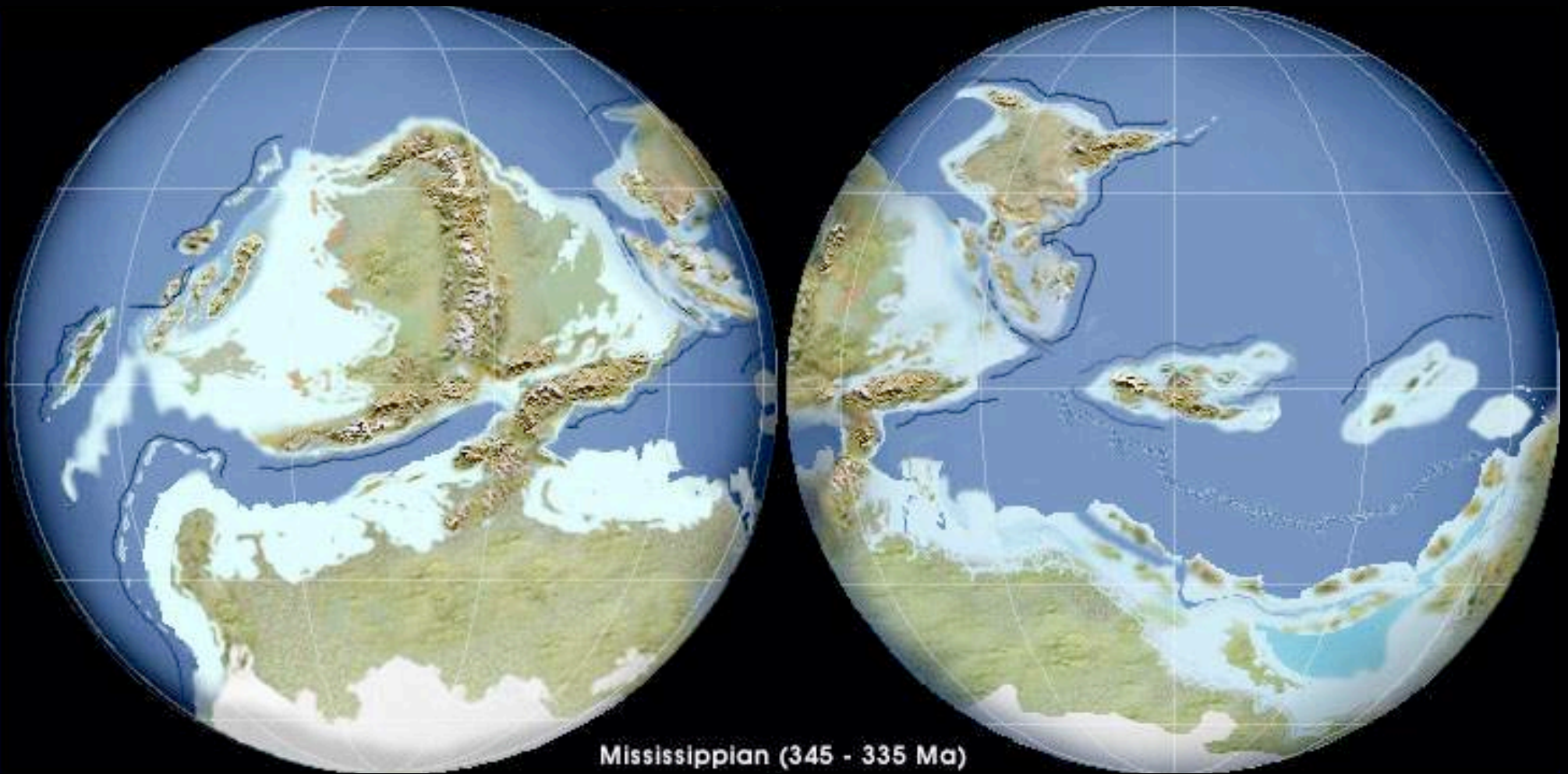
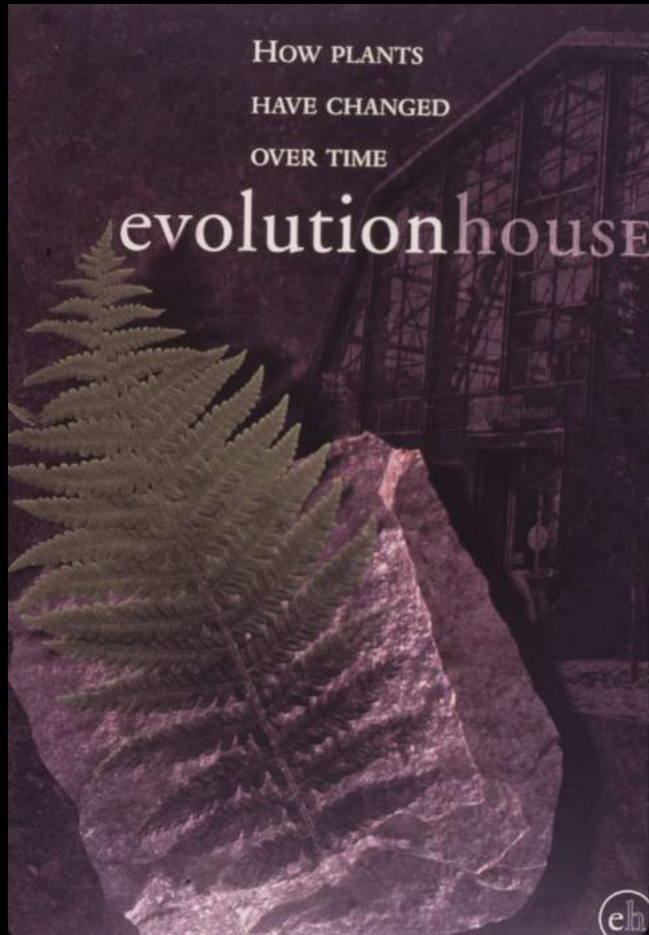


