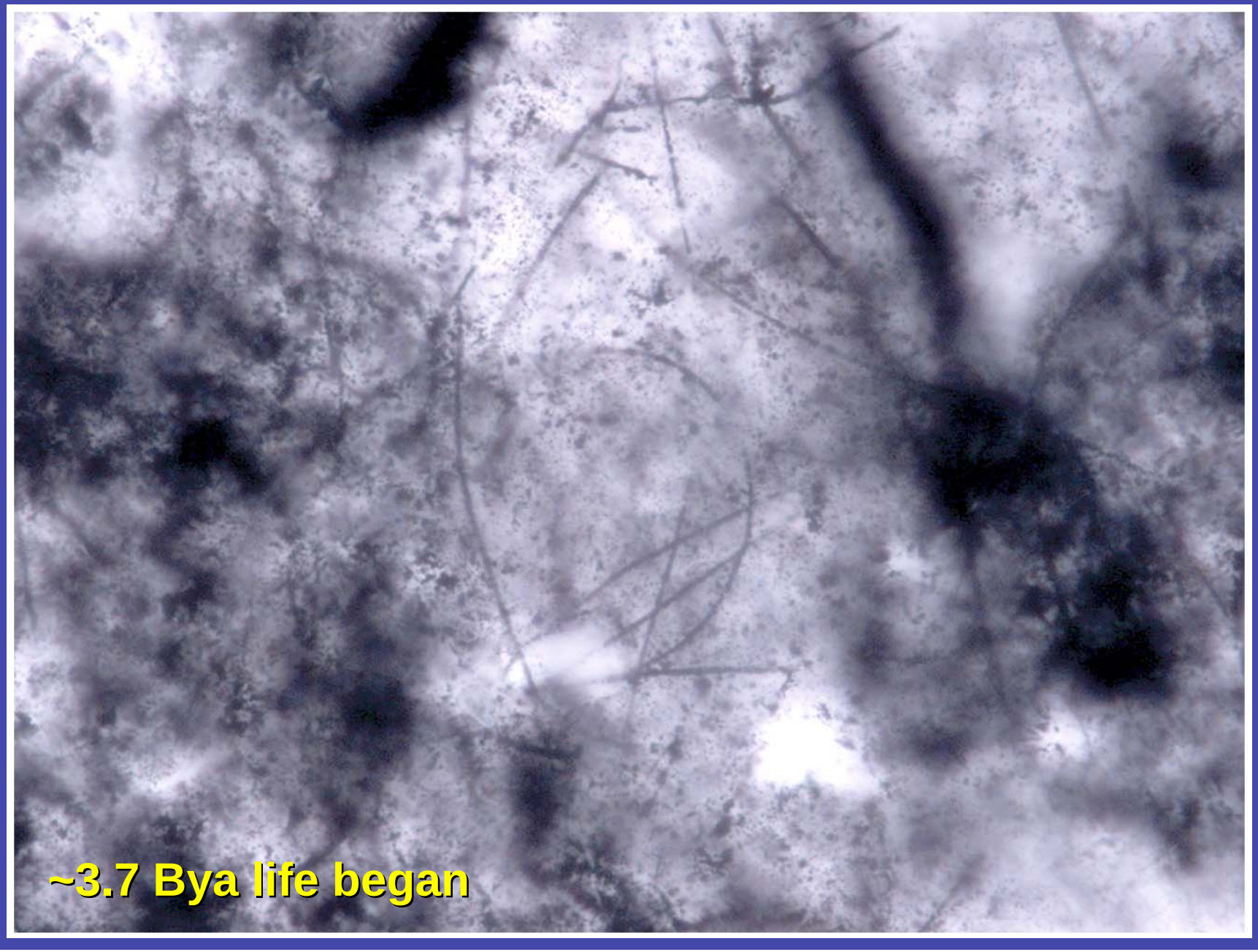
1) temperature

2) salinity

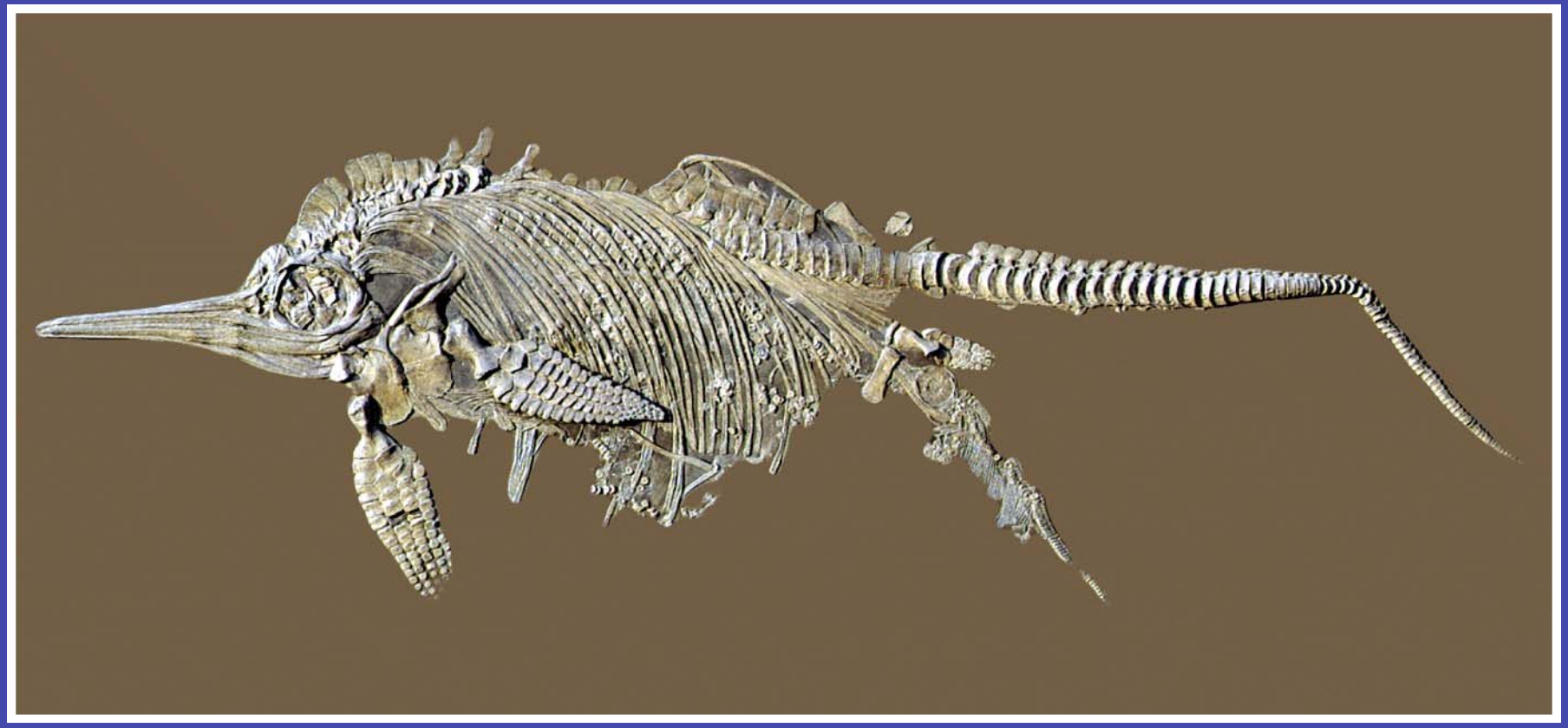
3) acidity



Oldest known fossil? Host rock 3.2 billion yrs old.



What two factors influence fossil preservation?

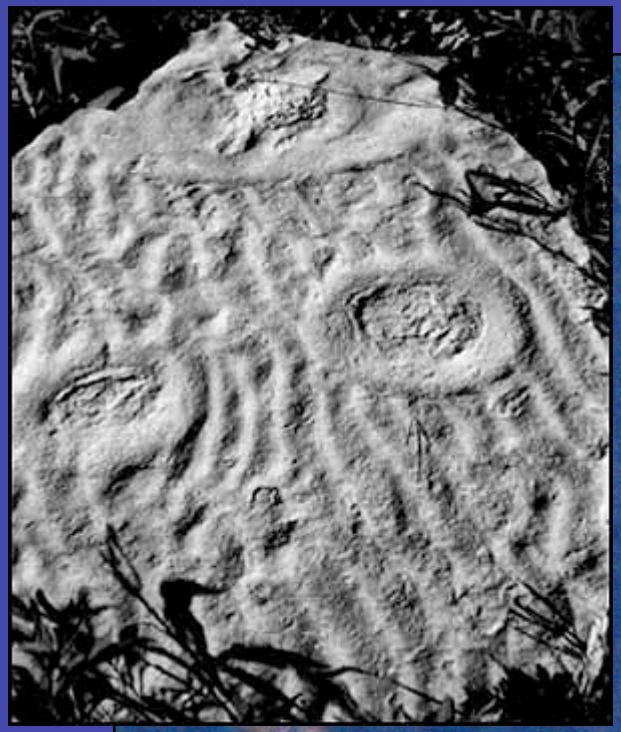


Icthyosaur (Jurassic 206-144 Mya)

What two factors influence fossil preservation?

1) Hard parts

2) Rapid burial



Cambrian (525 Mya)

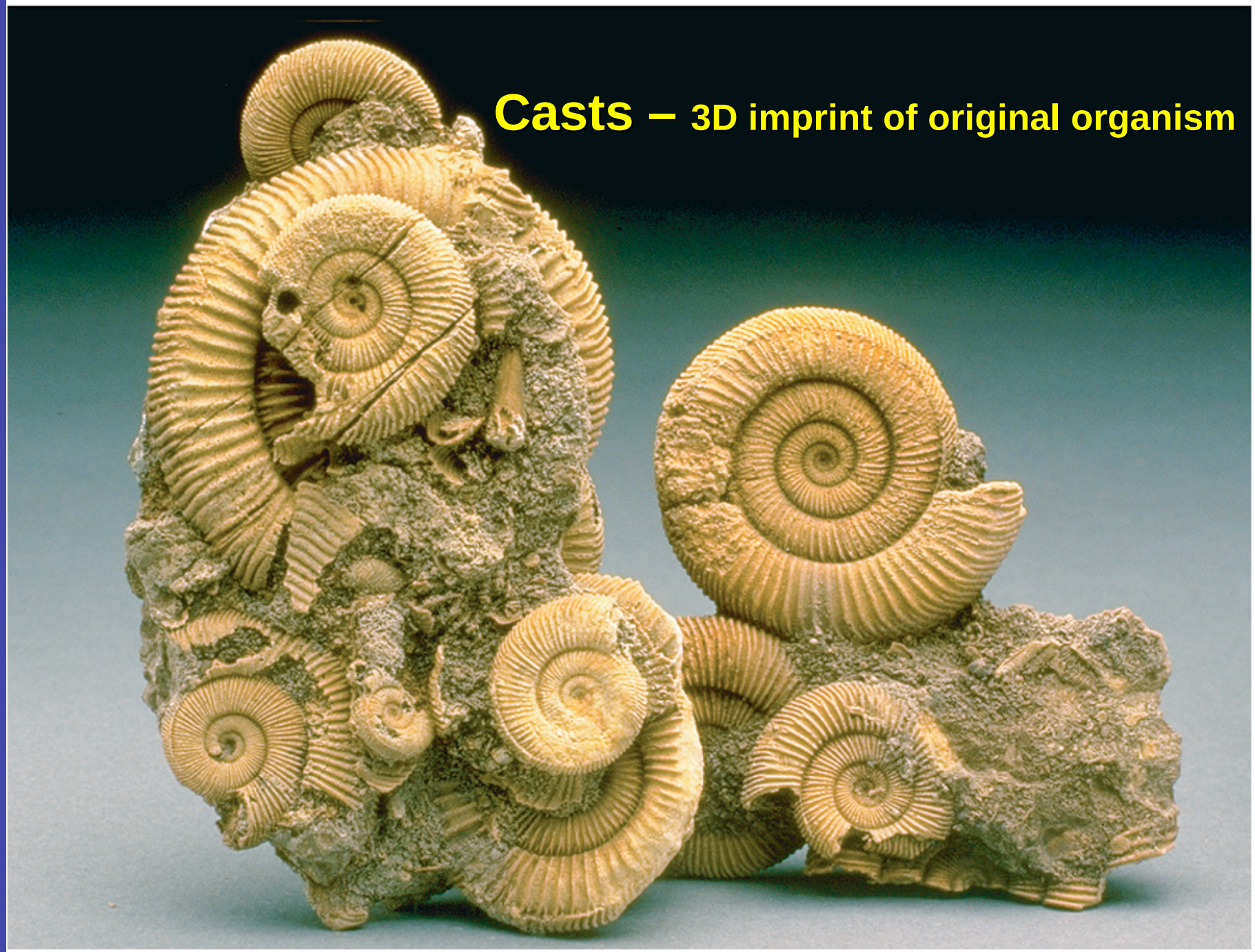


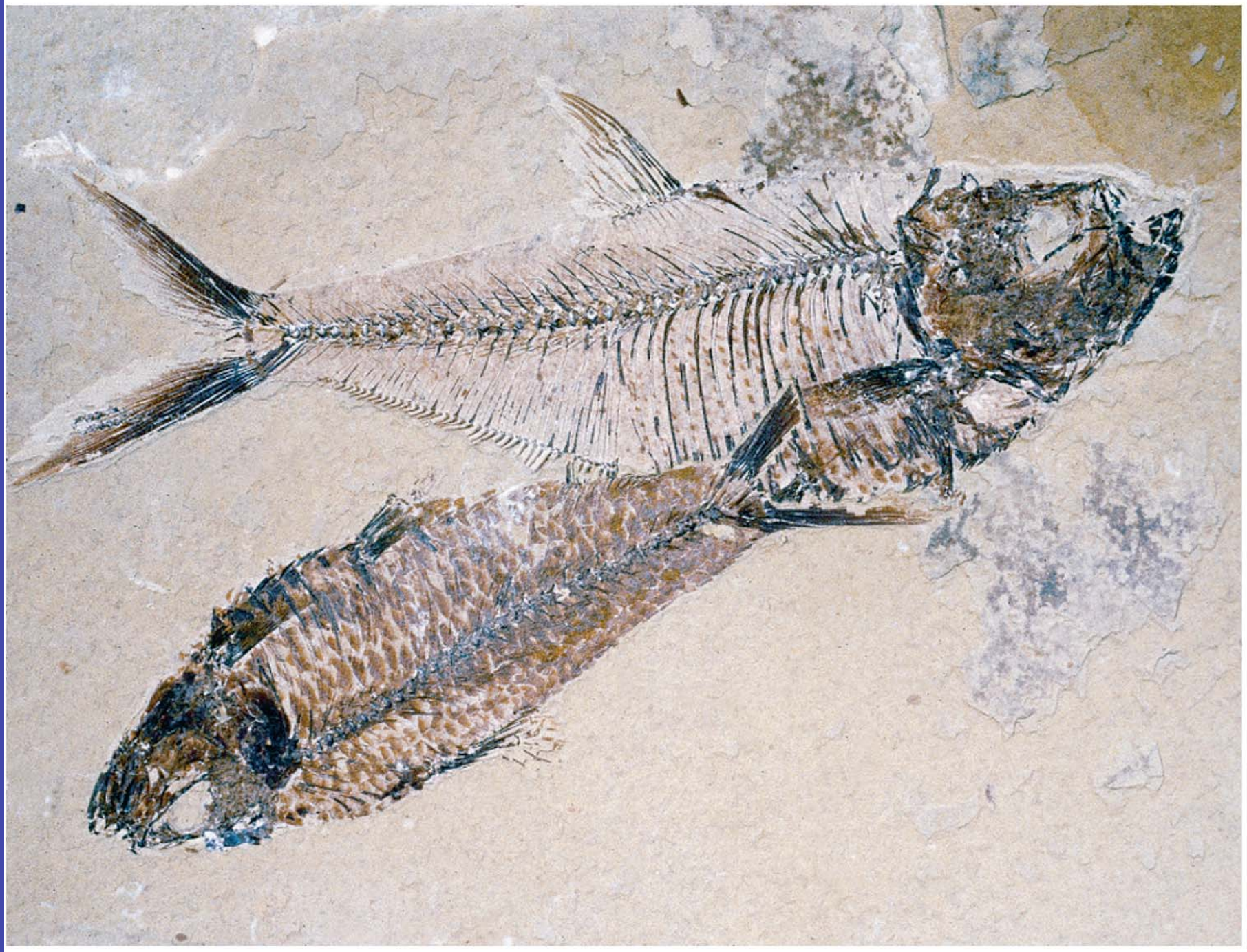
Eocene Mammal (54.8-33.7 Mya)

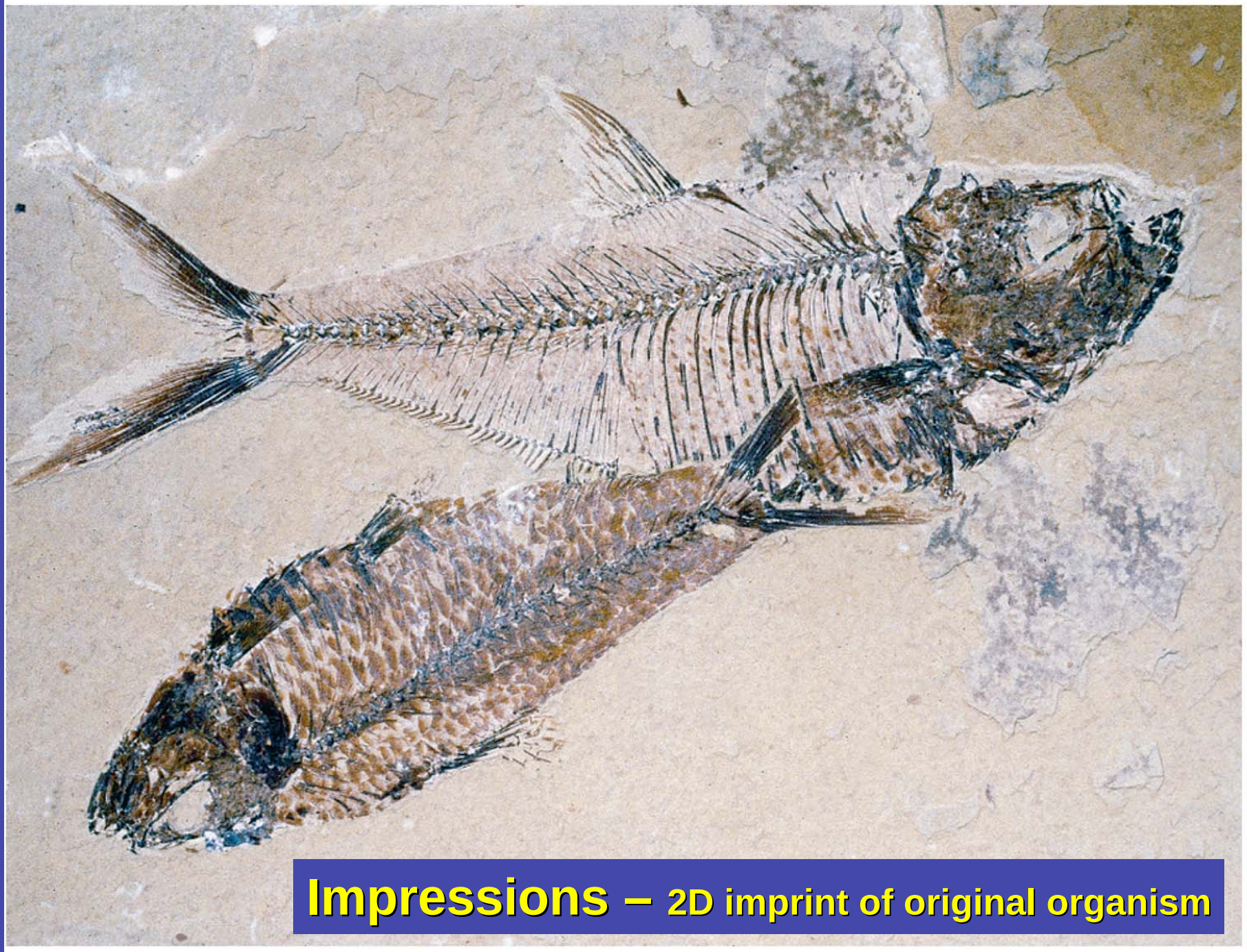



Petrified Wood – organic materials replaced with minerals




Casts – 3D imprint of original organism





Impressions – 2D imprint of original organism




Carbon films –
anoxic burial preserves carbon residue



What is this fossil?

A) Worm burrow

B) Dinosaur egg sack

C) Poop

D) Snakeskin

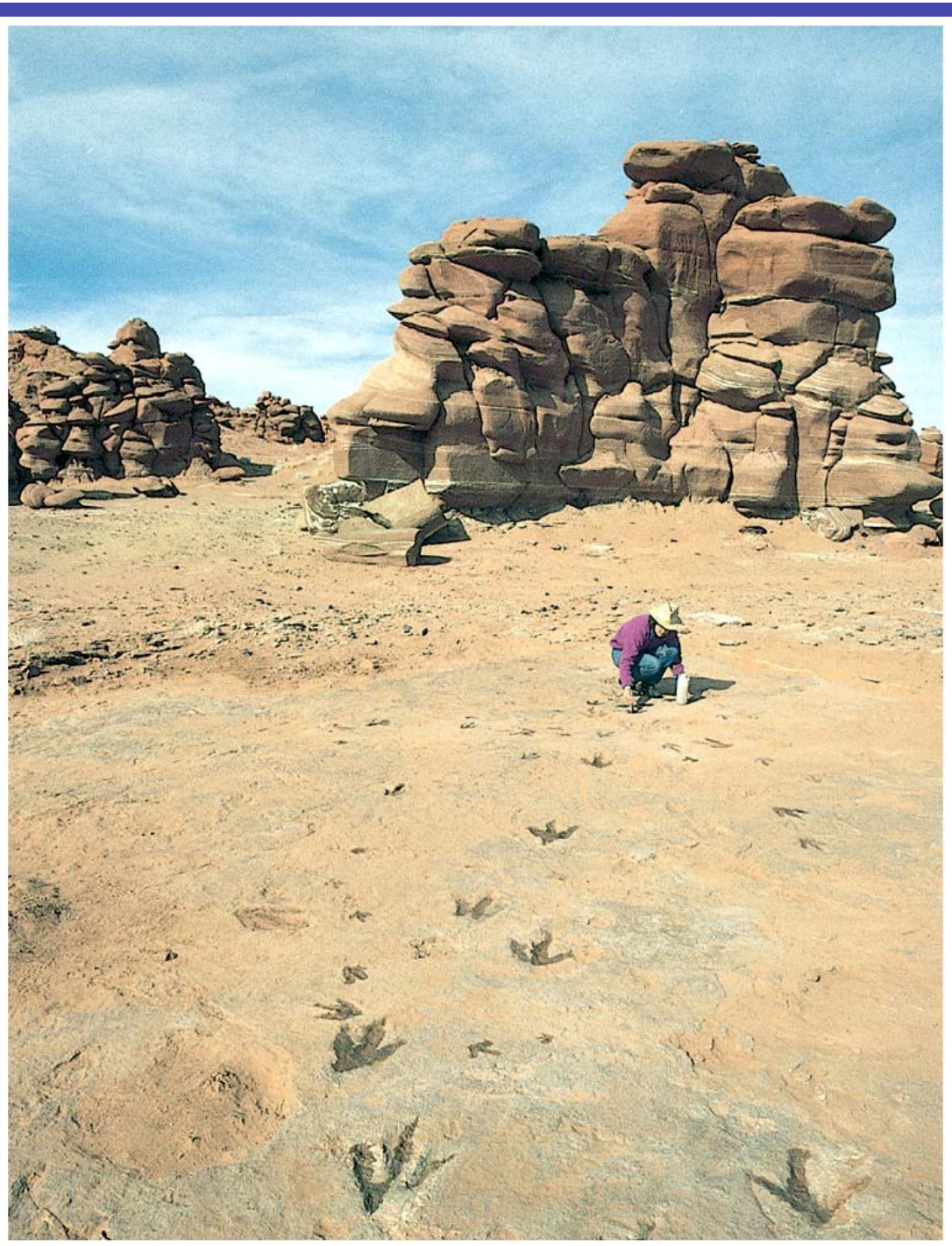
Coprolites (feces)



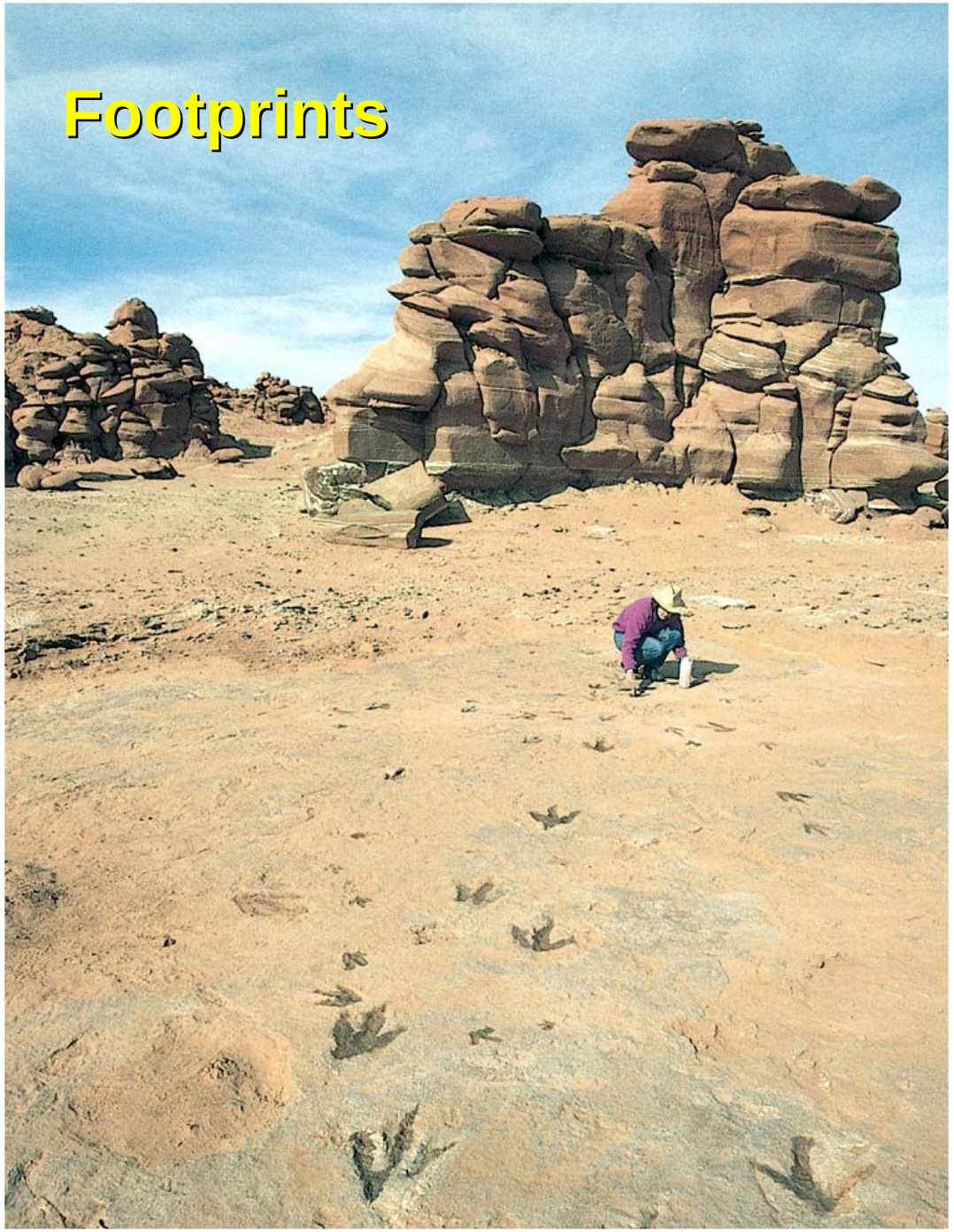





Amber – fossil tree resin

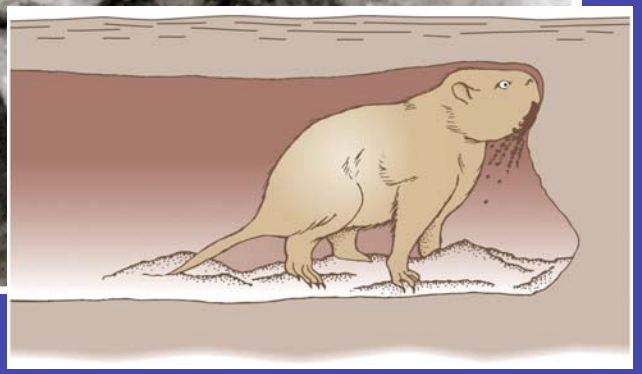


Footprints





Burrows



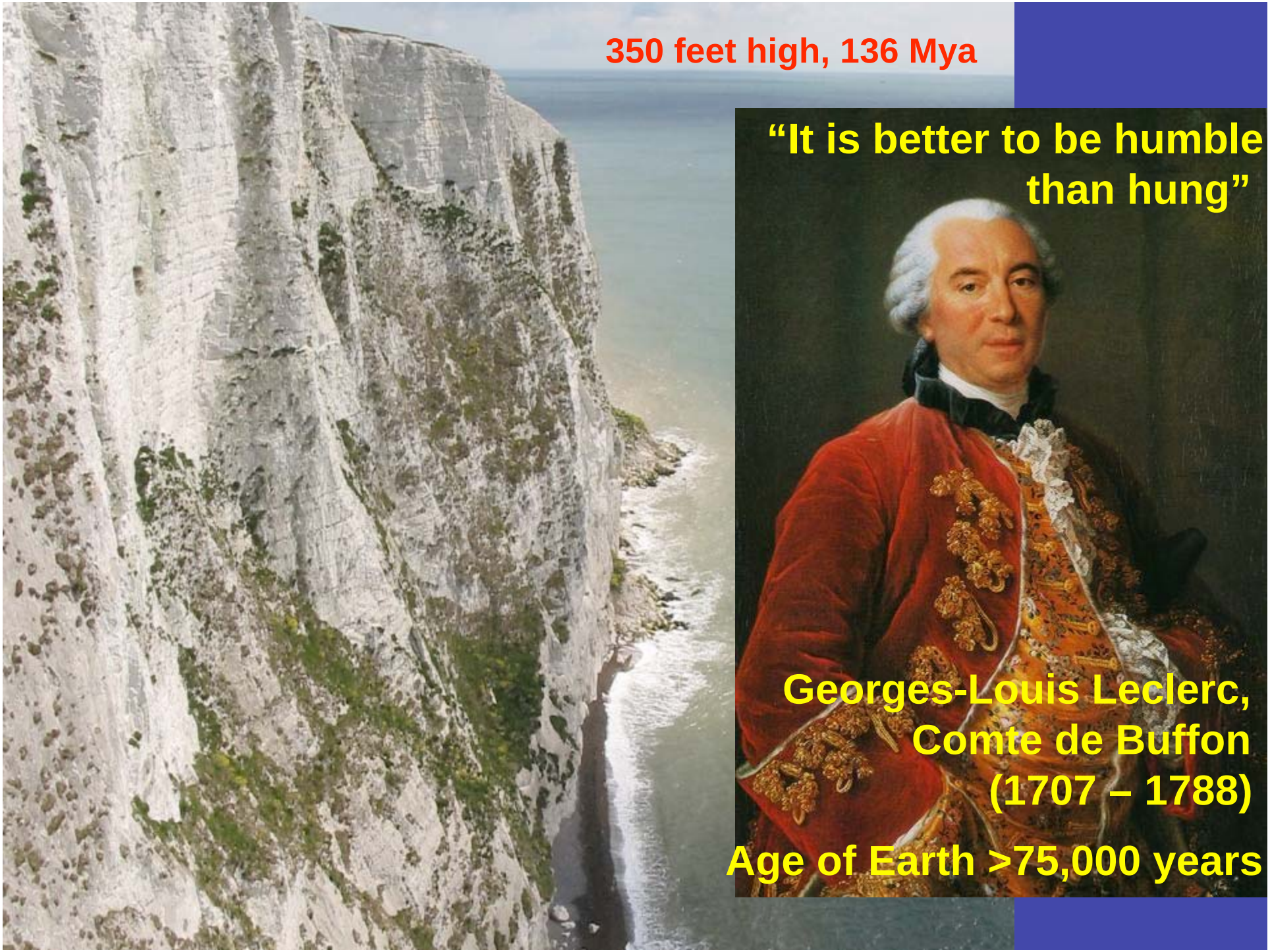
James Ussher (1581–1656) Anglican Archbishop of Armagh and Primate of All Ireland



4004 BC - Creation
(at nightfall preceding 23 October)

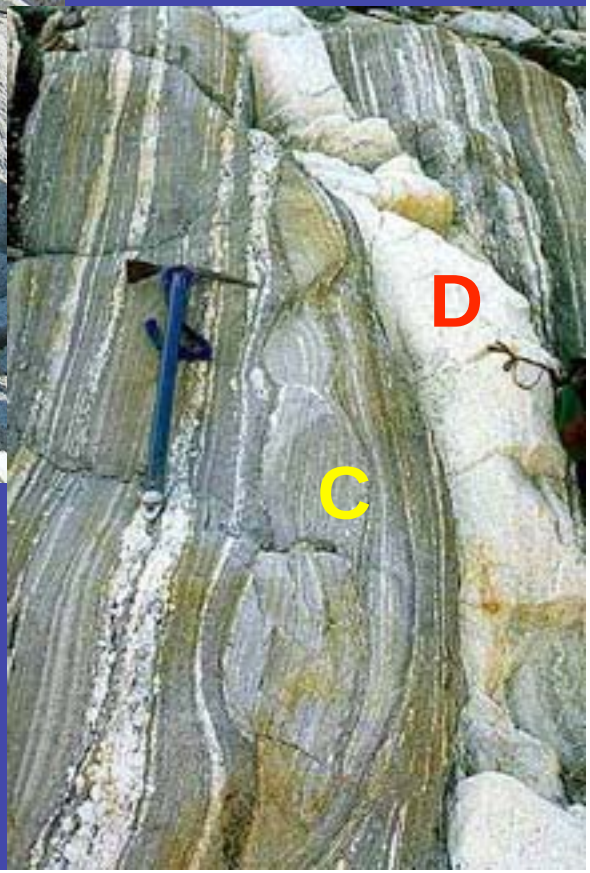
2348 BC - The Great Flood
1921 BC - Yahweh's call to Abraham
1491 BC - The Exodus from Egypt
1012 BC - The founding of the Temple in Jerusalem
586 BC - The destruction of Jerusalem by Babylon and the beginning of the Babylonian Captivity
4 BC - The birth of Christ

Published 1650, therefore age of Earth assumed to be 5,654 yrs old.


350 feet high, 136 Mya
"It is better to be humble than hung"
Georges-Louis Leclerc, Comte de Buffon (1707 – 1788)
Age of Earth >75,000 years

‘Principle of Cross-Cutting Relationships’





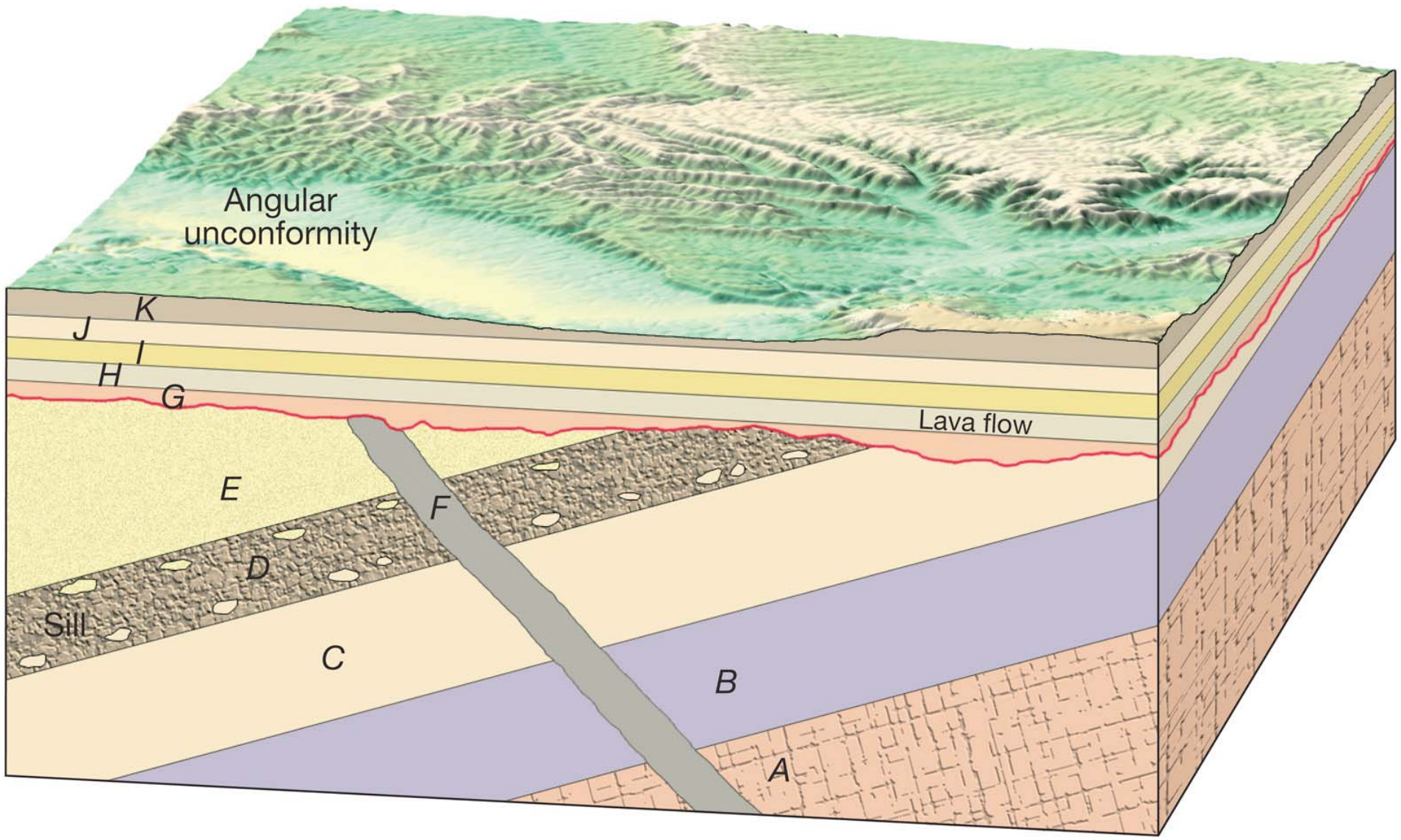
Which are youngest?

A) A&C, B) A&D, C) B&C, D) B&D



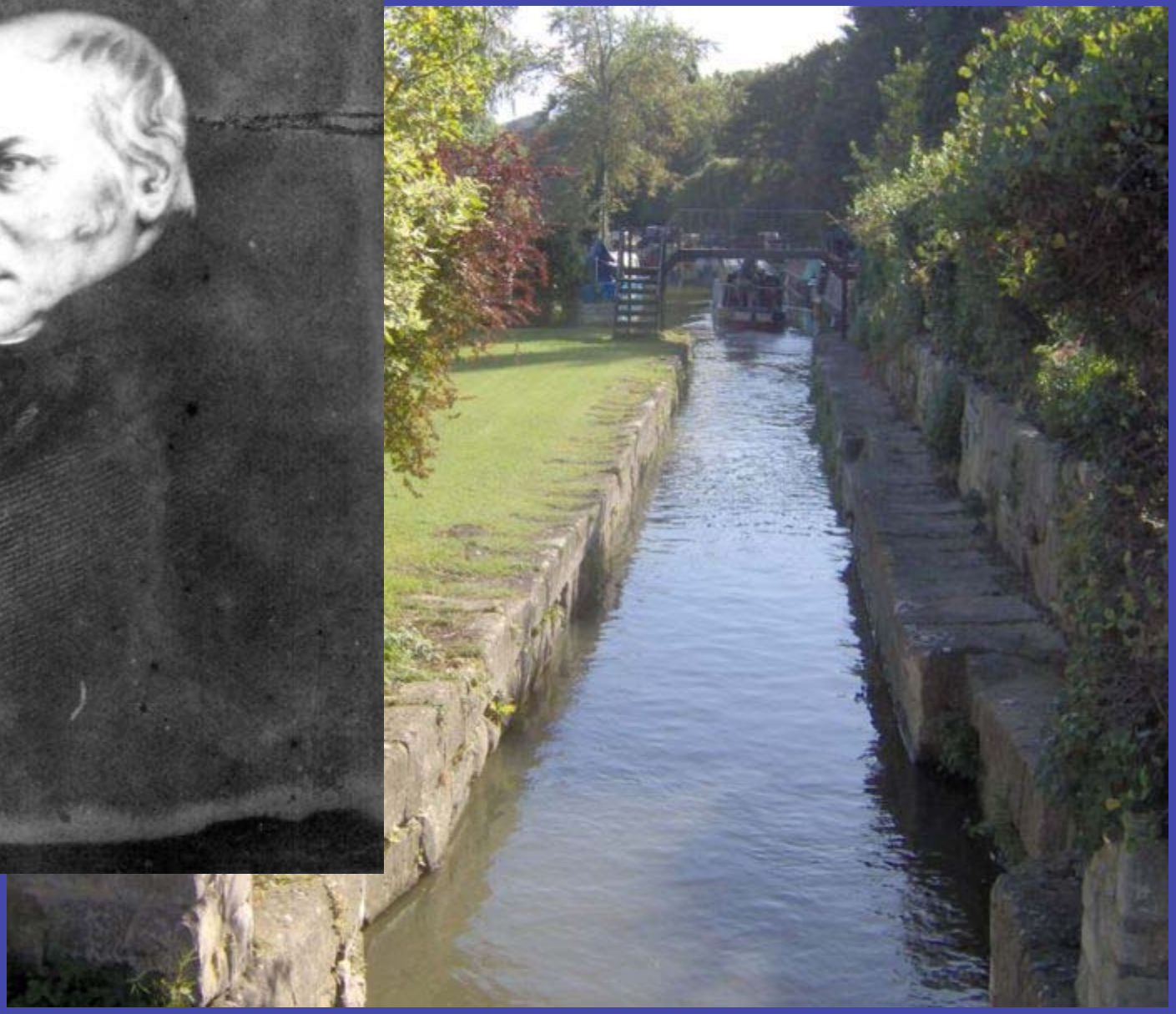
"the mind seemed to grow giddy by looking so far into the abyss of time" (1786)

Youngest material not cut (or overlain) by any other strata

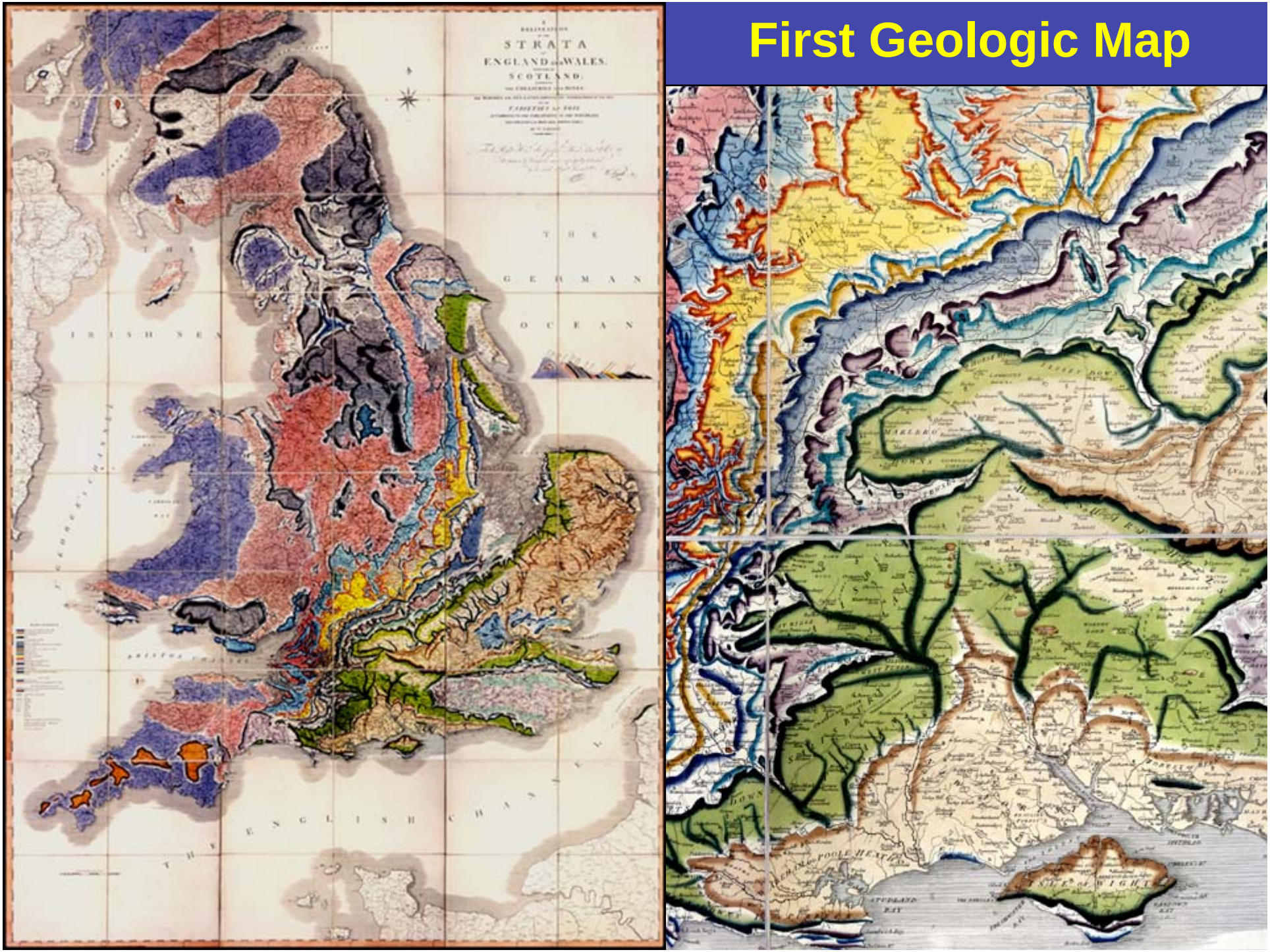


William “Strata” Smith (1769-1839)





First Geologic Map



Stratigraphic correlation

A

B

C

D

E









Stratigraphic correlation

A

B

C

D

E





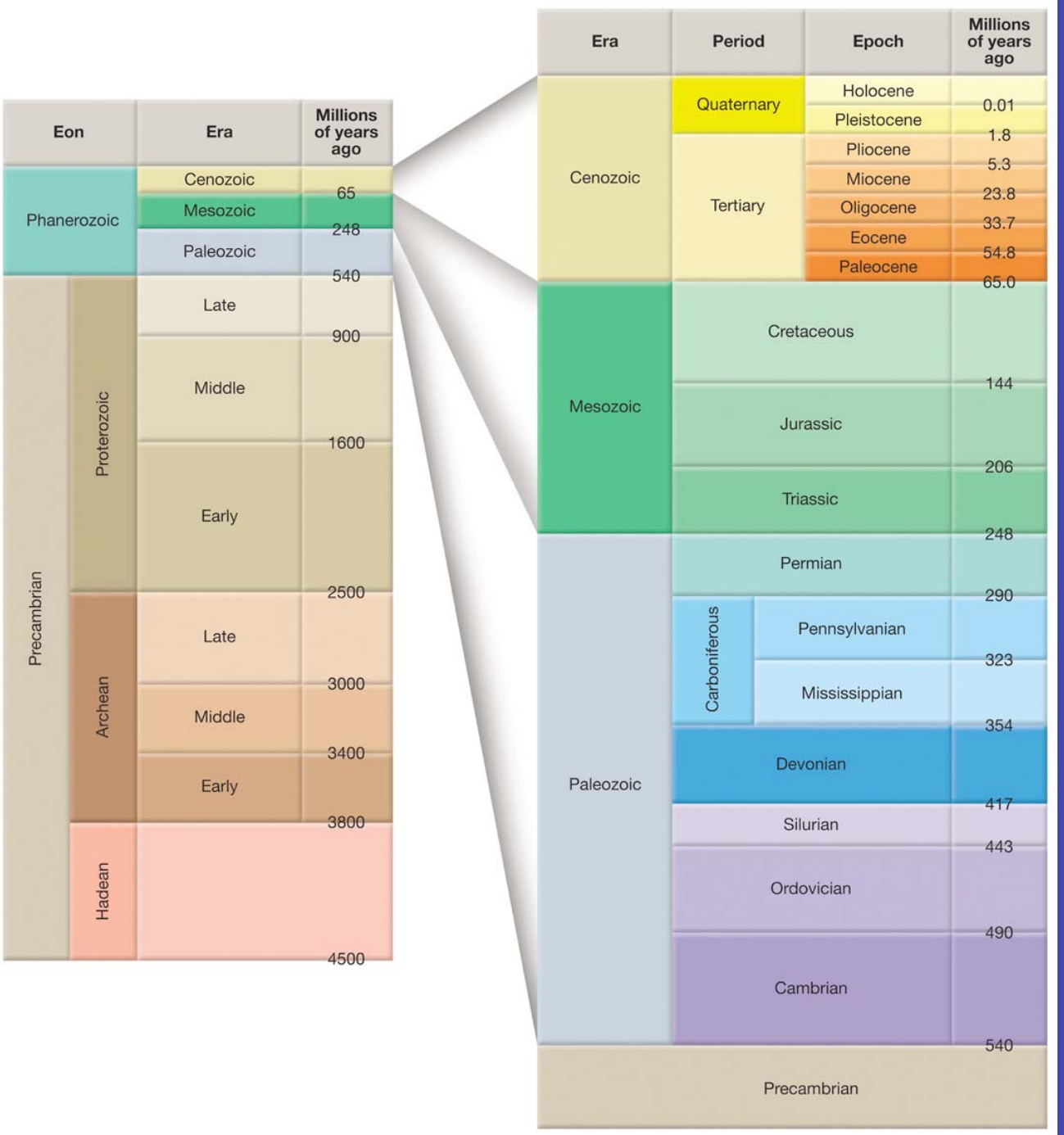




100Ka

200Ka

300Ka



Fossils define the:

"Geologic Timescale"



Radioactivity:

Henri Becquerel (1896)
Marie & Pierre Curie (1898)



chalcolite



pitchblende

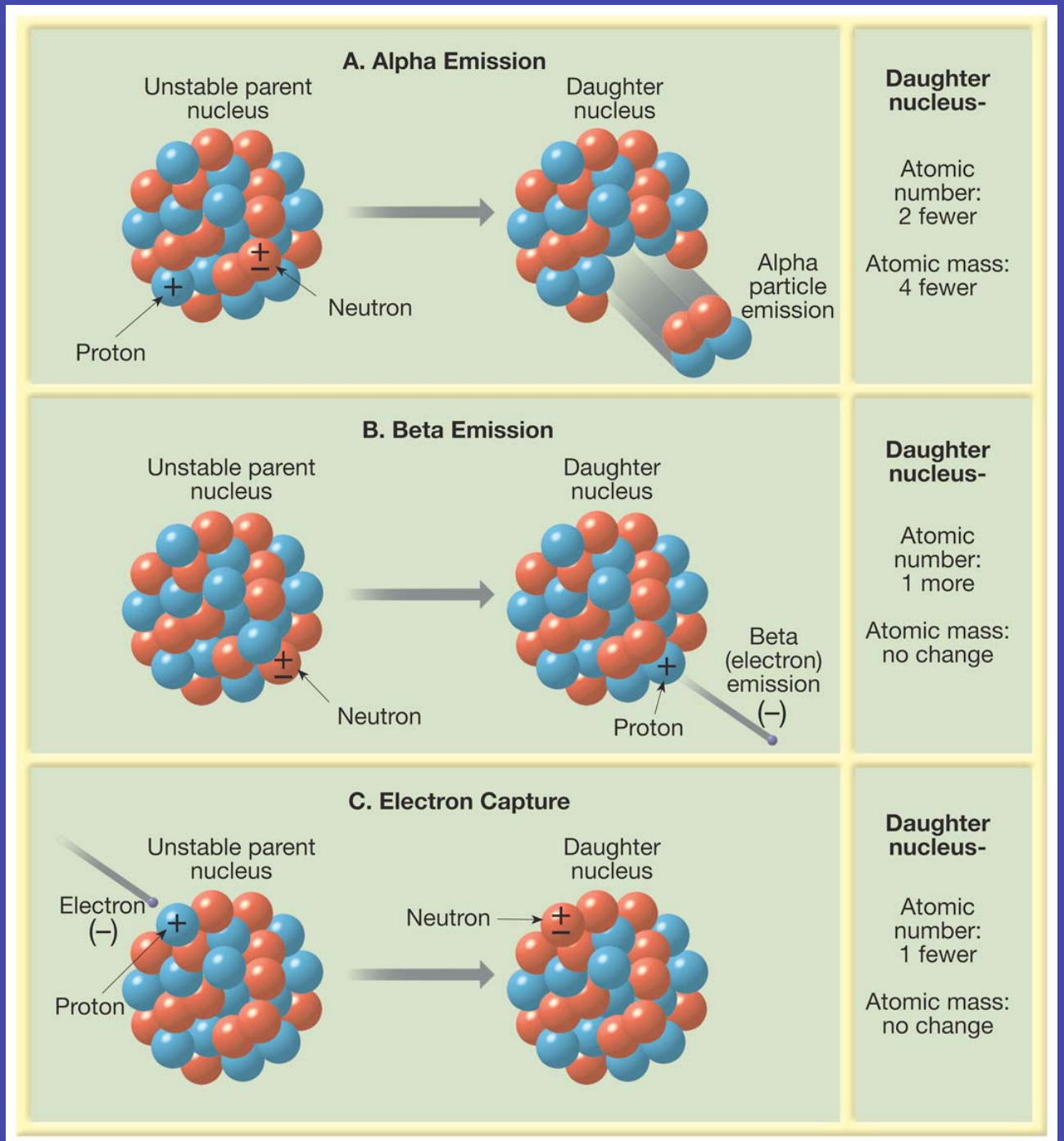


Isotope: same element, variable neutron number

Uranium isotopes:

	protons	neutrons
U-234	92	142
U-235	92	143
U-238	92	146





2 protons & 2 neutrons emitted

1 electron emitted

1 electron captured

Why do we care about radioactivity?





Where were you at 5am last Saturday?

A) Hiking lava flows on the Big Island!

B) Partying!

C) Sleeping!








CANADA



Why do we care about radioactivity?

1) Radioactivity produces HEAT energy
   (i.e. not all of Earth's heat has to have come from the Sun)

2) Radioactive decay happens on a measurable timescale – this gives us a calendar for Earth materials

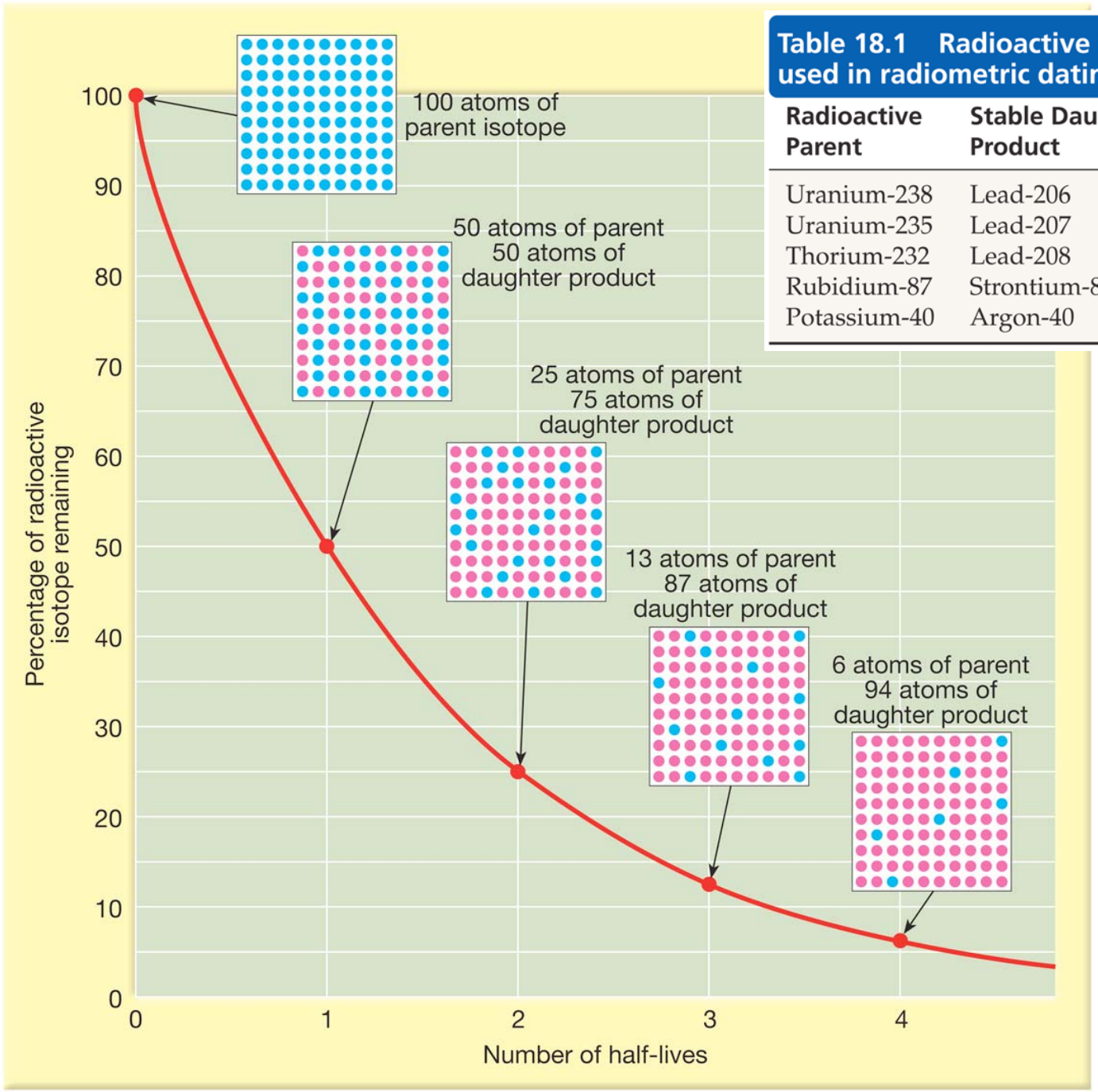
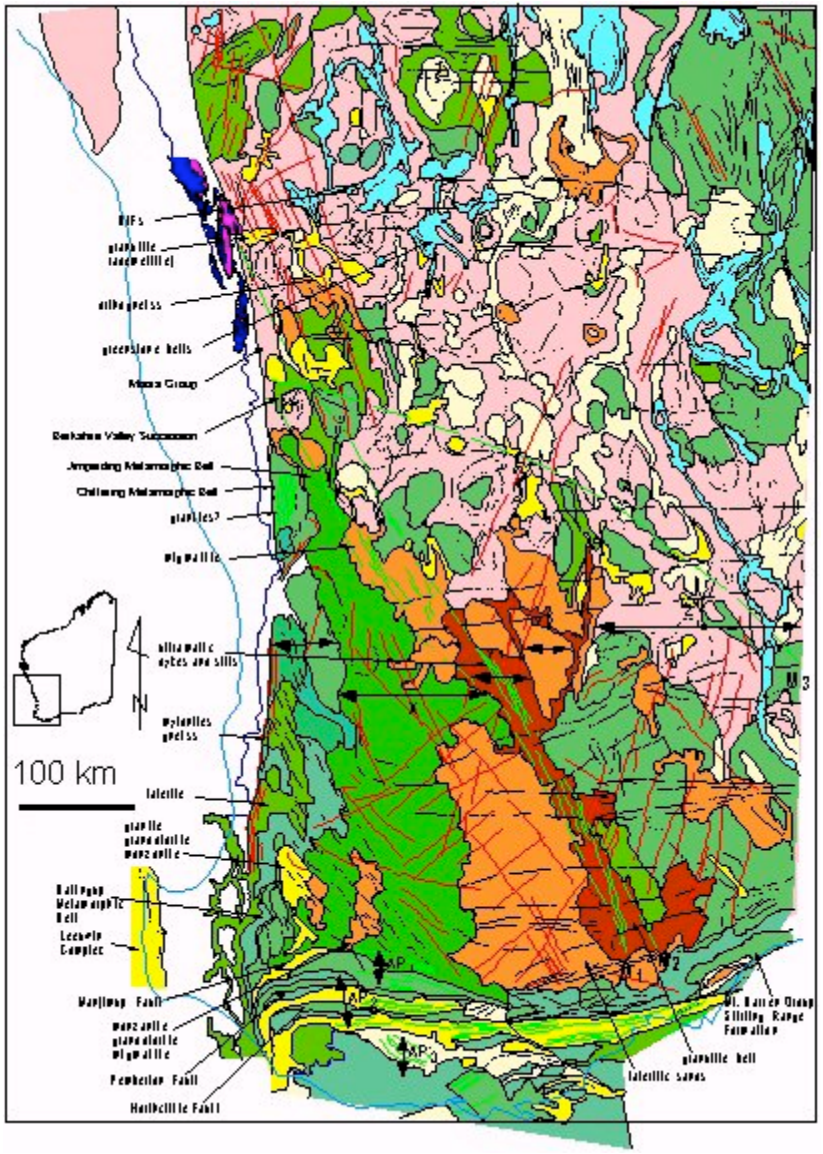


Table 18.1 Radioactive isotopes frequently used in radiometric dating.

Radioactive Parent	Stable Daughter Product	Currently Accepted Half-life Values
Uranium-238	Lead-206	4.5 billion years
Uranium-235	Lead-207	713 million years
Thorium-232	Lead-208	14.1 billion years
Rubidium-87	Strontium-87	47.0 billion years
Potassium-40	Argon-40	1.3 billion years

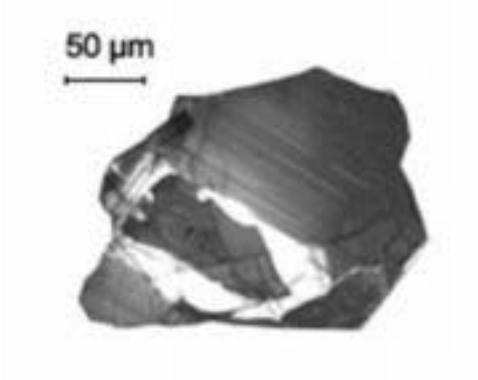
parent/ daughter ratio yields:

AGE





Oldest rock on Earth
4.404 Bya



Jack Hills, Western Australia



Age of Earth from meteorites = 4.56 billion years

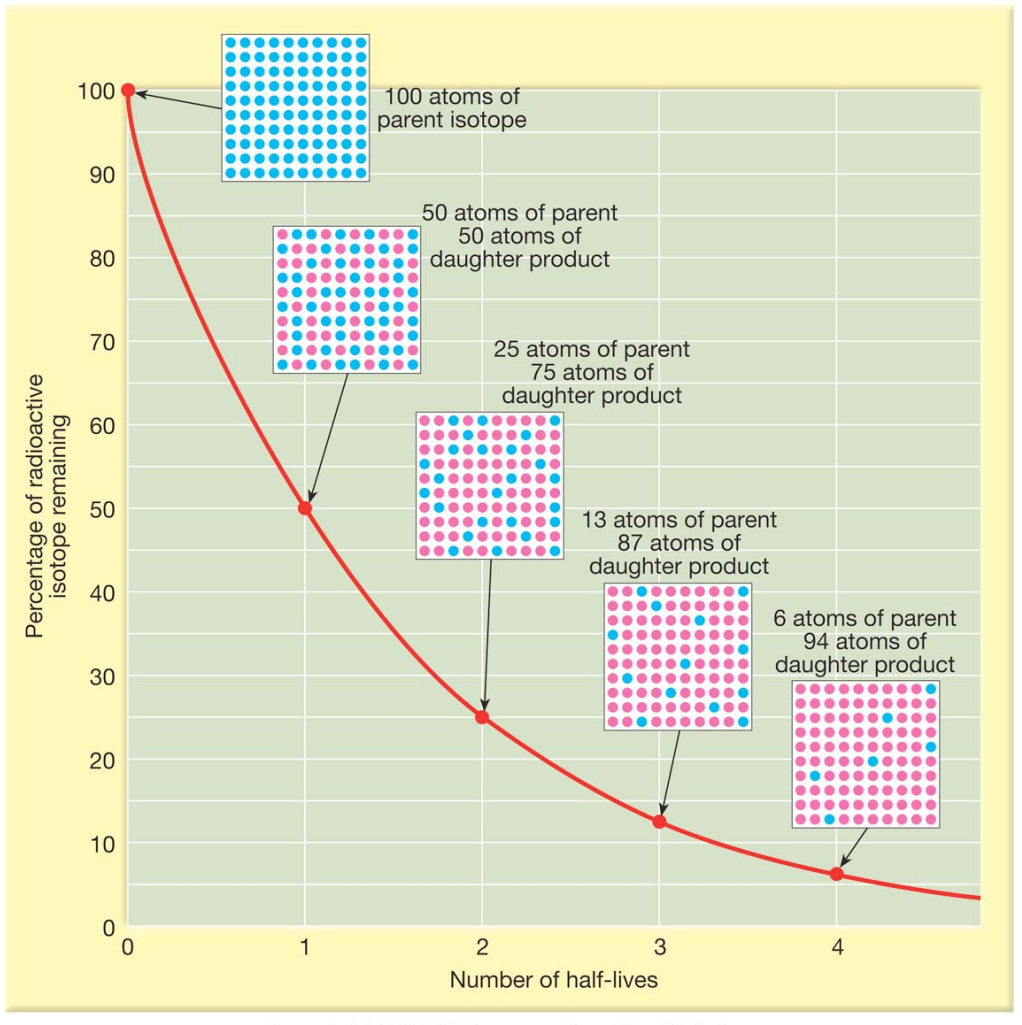


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Rock B contains:
Potassium-40
P/D = 25/75

What is the minimum age of rock A?

How do you know? (show your work!)

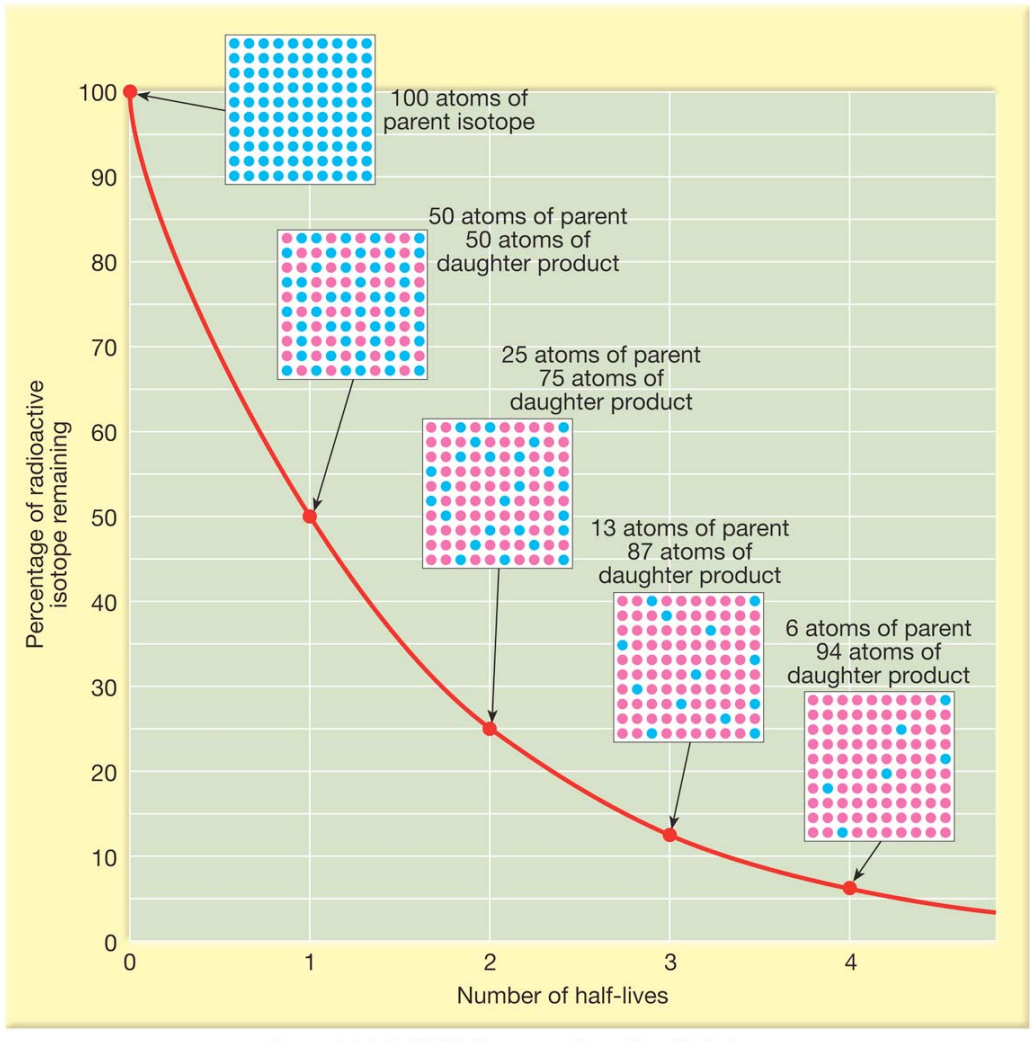
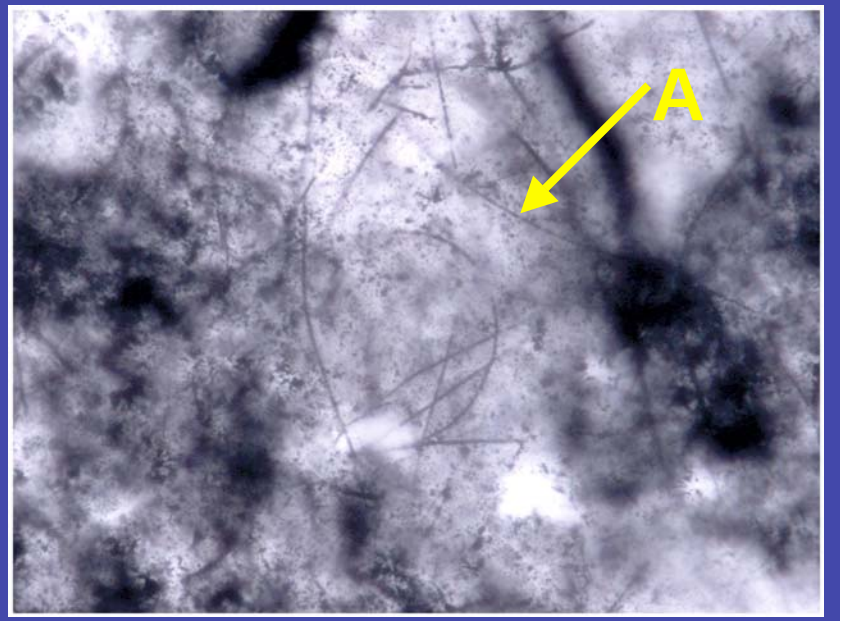


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Fossil A contains: Uranium-235 P/D = 4.5/95.5

Fossil A is in a metamorphic rock

What are the minimum & maximum ages of this fossil?

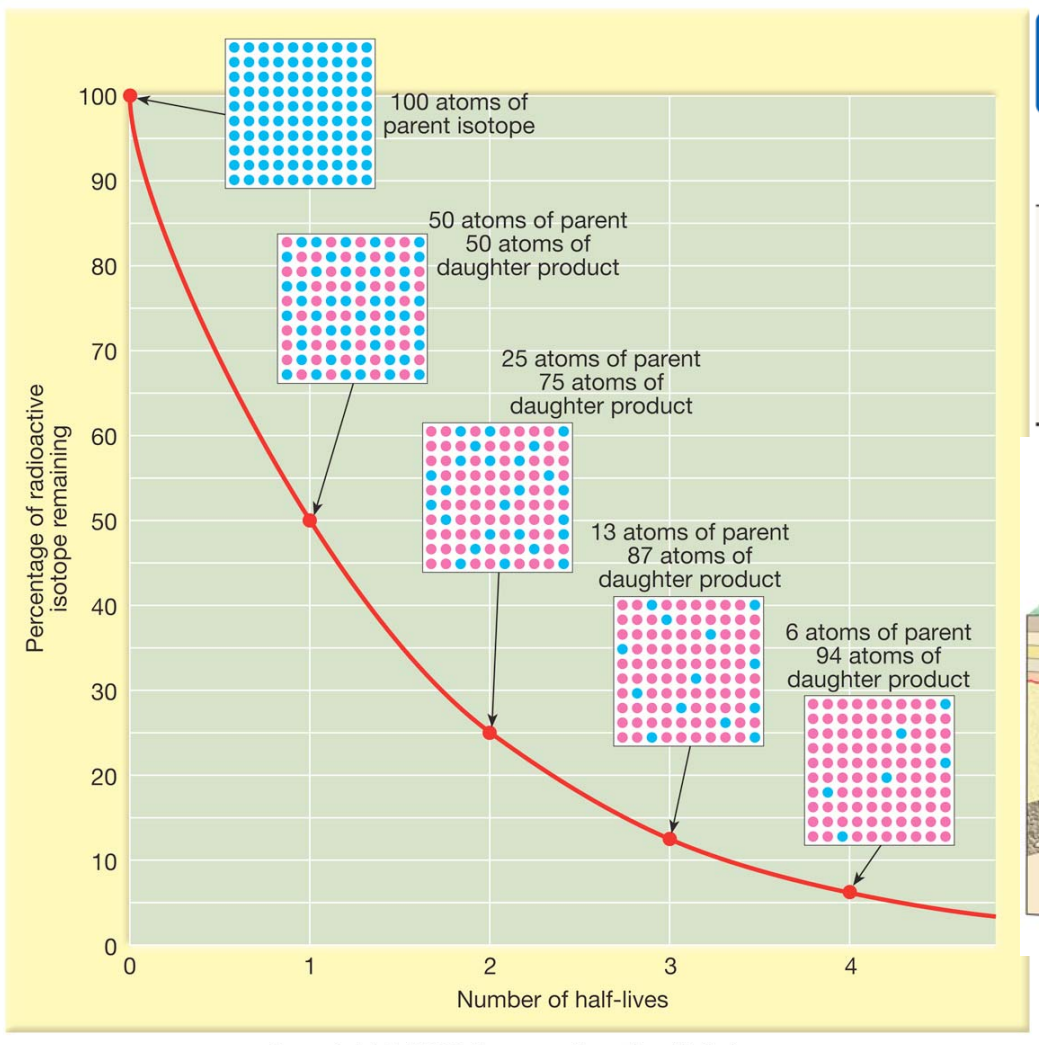
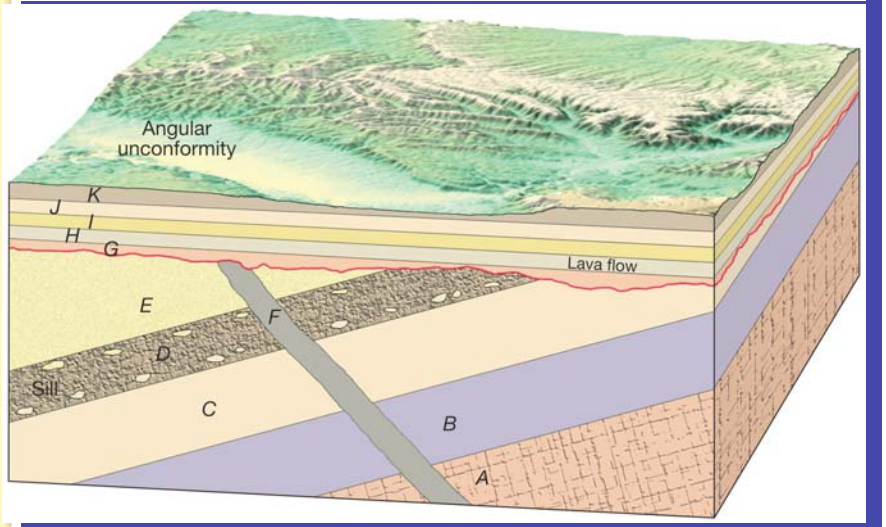


Table 18.1 Radioactive isotopes frequently used in radiometric dating.

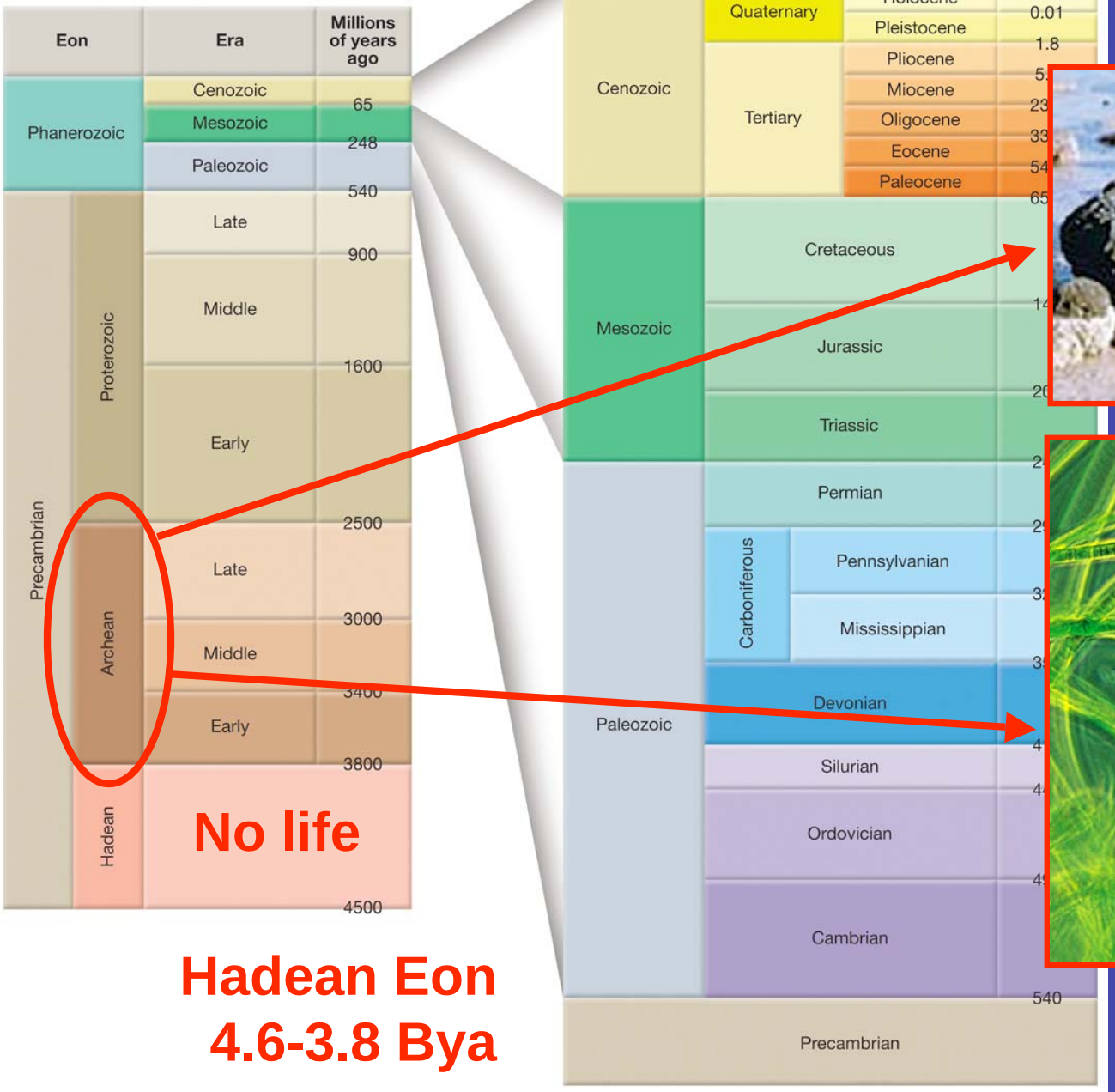
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Rubidium-87	Strontium-87	47.0 billion years
Potassium-40	Argon-40	1.3 billion years



C contains:
Potassium-40
P/D = 13/87

A contains:
Uranium-238
P/D = 50/50

What is the range of possible ages for B?

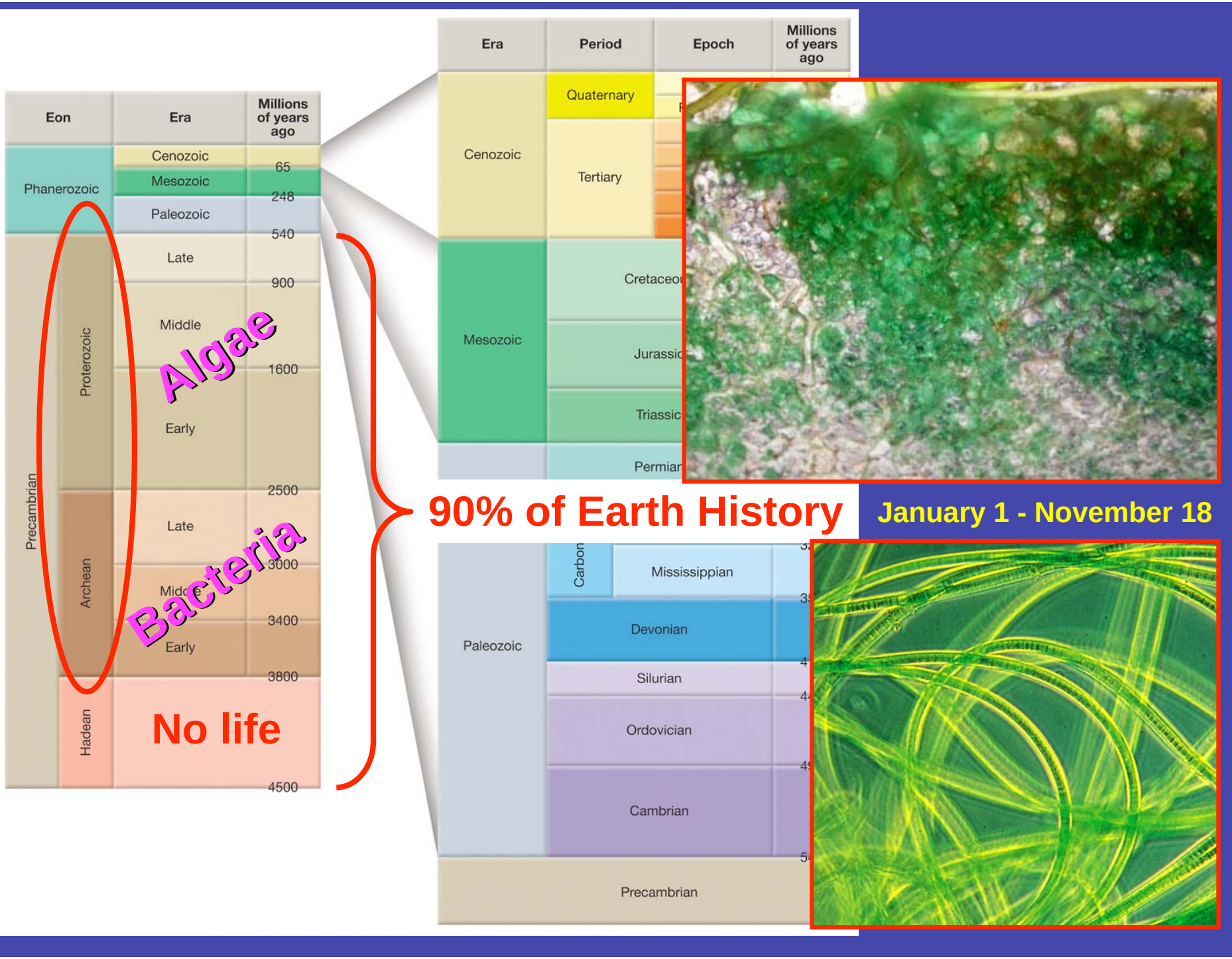


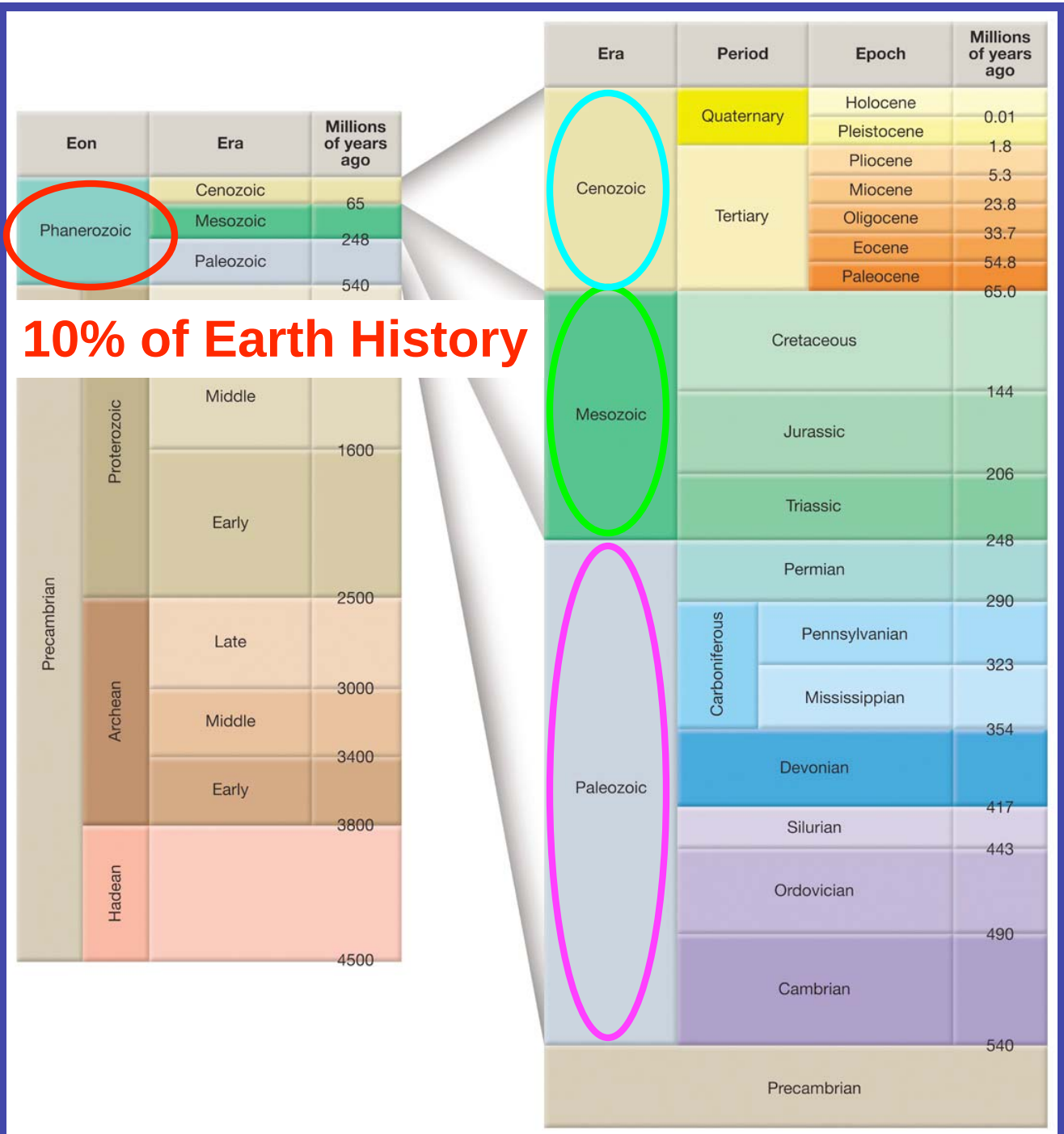


“Stromatolites”



Bacteria


Eon
Era
Millions of years ago
Phanerozoic
Cenozoic
Mesozoic
Paleozoic
65
248
540
Precambrian
Proterozoic
Late
Middle
Early
900
1600
2500
Archean
Late
Middle
Early
3000
3400
3800
Hadean
4500
Algae
Bacteria
No life
Era
Period
Epoch
Millions of years ago
Cenozoic
Quaternary
Tertiary
Mesozoic
Cretaceou
Jurassic
Triassic
Permian
90% of Earth History
January 1 - November 18
Paleozoic
Carbon
Mississippian
Devonian
Silurian
Ordovician
Cambrian
Precambrian



Phanerozoic

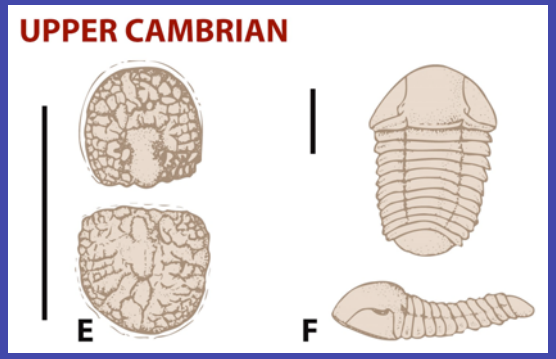
“Visible life”

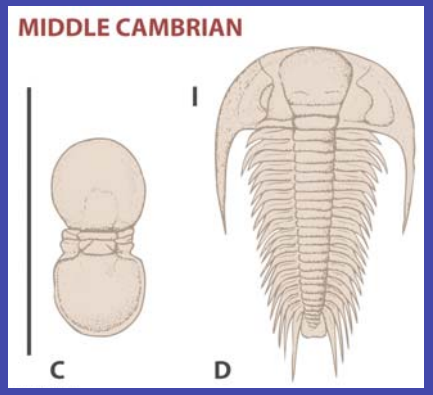
Recent life

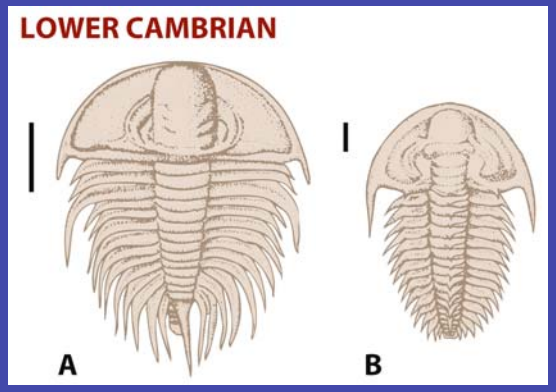
Middle life

Ancient life

Early Paleozoic (Ancient Life) – Trilobites: arthropods, 15k species









Middle Paleozoic (A.L.) – Jawed Fish: vertebrate predator; Seed Plants

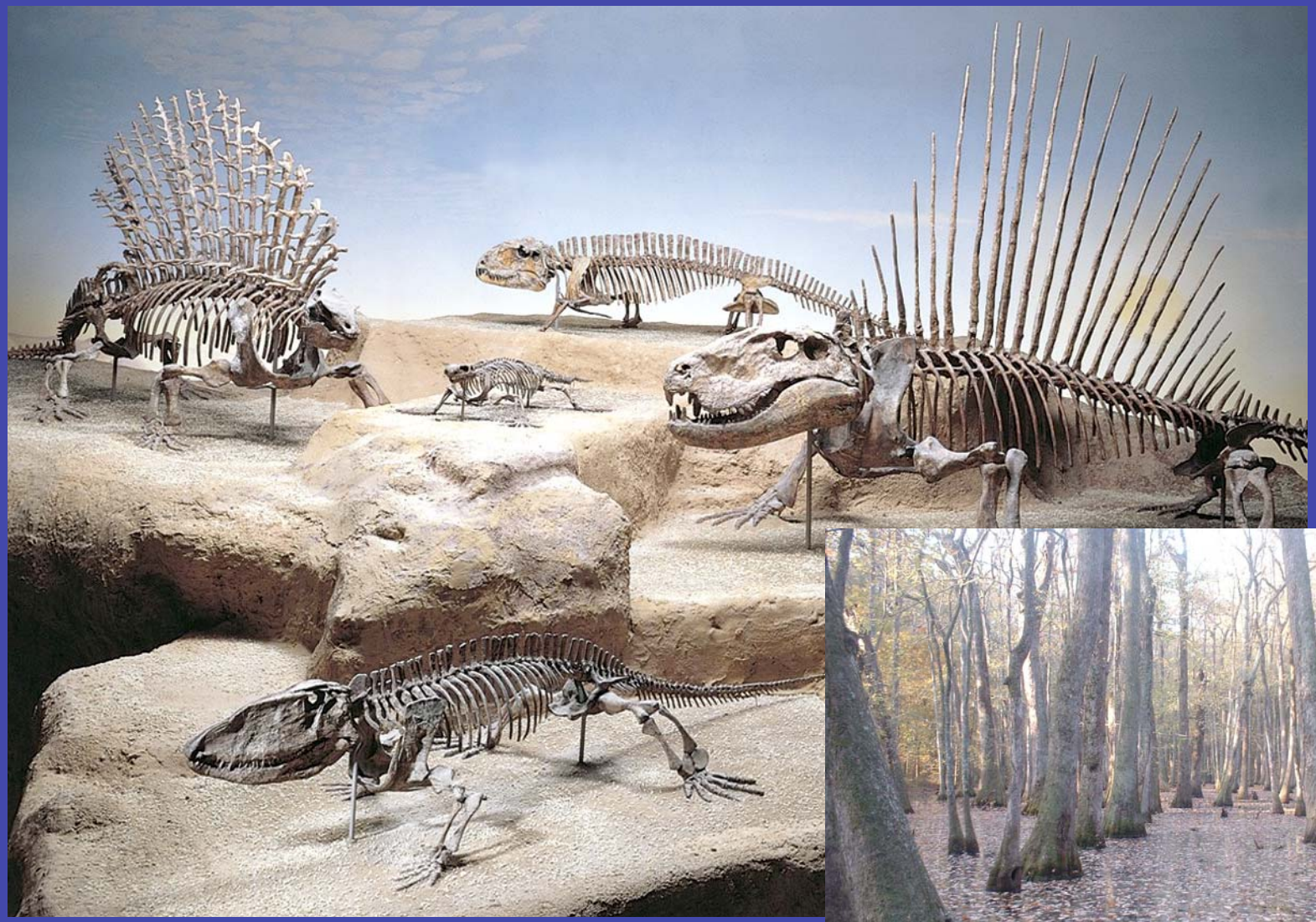


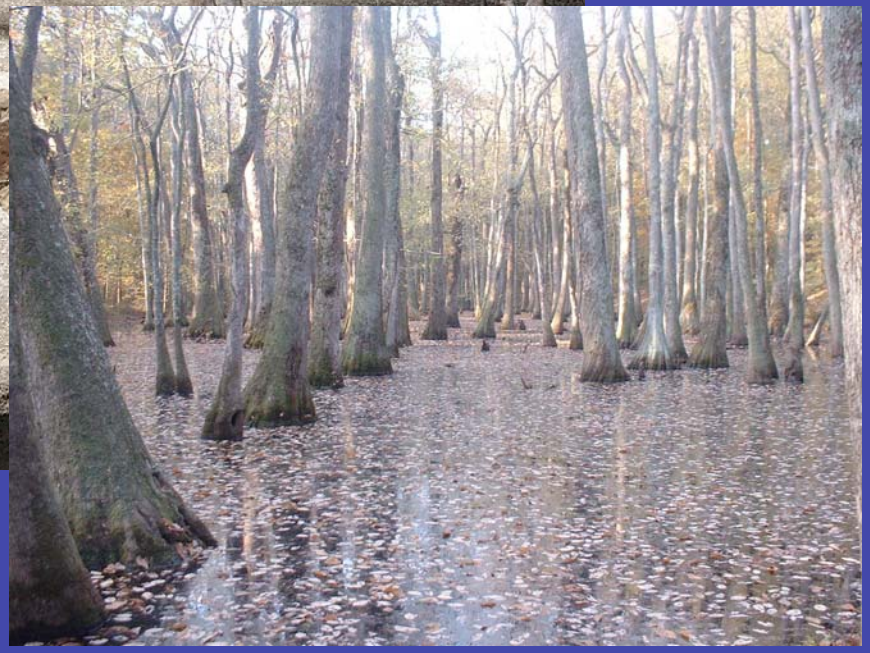






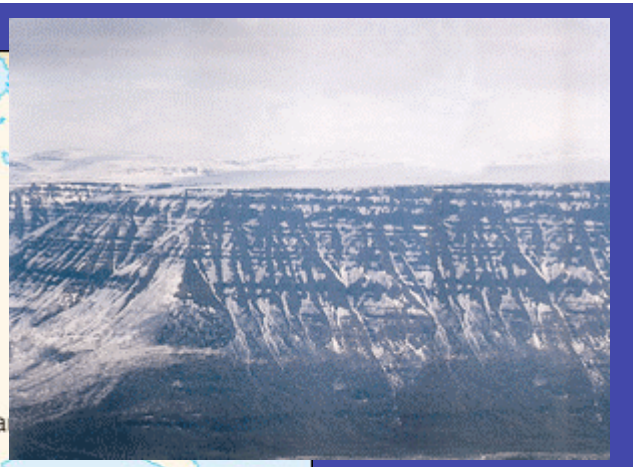
Late Paleozoic (A.L.) – Reptiles such as Dimetrodon, Coal Swamps





December 11





Permian Extinction

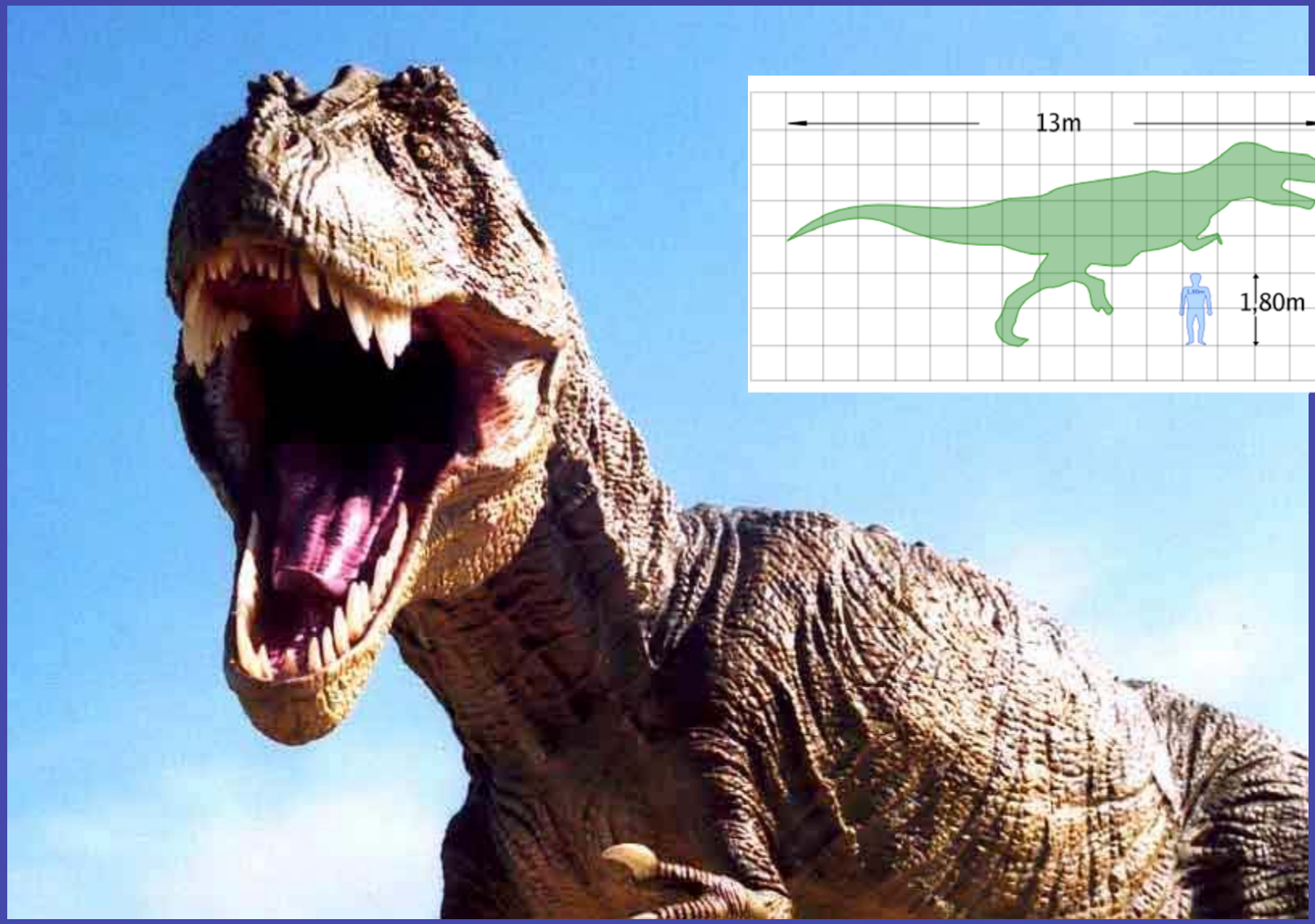
96% marine

70% terrestrial

Siberian Flood basalts: 251-250 Mya, 1-4 million km^3

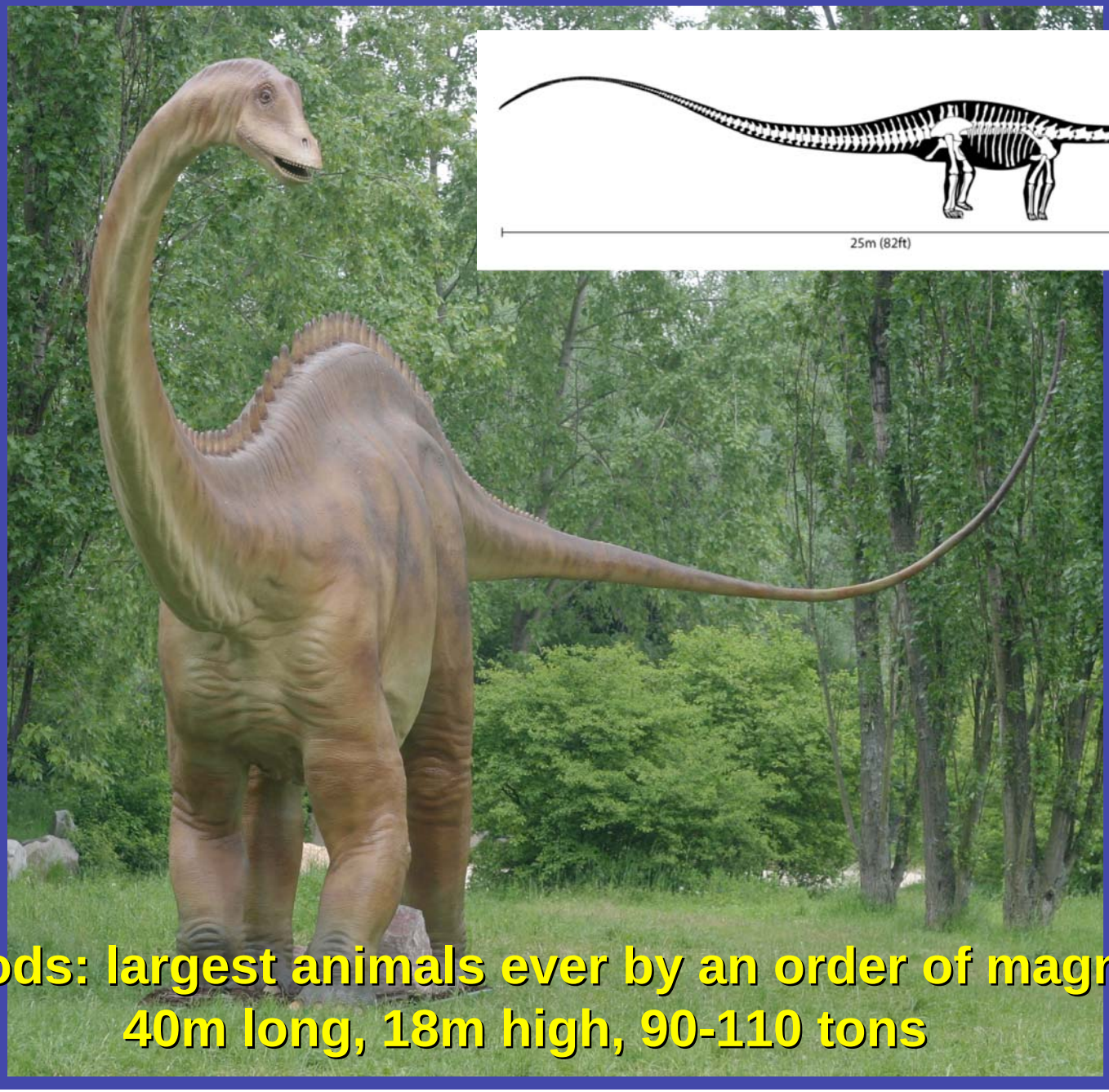


Early Mesozoic (Middle Life) – DINOSAURS!



T-rex: bipedal predator 13m long, 7.5 tons, hollow bones

Early Mesozoic (Middle Life) – DINOSAURS!



Sauropods: largest animals ever by an order of magnitude
40m long, 18m high, 90-110 tons

What are dinosaurs closest modern relatives?







A) Reptiles
B) Birds
C) Mammals
D) Amphibians

Early Mesozoic (Middle Life) – DINOSAURS!

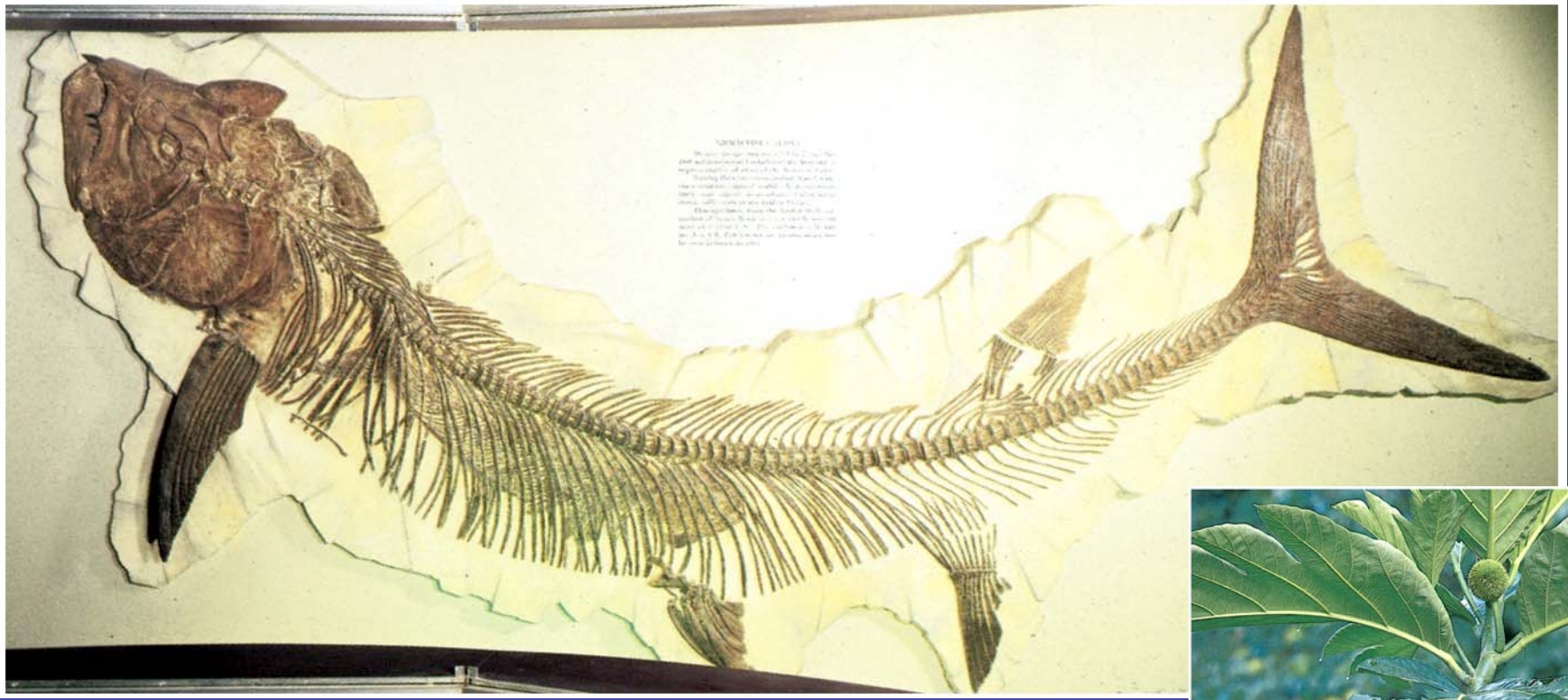




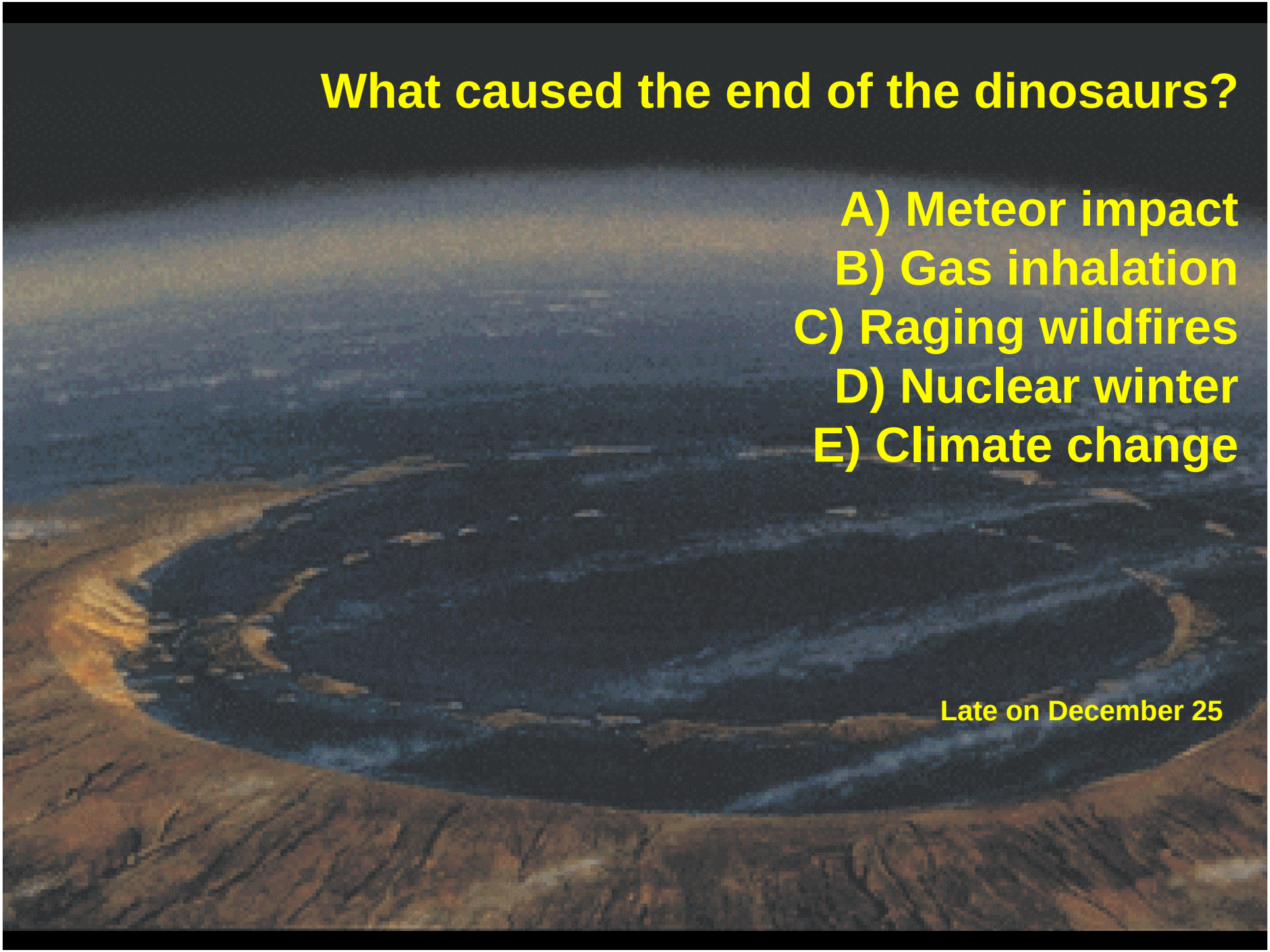
Median dinosaur weight 2 tons



Late Mesozoic (Middle Life) – Chalk (Cretaceous), modern fish

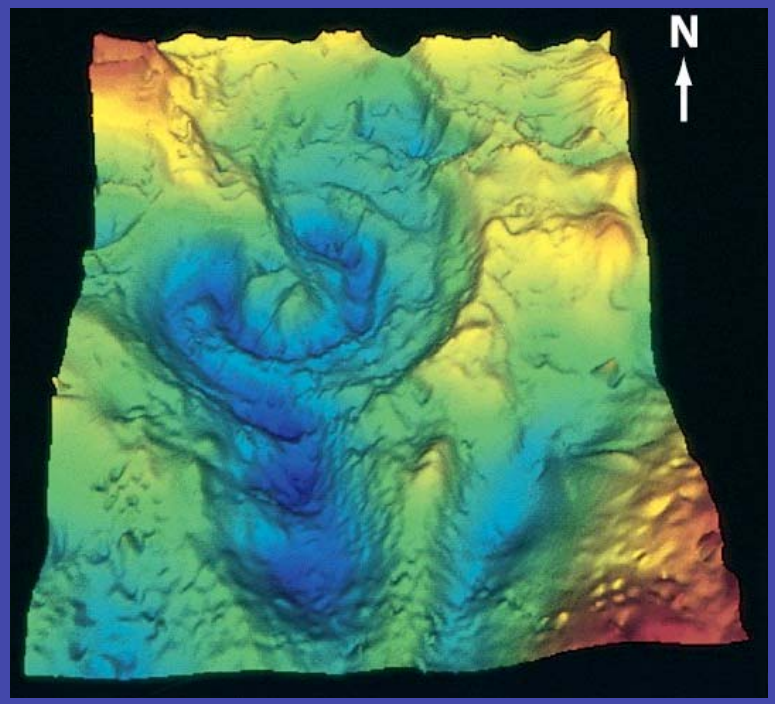




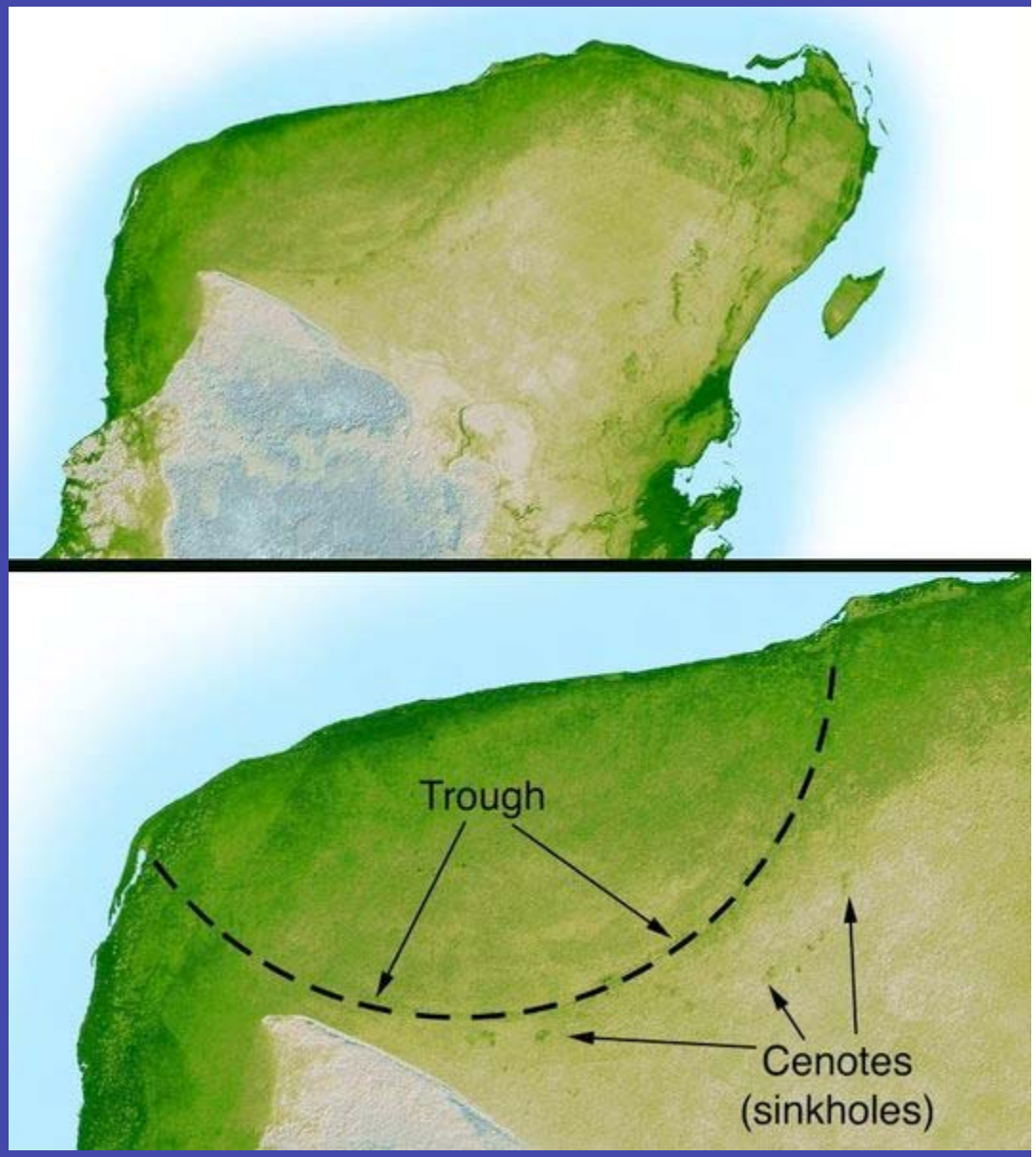

What caused the end of the dinosaurs?
A) Meteor impact
B) Gas inhalation
C) Raging wildfires
D) Nuclear winter
E) Climate change
Late on December 25

Chicxulub Crater – >180km across





Andesite layer 1.3km down



10 km across ***(not to scale!)***



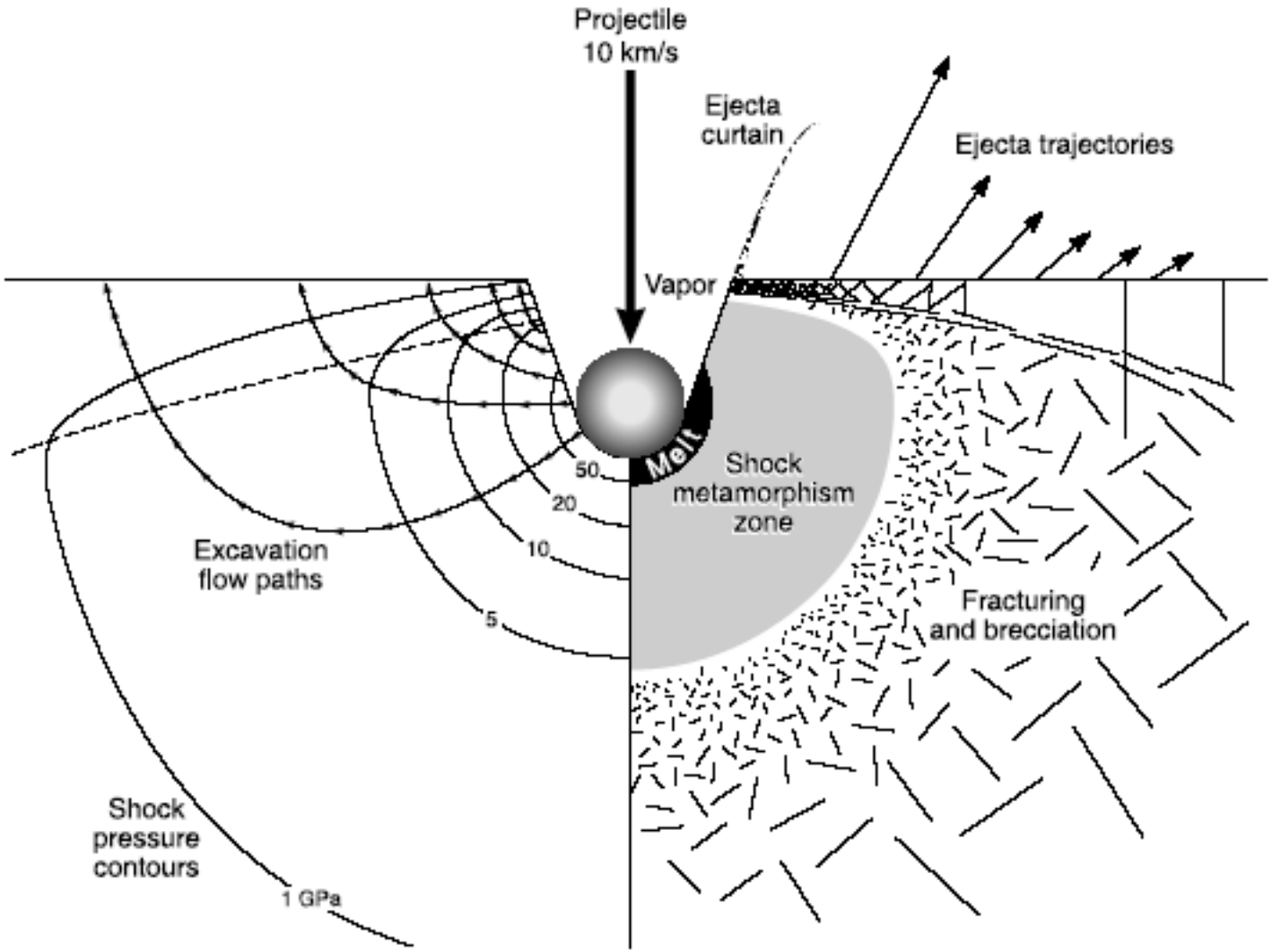
2 million times more powerful than largest nuclear explosion

K/T Boundary

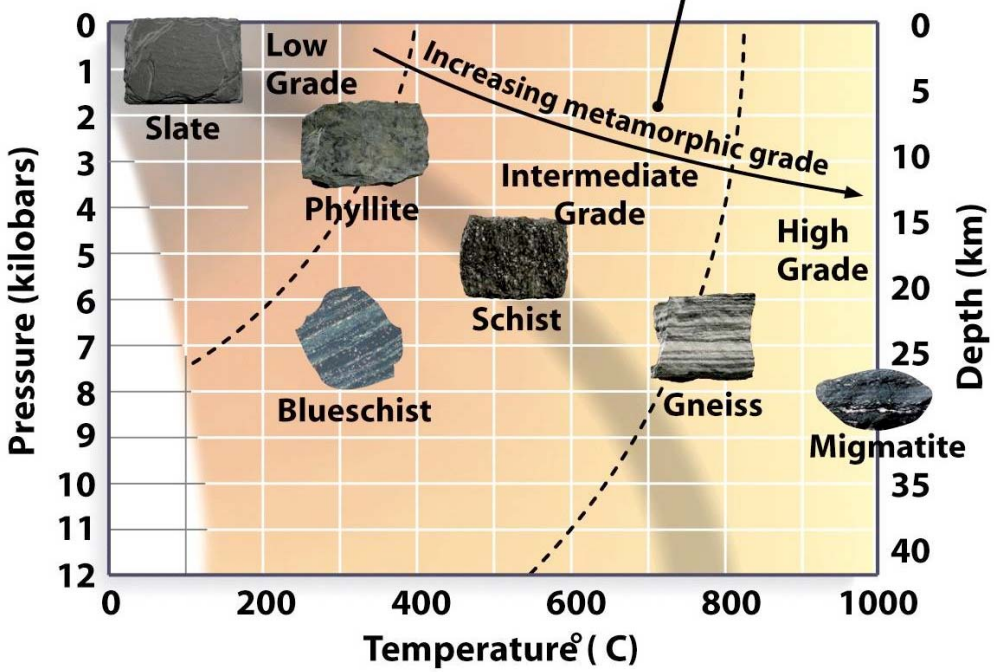
65 Mya



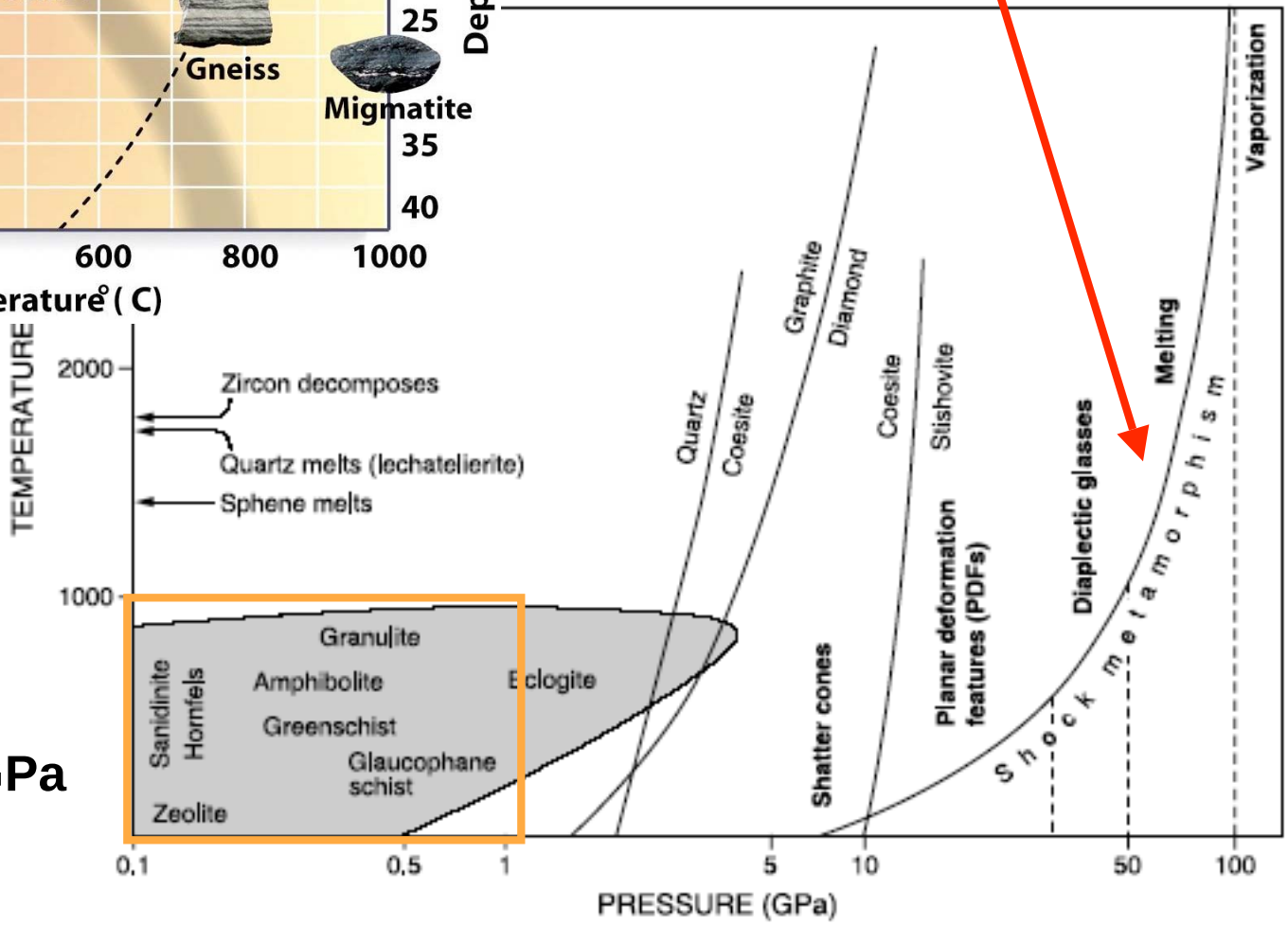
spherules


Projectile
10 km/s
Ejecta
curtain
Ejecta trajectories
Vapor
Melt
Shock
metamorphism
zone
50
20
10
5
Excavation
flow paths
Fracturing
and brecciation
Shock
pressure
contours
1 GPa

Normal metamorphism



Shock metamorphism



10 kilobars = 1 GPa

10 km across ***(not to scale!)***

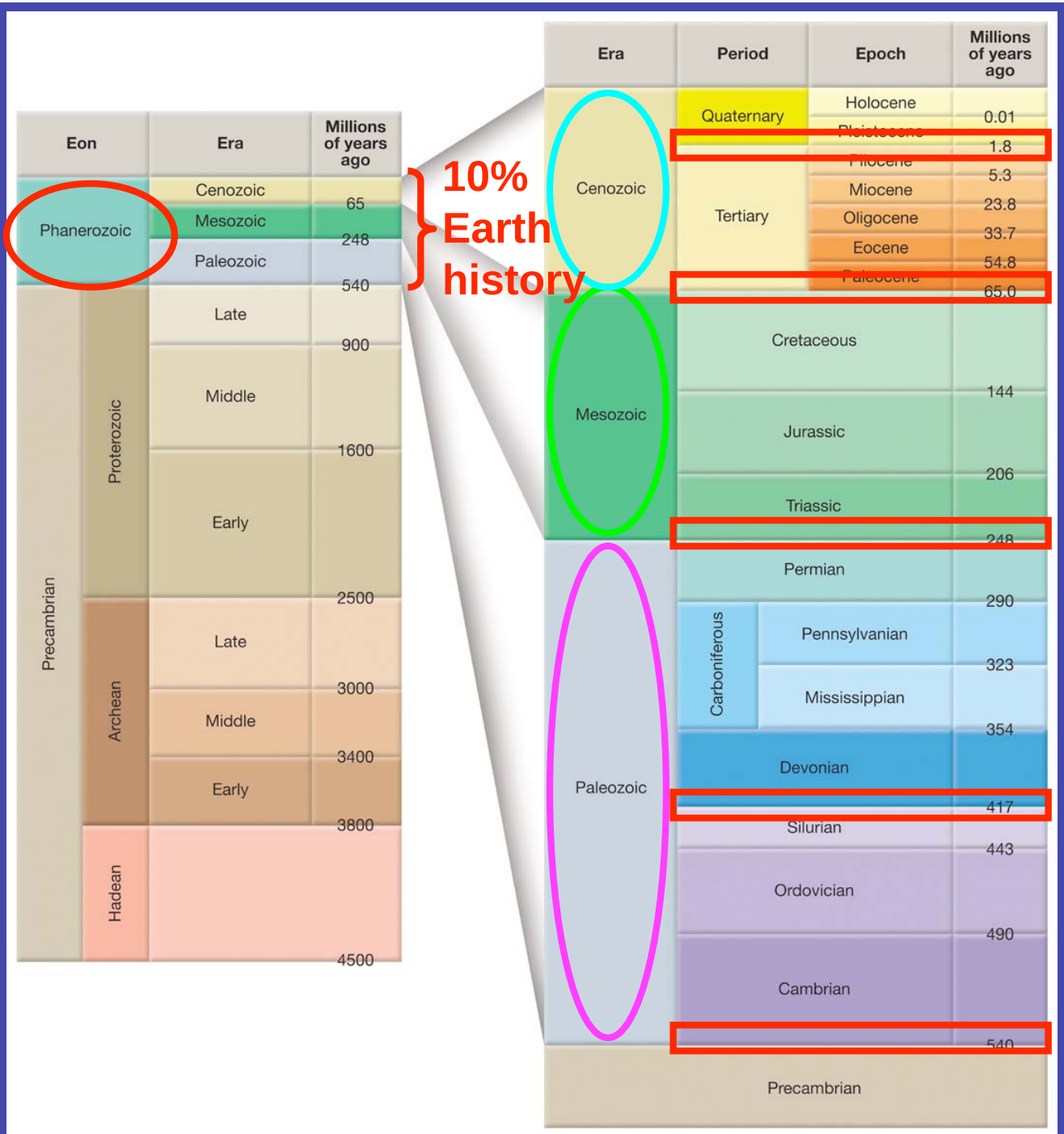


1) Mega-tsunami kilometers high

2) Nuclear winter from atmospheric debris



spherules



What Organizes the Geologic Timescale?

A) Time

B) Life

C) Fossils

D) Extinctions

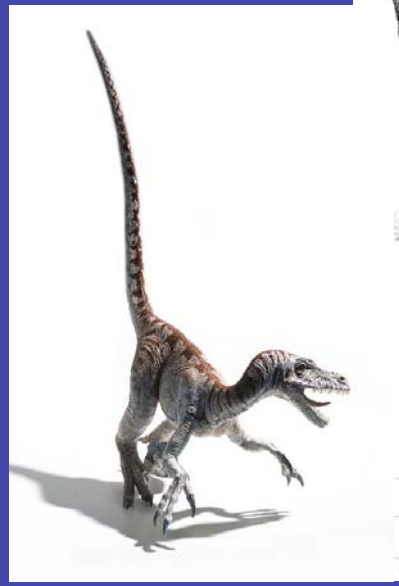
E) Climate Change

Early Cenozoic (Recent Life) – Radiation of mammals

What dinosaur do paraceratherium resemble?

A) T-rex
B) Velociraptor
C) Sauropod
D) Pterodactyl





Paraceratherium: gigantic hornless rhinoceros



Where do you find palm fronds today?



Fossil palm frond



Bahamas



Hawaii

Wyoming?



Where would you expect to find alligators today?

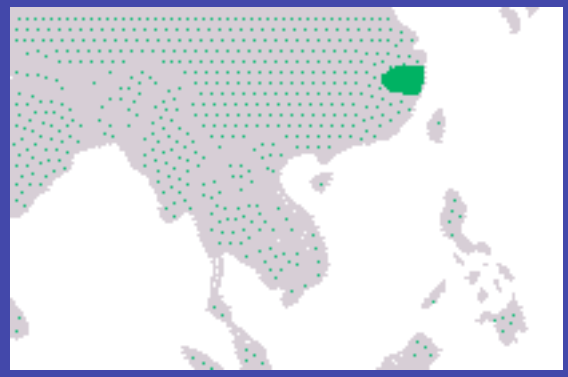


Where would you expect to find alligators today?



Everglades

China





Where would you expect to find alligators today?





Alligator fossils found on Ellesmere Island

78° North
(north of
Greenland)
54.8-33.7 Mya
Eocene

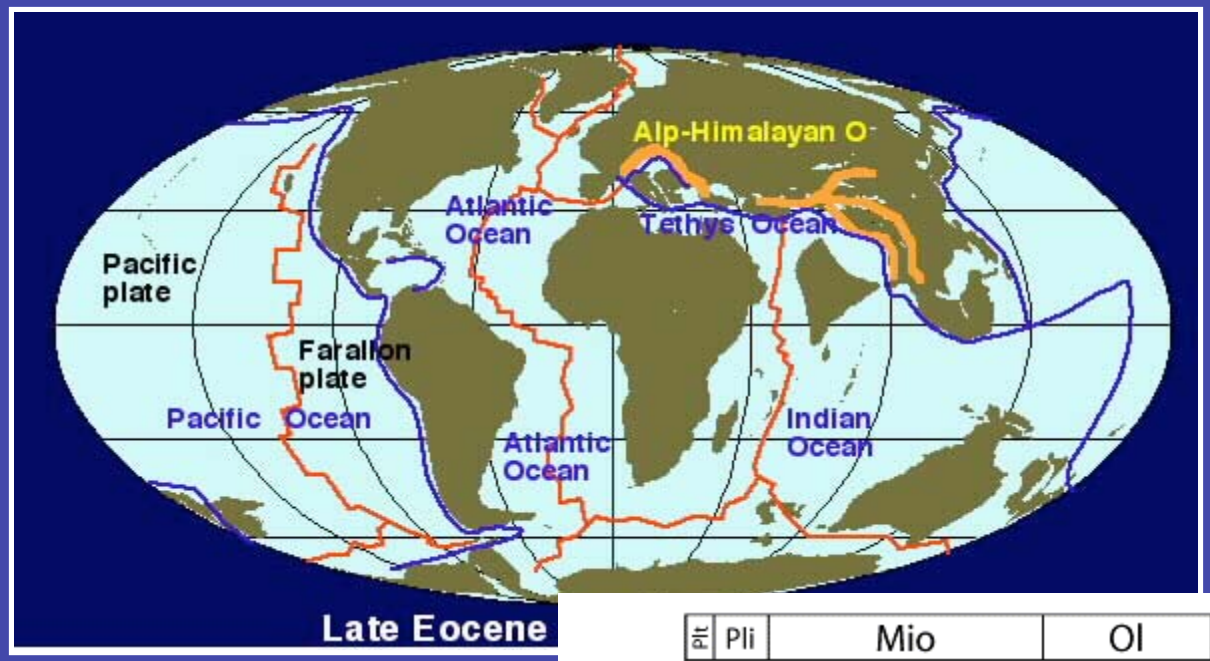






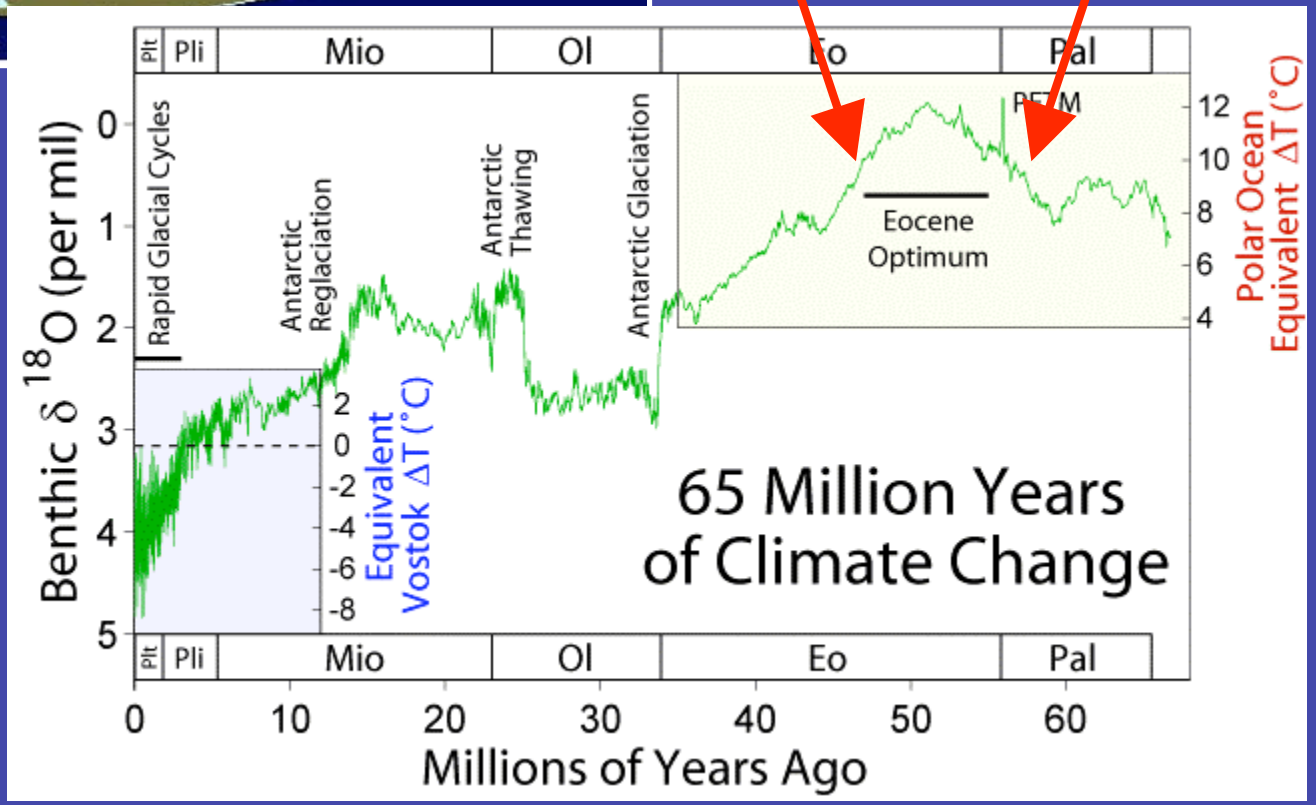
Why was Eocene climate so different from today?

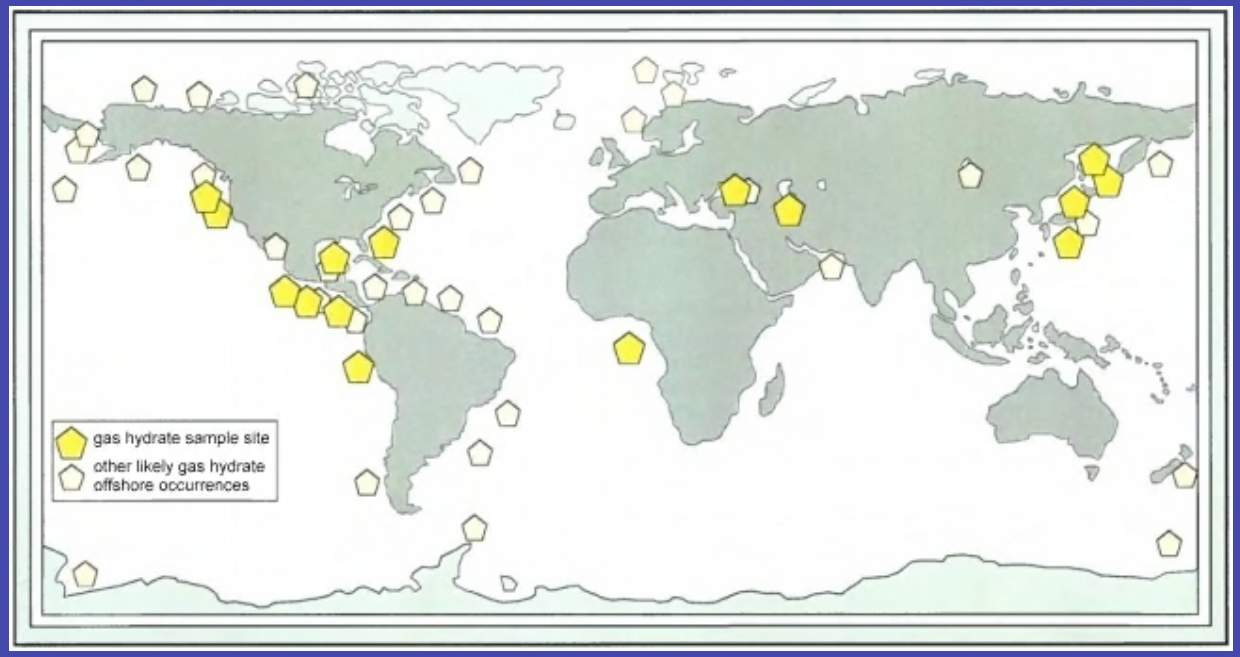


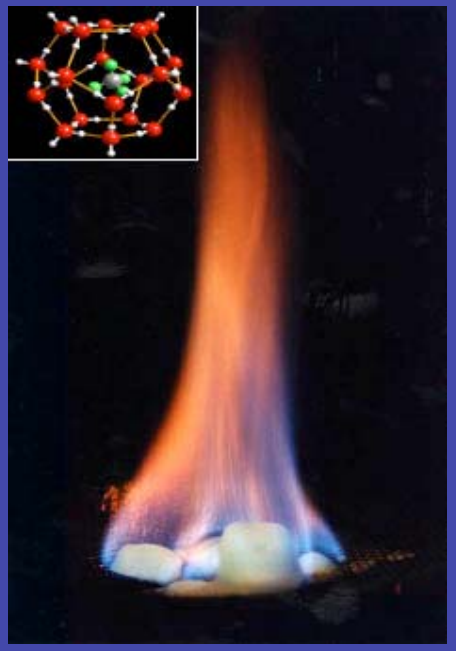


What was going on here to change global temperature?

Paleocene-Eocene Thermal Maximum



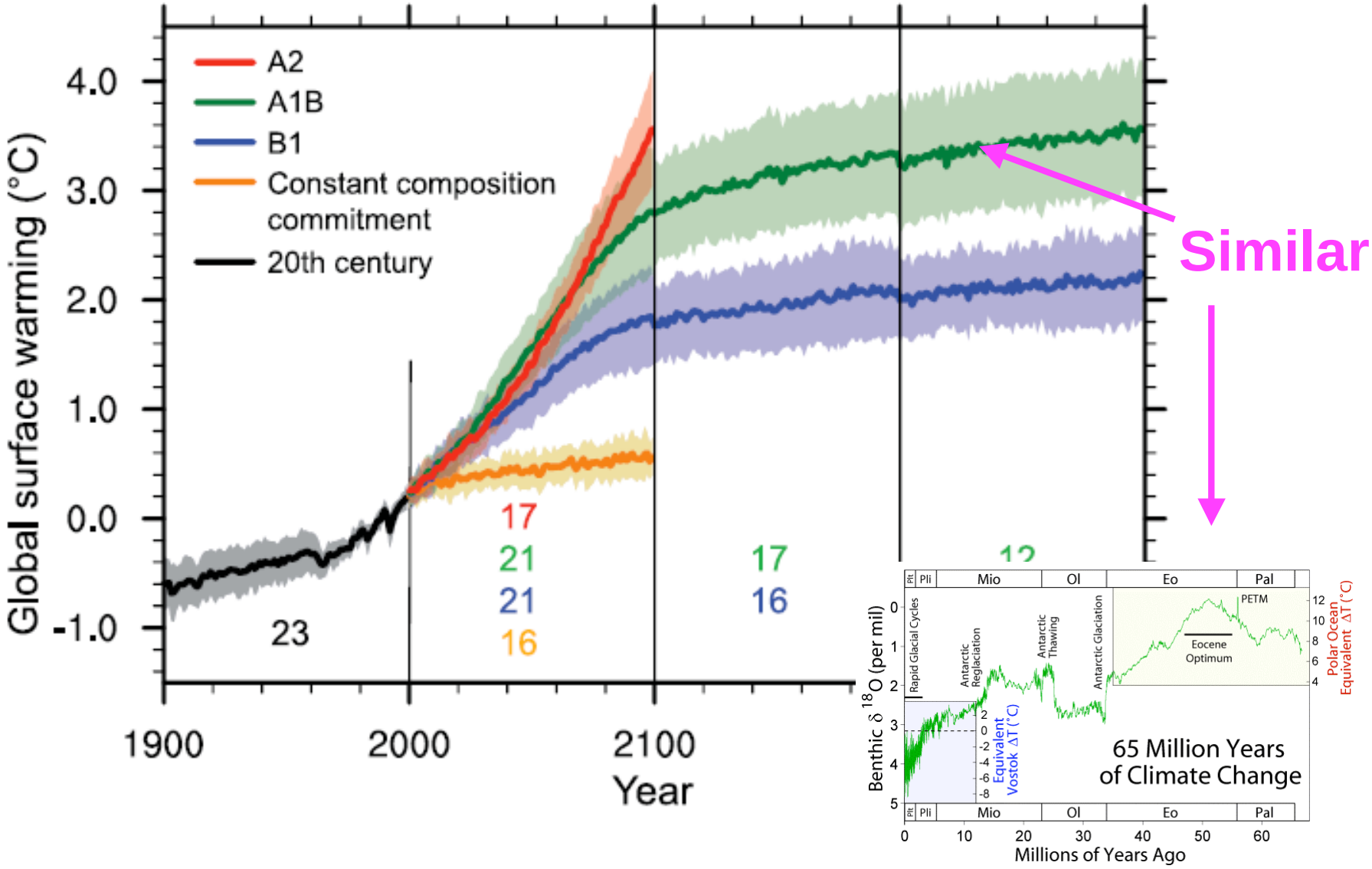




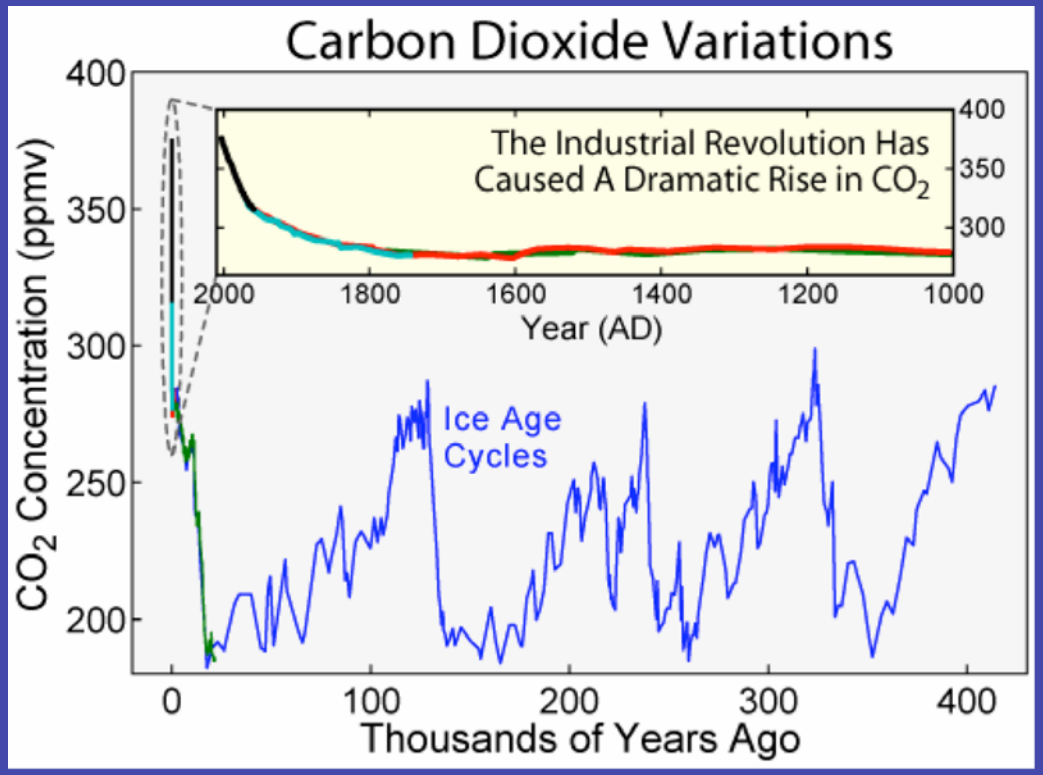
Sea surface temperatures rose 5-8ºC
Arctic Ocean sea surface temperatures were 23ºC
Drastic changes in ocean chemistry
Massive worldwide extinctions

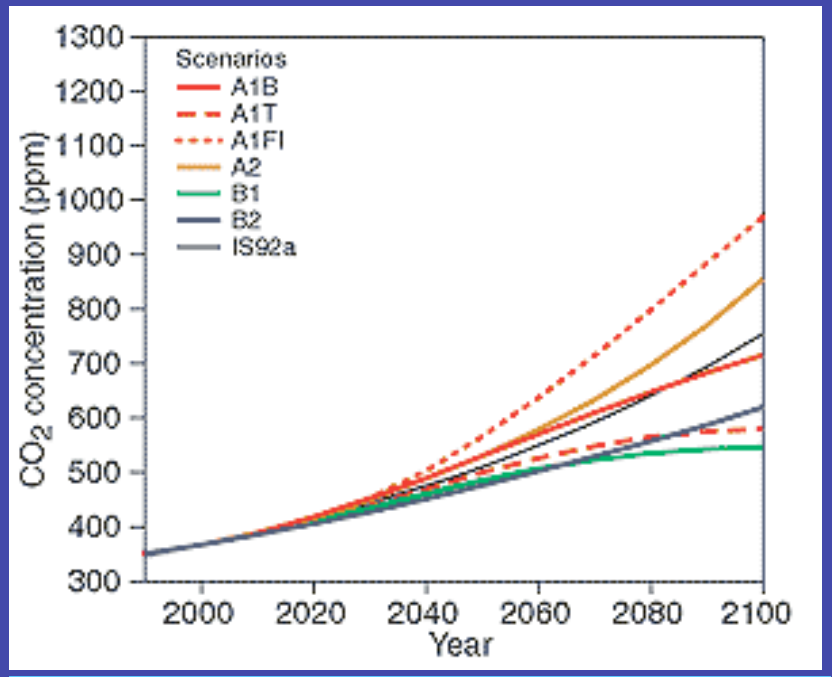
Sudden “global warming” caused by methane?

How is temperature projected to change in our lifetimes?



Intergovernmental Panel on Climate Change 2007







Could we have alligators in the Arctic again?





The New York Times

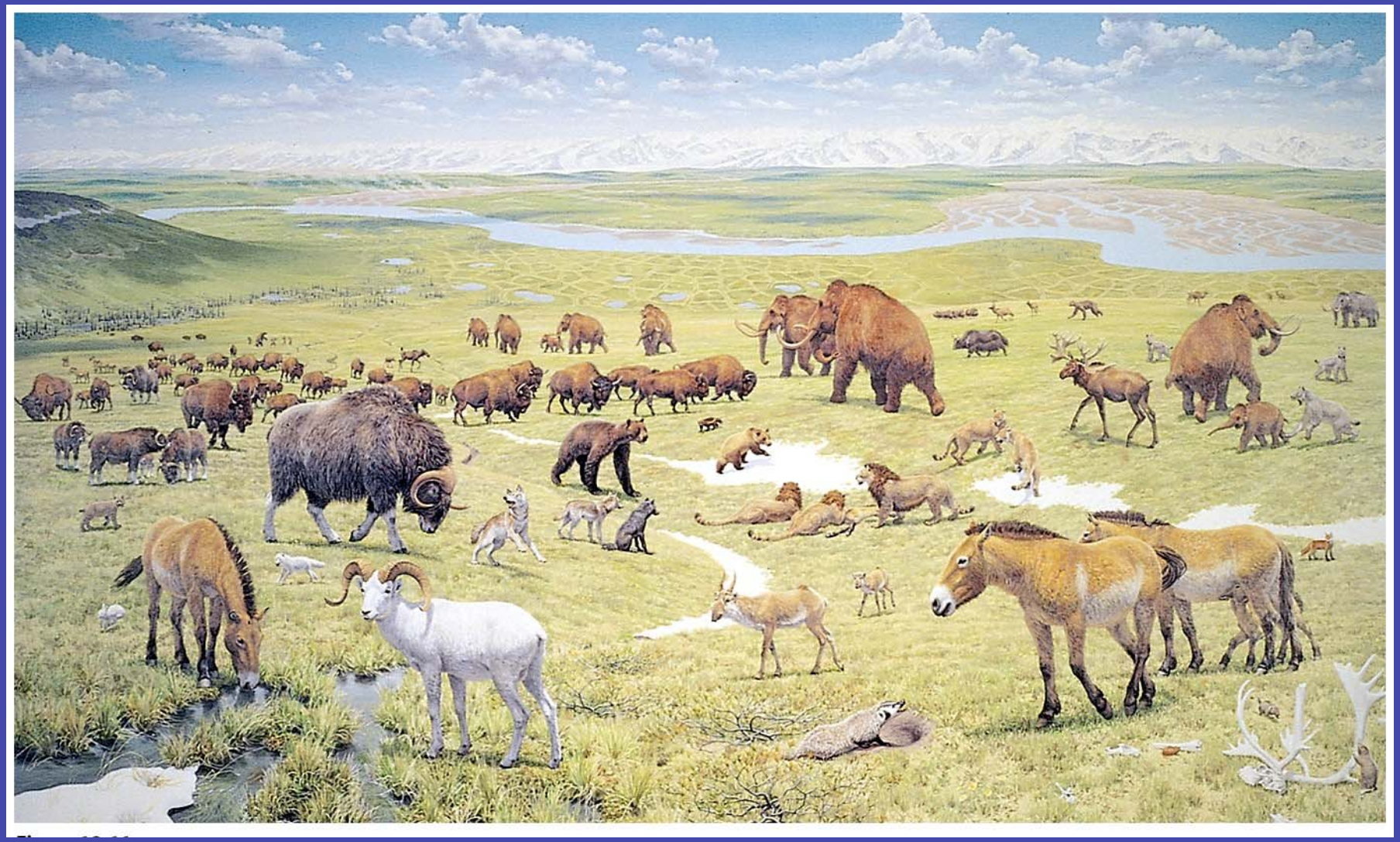
Grim Outlook for Polar Bears

By ANDREW C. REVKIN
Published: October 2, 2007

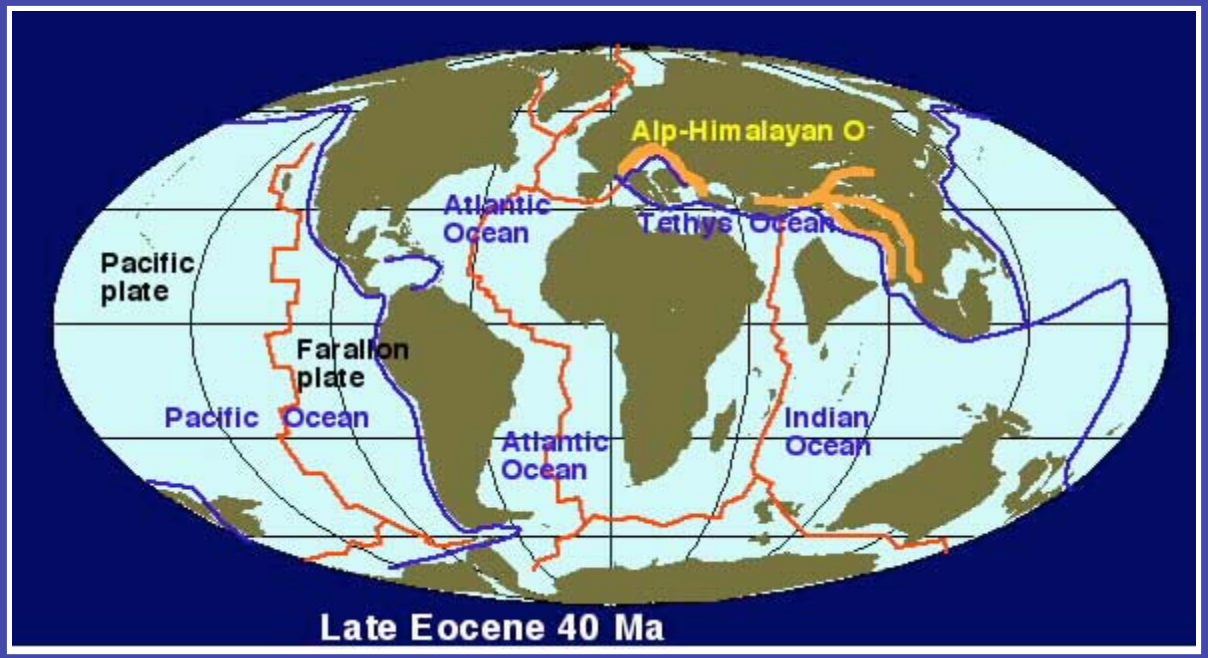
Two biologists who measure field time with polar bears in decades sat in a federal building here, envisioning two possible fates for this denizen of ice in a warming world -- and neither future looked bright.

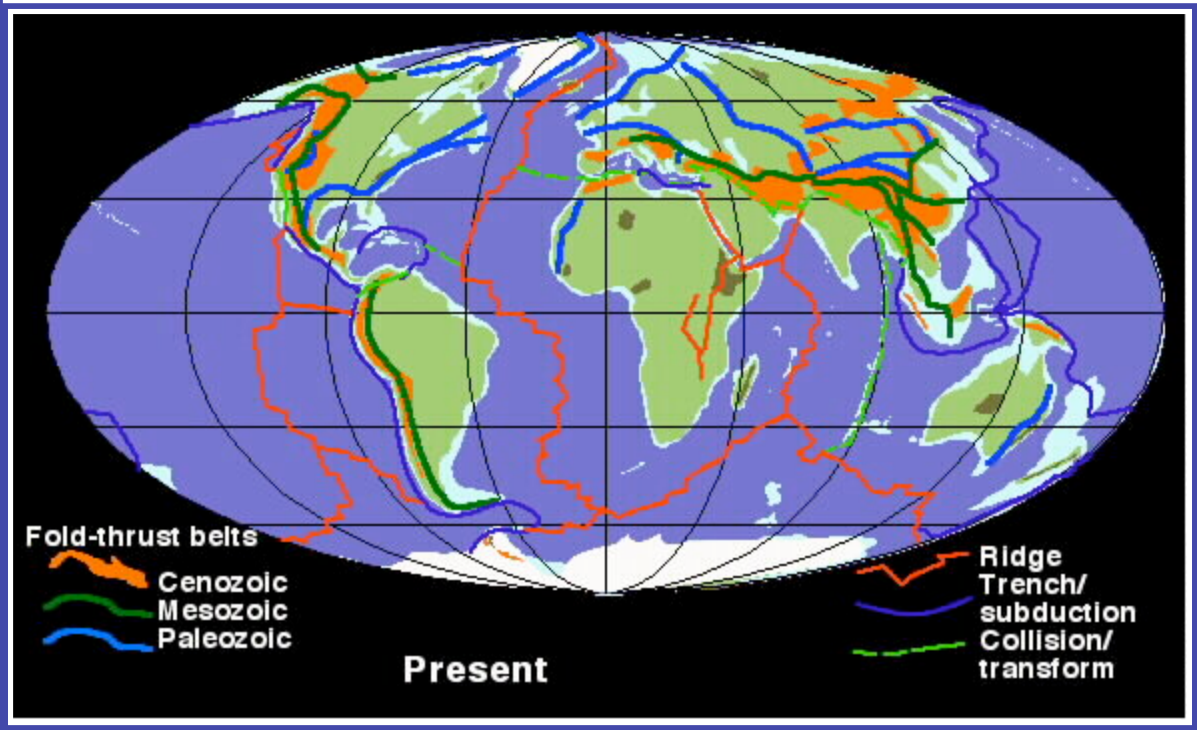


Late Cenozoic (Recent Life) – Diversification of mammals



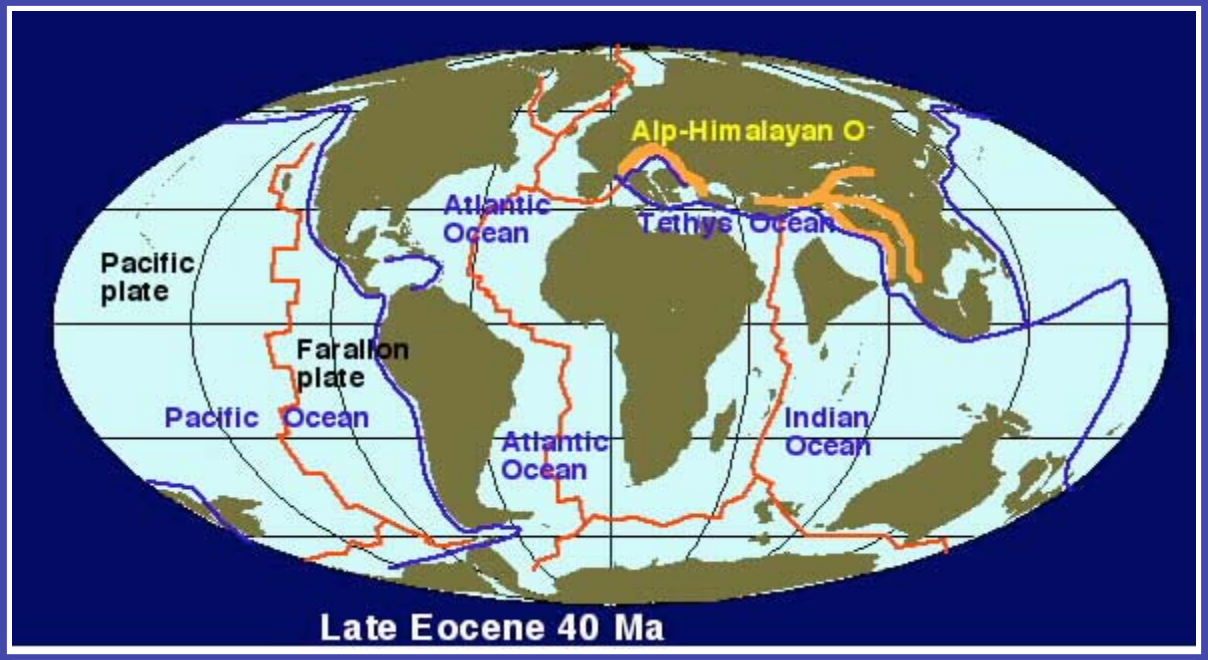
Grassland species thrive

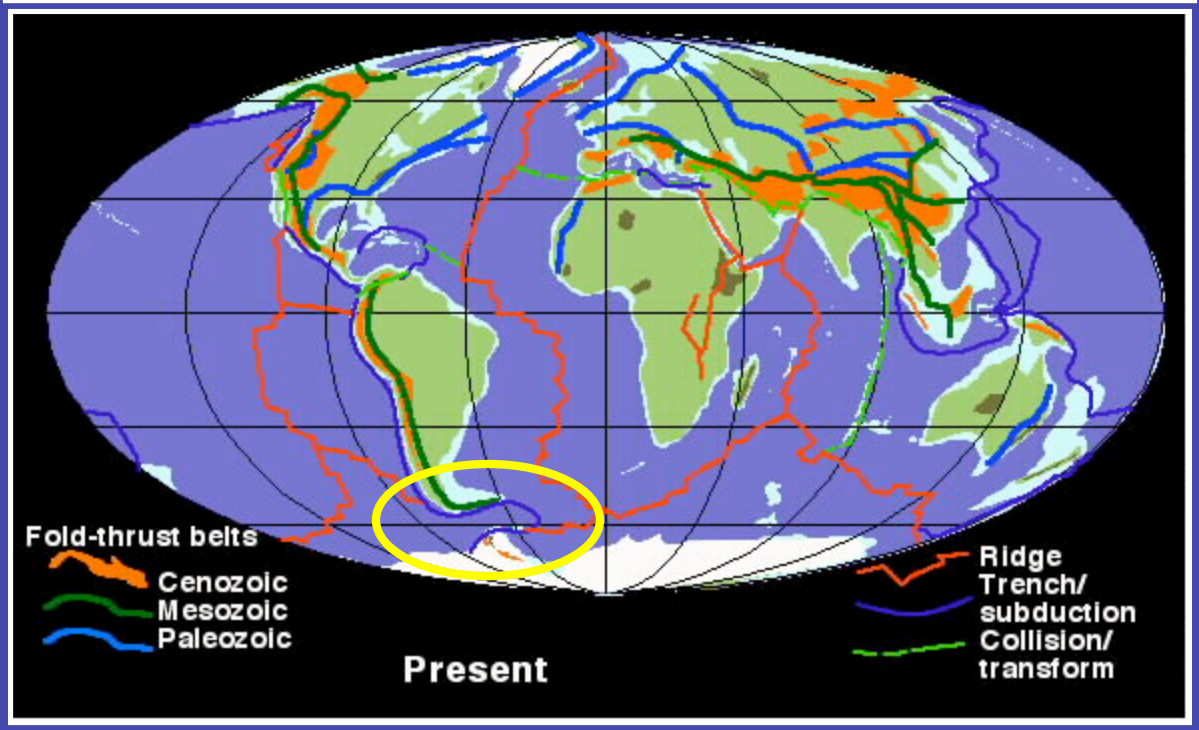




What happened between Eocene and Oligocene?

Have the positions of Wyoming and Ellesmere changed much over the last 40 Mya?



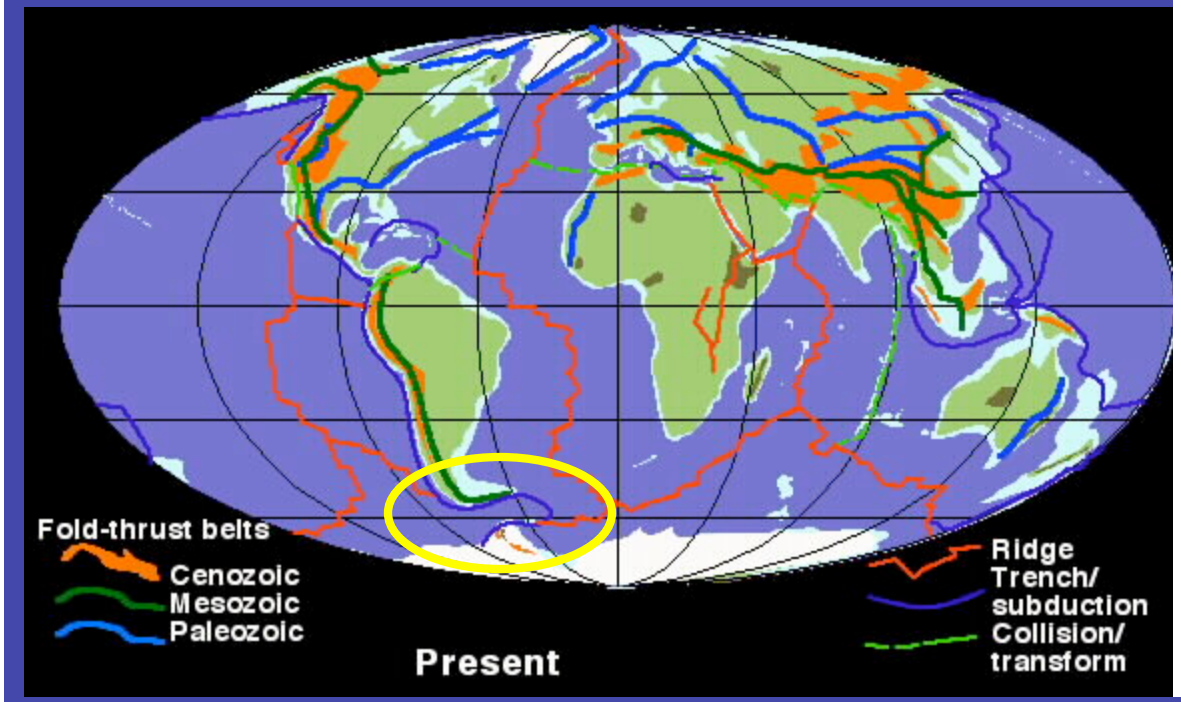


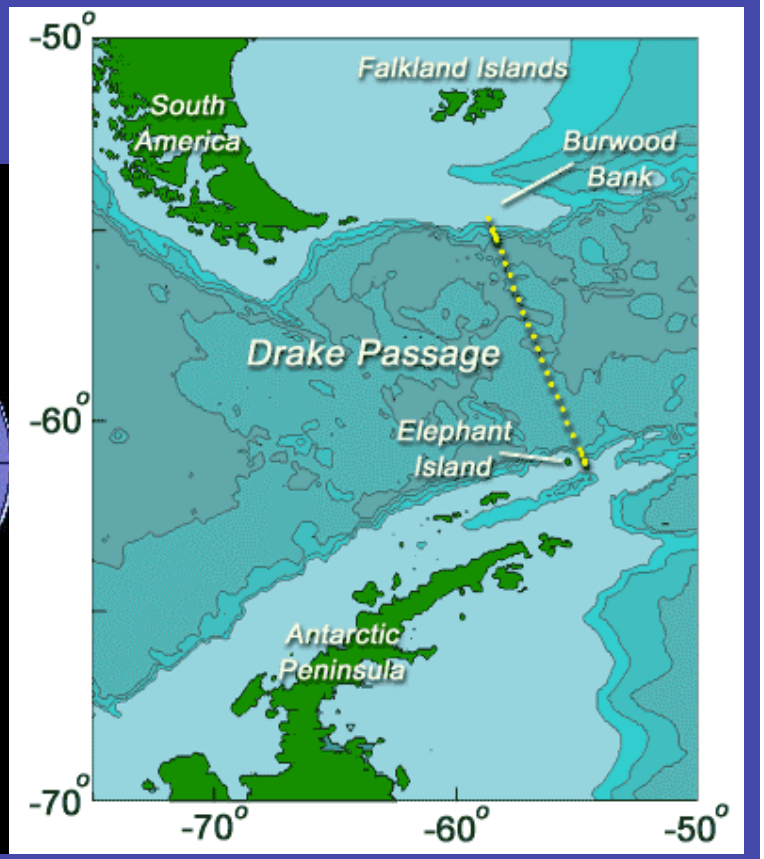
Opening of Drake Passage

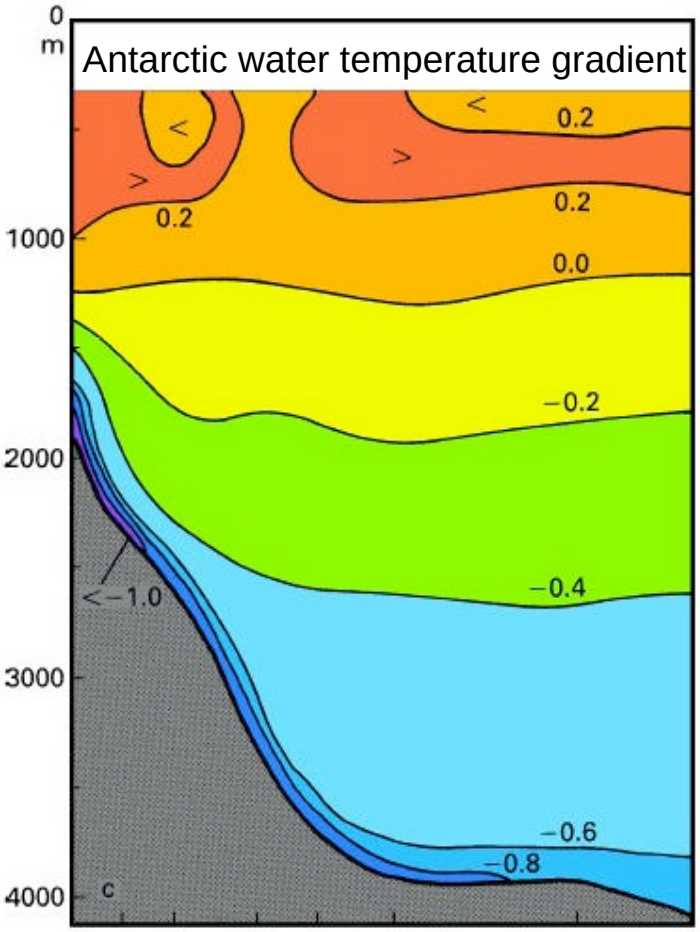
Antarctic Circumpolar Gyre

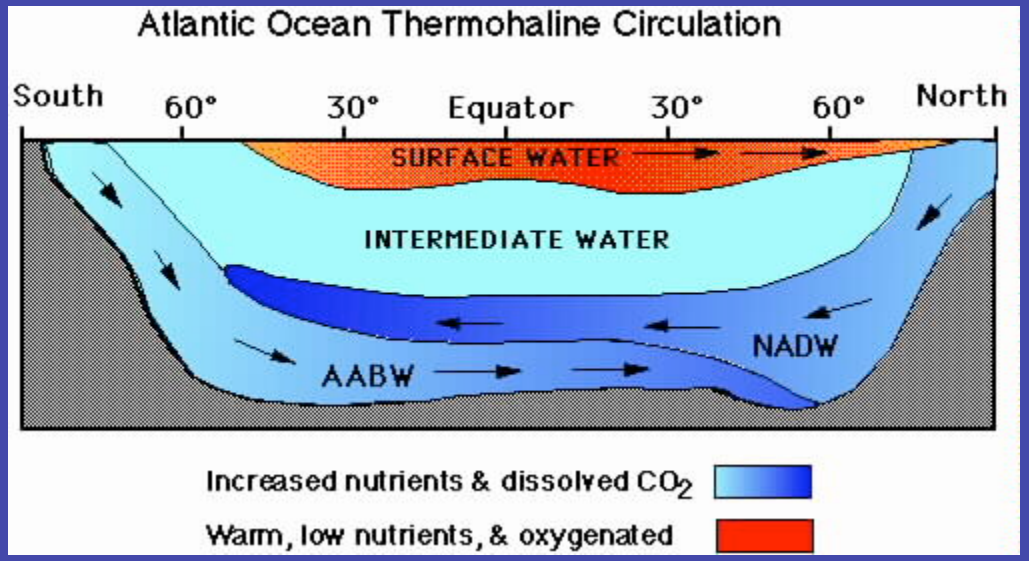


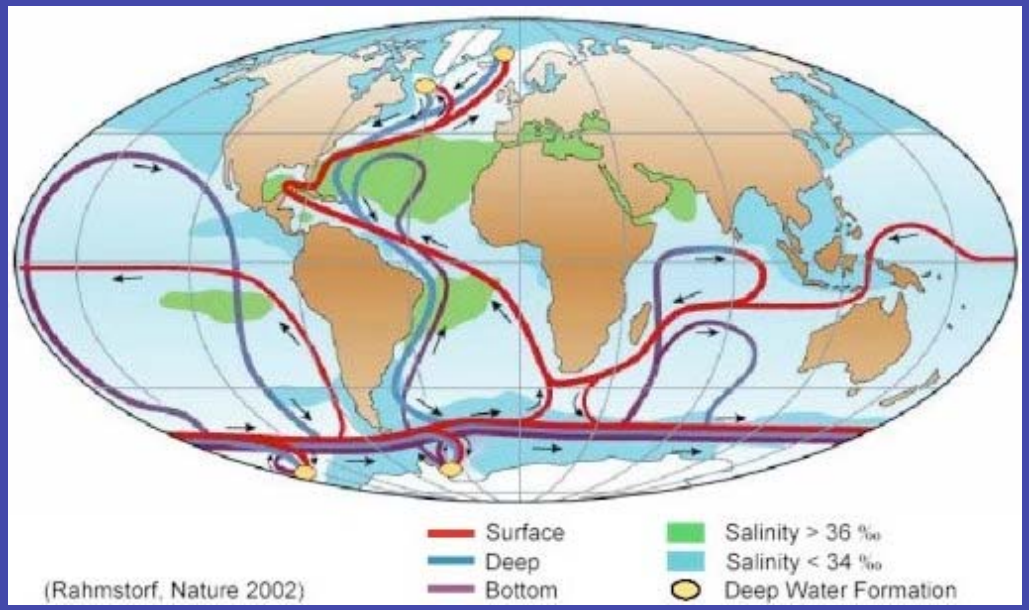










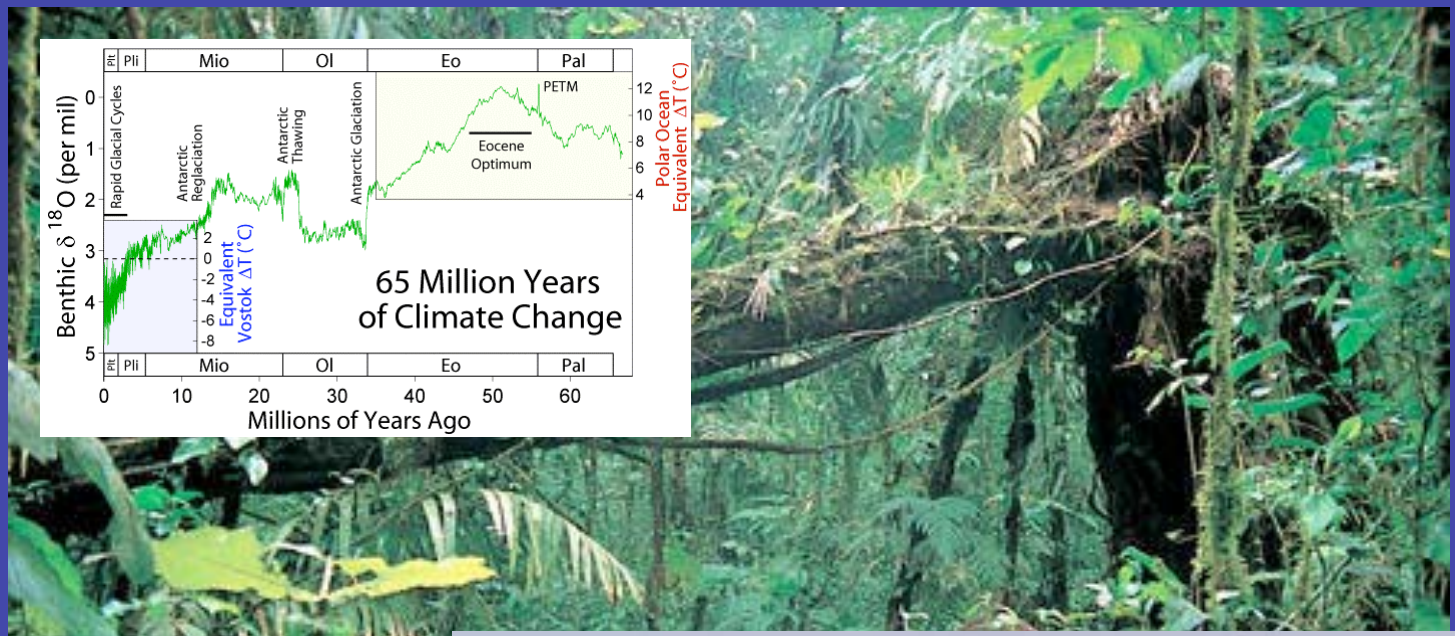


Cold Antarctic water is circulated around the globe by oceanic currents

How are cold oceans going to affect precipitation and temperature on land?



A) Increase P & T
B) Decrease P & T
C) Increase P, Decrease T
D) Decrease P, Increase T
E) No impact



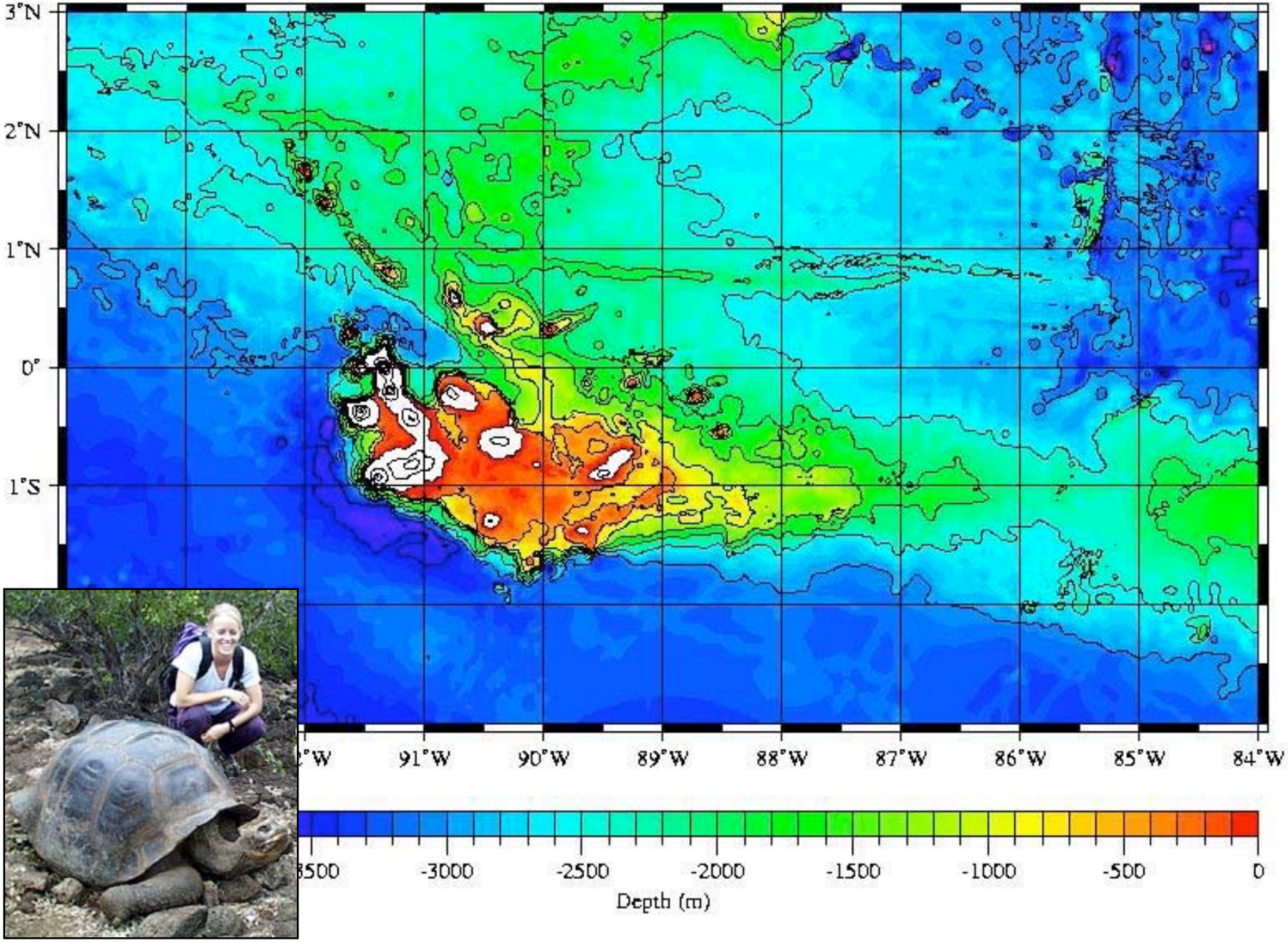
Transition from tropical to grassland environment





Cooling and drying worldwide

What is direction of plate motion? A) East B) West C) North D) South







Charles Darwin
(1809-1882)





Voyage of the HMS Beagle
(1831-1836)

Galápagos tortoise

Average age 150 years
Weights up to 660 pounds

















13 original subspecies
11 survive today

If each tortoise lives on average 150 years, how long would it take to see evolutionary change?















A) <10,000 yrs
B) >1,000,000 yrs



Harriet (1830-2006)

Collected by Darwin?

Lonesome George

Last Pinta Tortoise



Evolution & Natural Selection





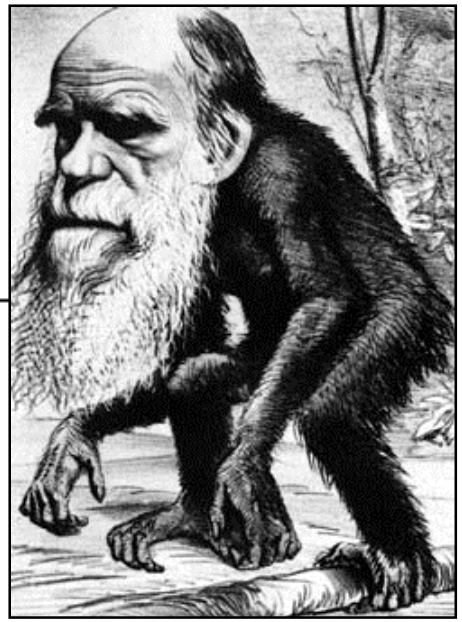




Do we share a common ancestry?







Pleistocene | Pliocene | Miocene

Split between human and chimpanzees using molecular clock, about 5 Ma

Sahelanthropus tchadensis

Genus Paranthropus

Age of bones found in Kenya, about 6 Ma

Orrorin tugenensis

P. robustus

P. boisei

P. aethiopicus

Genus Ardipithecus

Ar. kadabba

Ar. ramidus

A. anamensis

A. afarensis

A. bahrelghazali

A. africanus

A. garhi

Genus Australopithecus

H. habilis

H. floresiensis

H. georgicus

H. erectus

H. heidelbergensis

H. neanderthalensis

H. sapiens

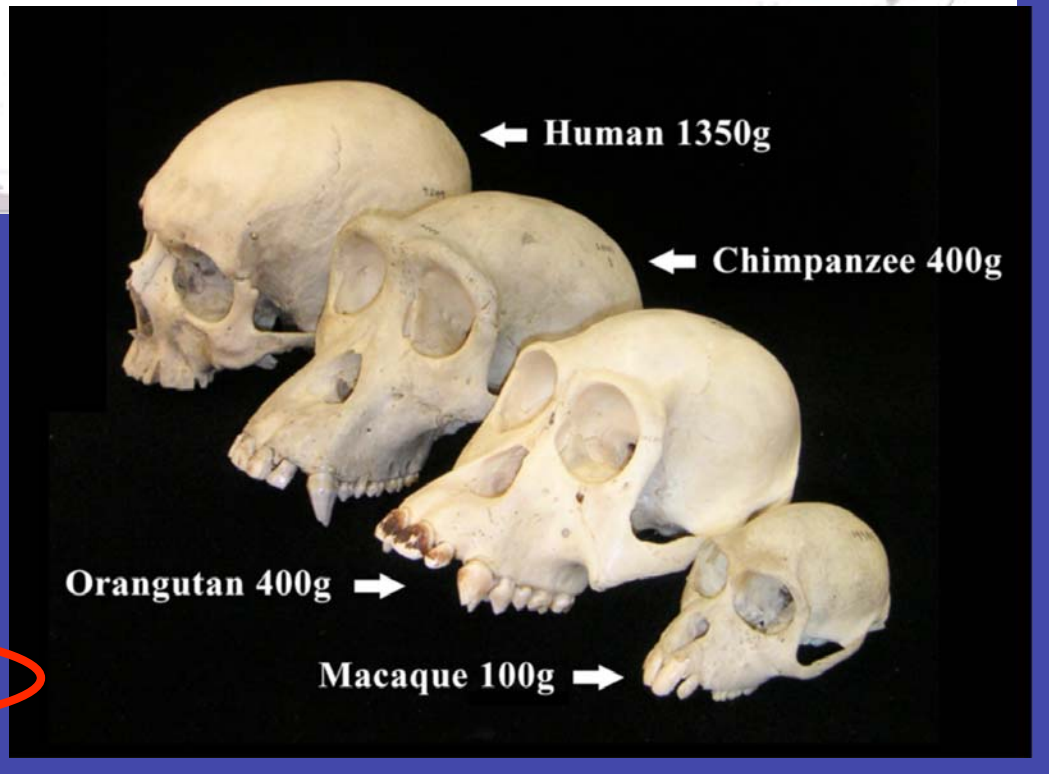
Genus Homo

0 Years | 1e+06 | 2e+06 | 3e+06 | 4e+06 | 5e+06

What do evolution and natural selection imply about the passage of time?

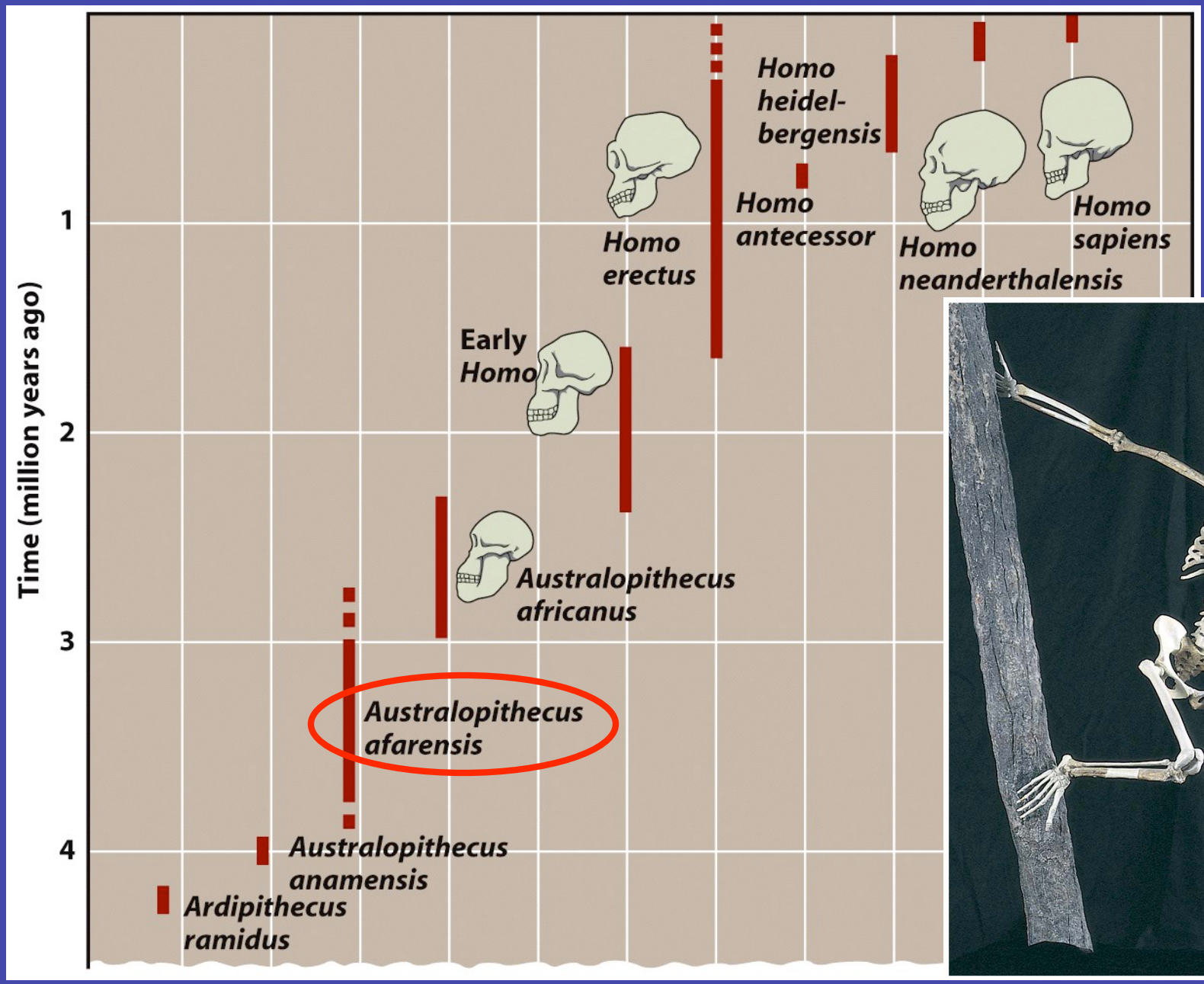
Origin of Humans



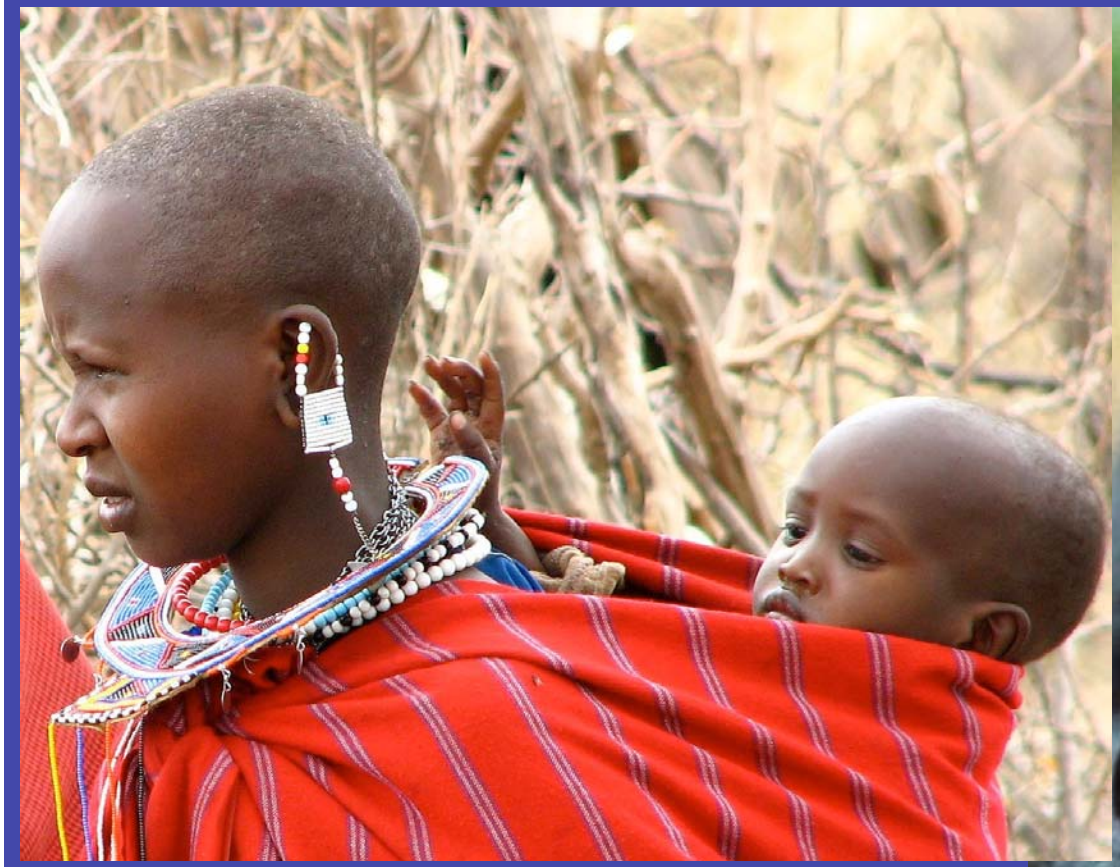


December 31, 11:42pm

Late (late) Cenozoic (Recent Life) – Human Evolution



Lucy





How do our young differ?



Where will humans thrive?

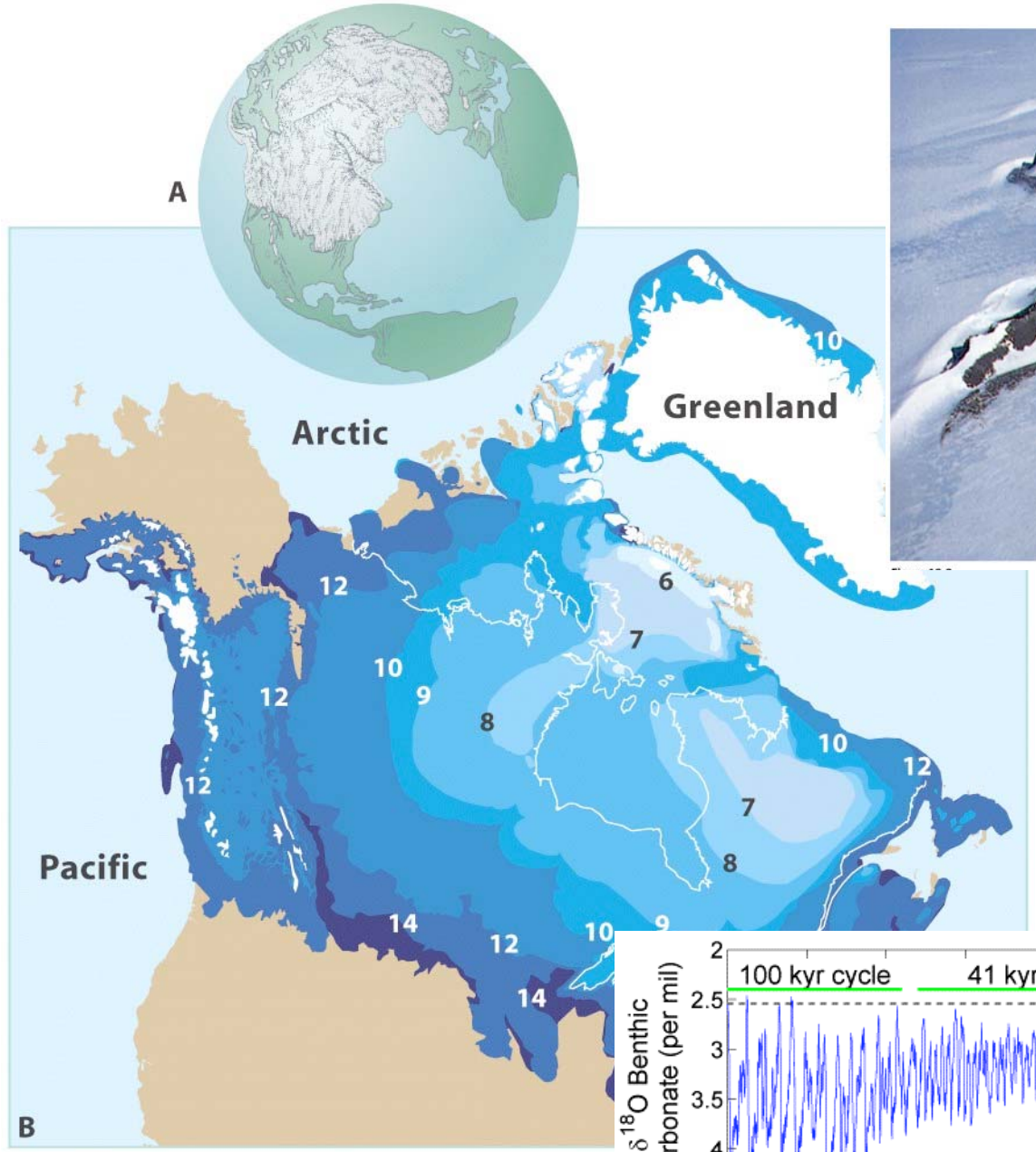


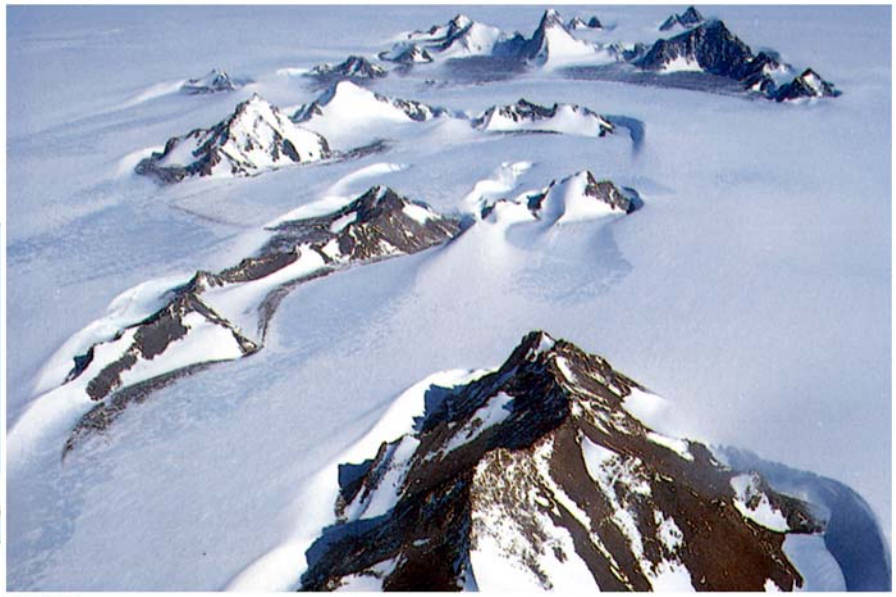
Where will chimps thrive?



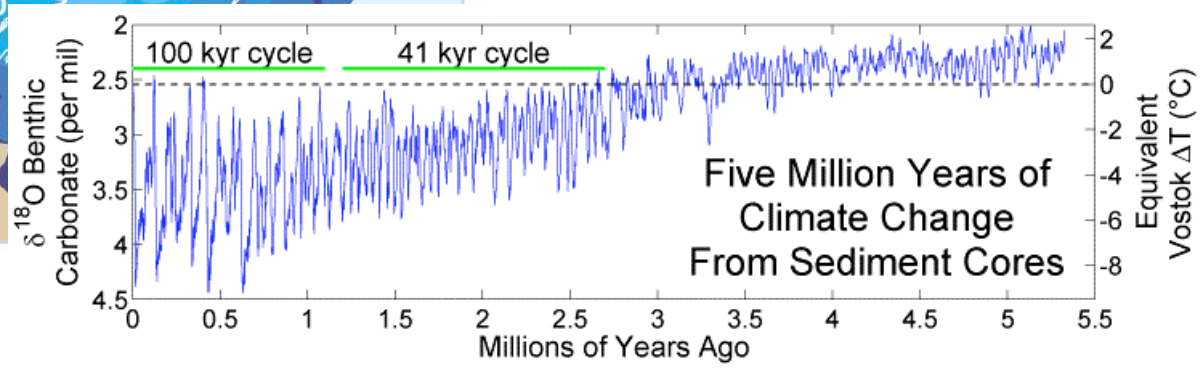
Forces driving human evolution:

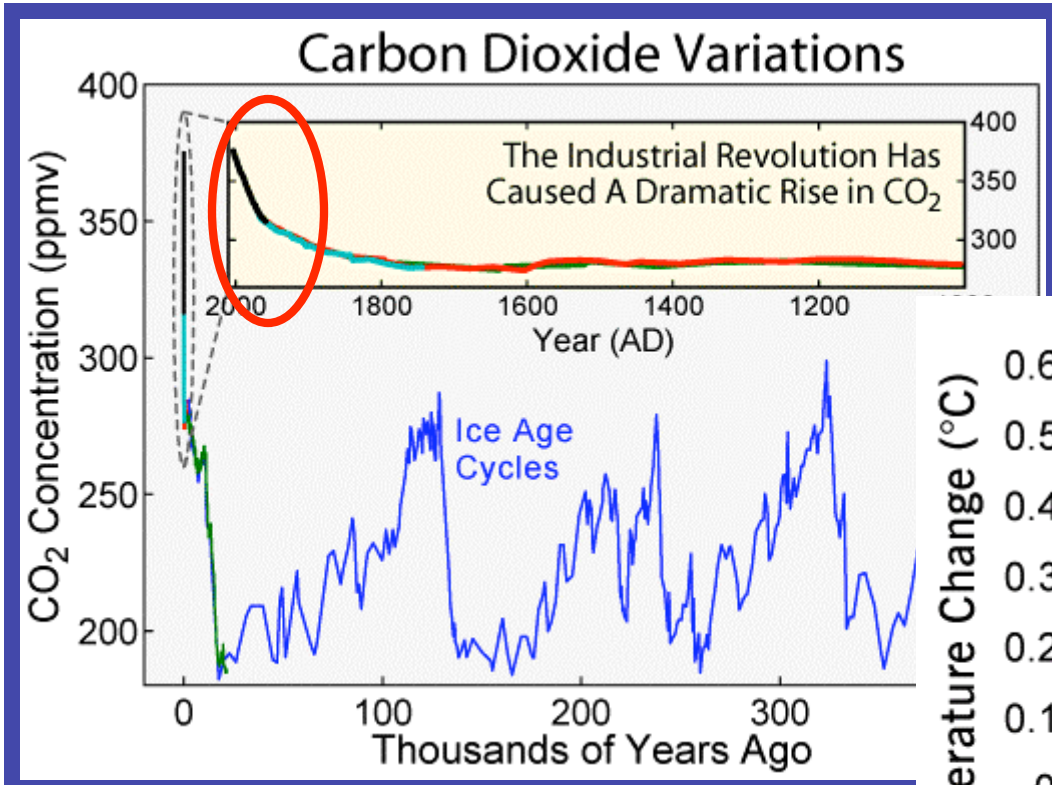
1. **Migration**
2. **Mutation** (caused by something external)
3. **Genetic drift** (random genetic change)
4. **Natural selection** (survival of fittest)





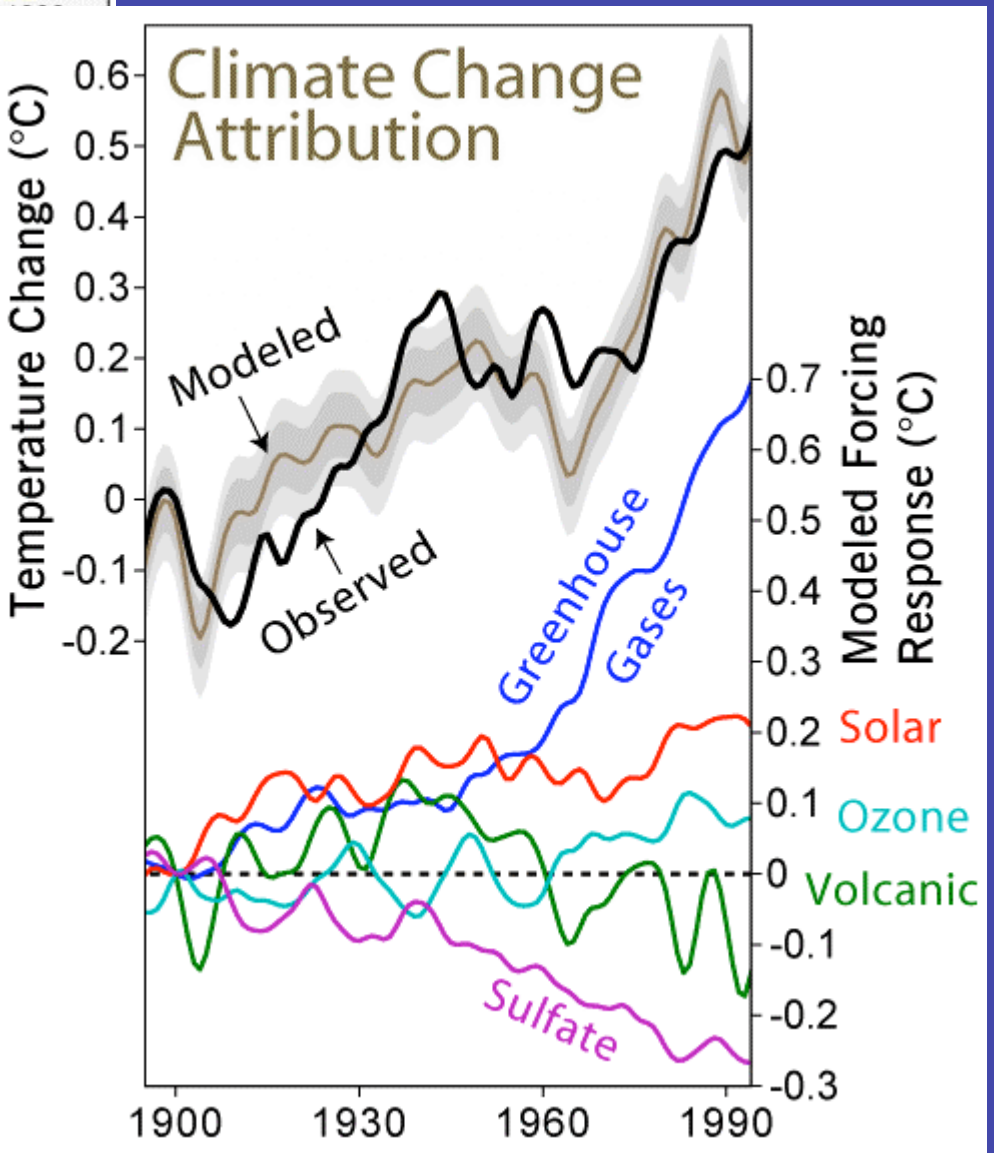
Ice ages controlled human migration patterns

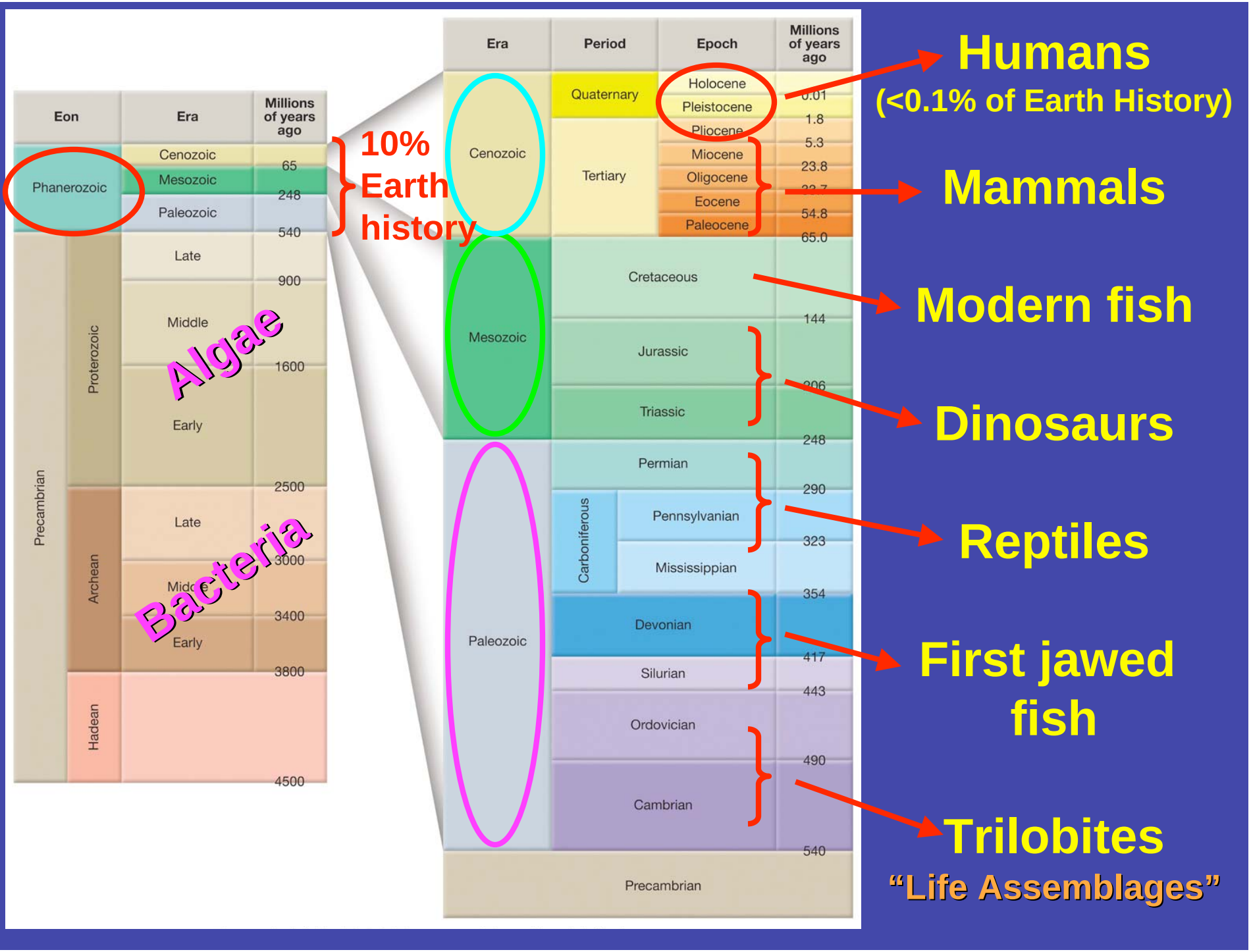


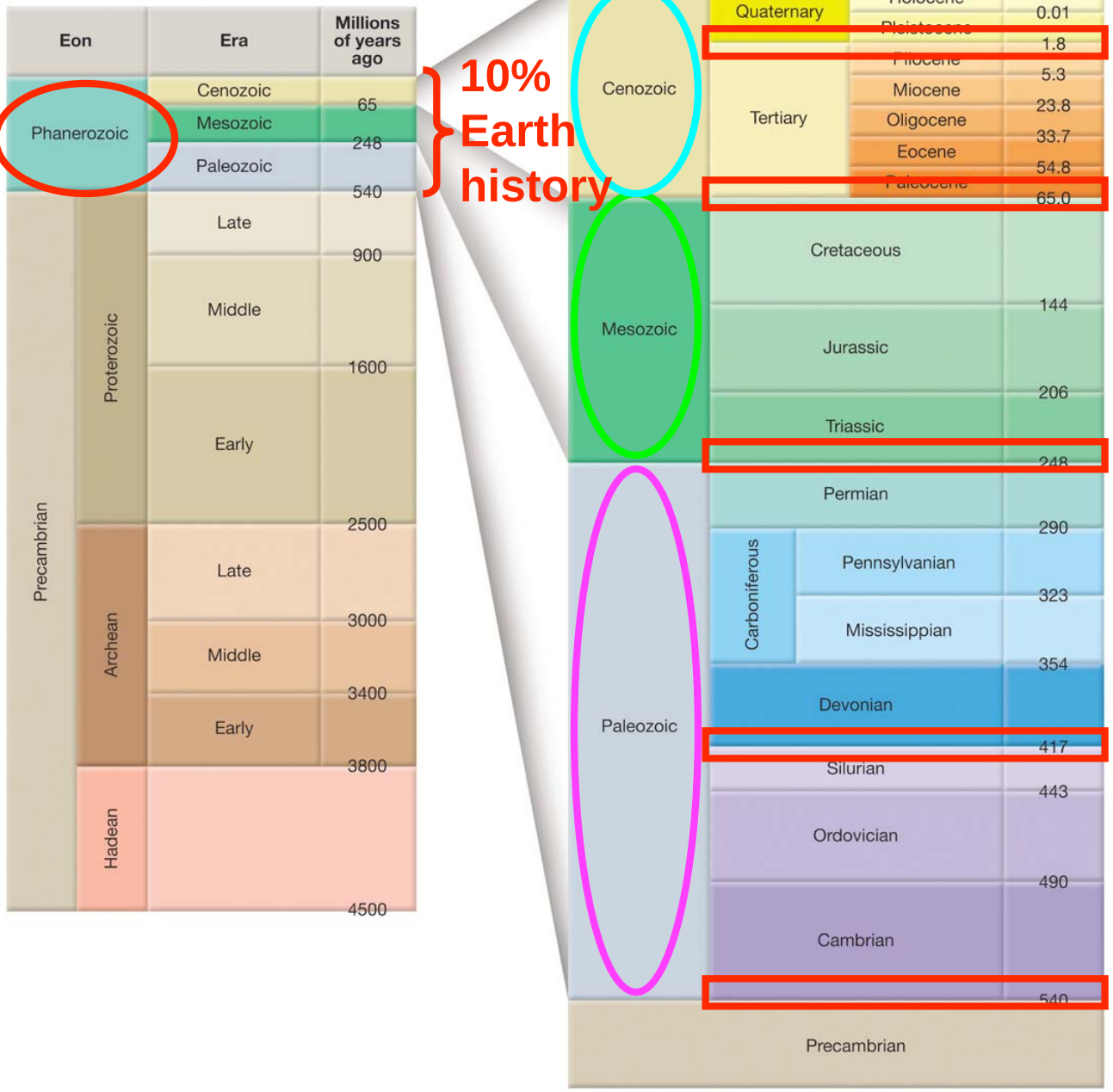


Burning of fossil fuels

CO_2 increases highly correlated with rising temperatures




Eon
Era
Millions of years ago
Phanerozoic
Cenozoic
Mesozoic
Paleozoic
65
248
540
Precambrian
Proterozoic
Late
Middle
Early
900
1600
2500
Archean
Late
Middle
Early
3000
3400
3800
Hadean
4500
Algae
Bacteria
10% Earth history
Era
Period
Epoch
Millions of years ago
Cenozoic
Quaternary
Holocene
Pleistocene
0.01
1.8
Tertiary
Pliocene
Miocene
Oligocene
Eocene
Paleocene
5.3
23.8
54.8
65.0
Mesozoic
Cretaceous
Jurassic
Triassic
144
206
248
Paleozoic
Permian
Carboniferous
Pennsylvanian
Mississippian
Devonian
Silurian
Ordovician
Cambrian
290
323
354
417
443
490
540
Precambrian
Humans
(<0.1% of Earth History)
Mammals
Modern fish
Dinosaurs
Reptiles
First jawed fish
Trilobites
“Life Assemblages”



Extinctions define boundaries on geologic timescale:

1) Meteorite Impacts
2) Plate Reorganization
3) Volcanism
4) Astronomical Events
5) Etc…

Result:

Climate change







Where will evolution take us next ?