Paleo-biogeography

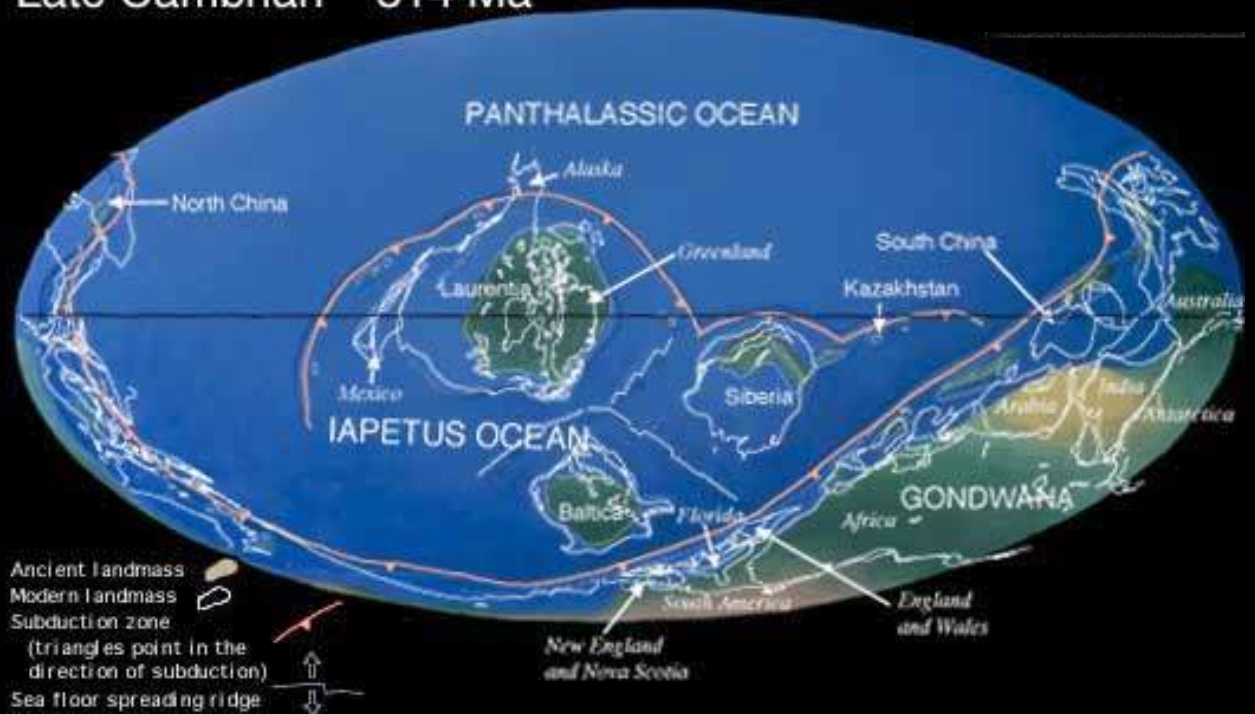


Paleo-biogeography



Why study fossils?

Late Cambrian 514 Ma



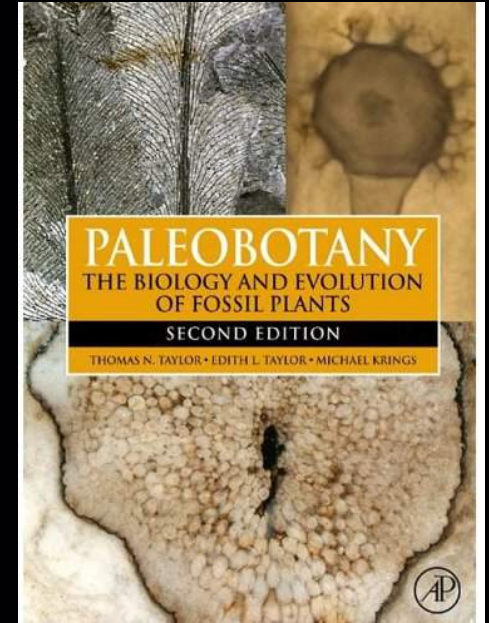
- paleo-geology
- paleo-climatology
- paleo-vegetation
- paleo-floristics/faunistics

- fossils for historical biogeography: “clock-calibration”

Paleo-biogeography



Sun Ge and David Dilcher and
earliest eudicot fossil at 124 mya



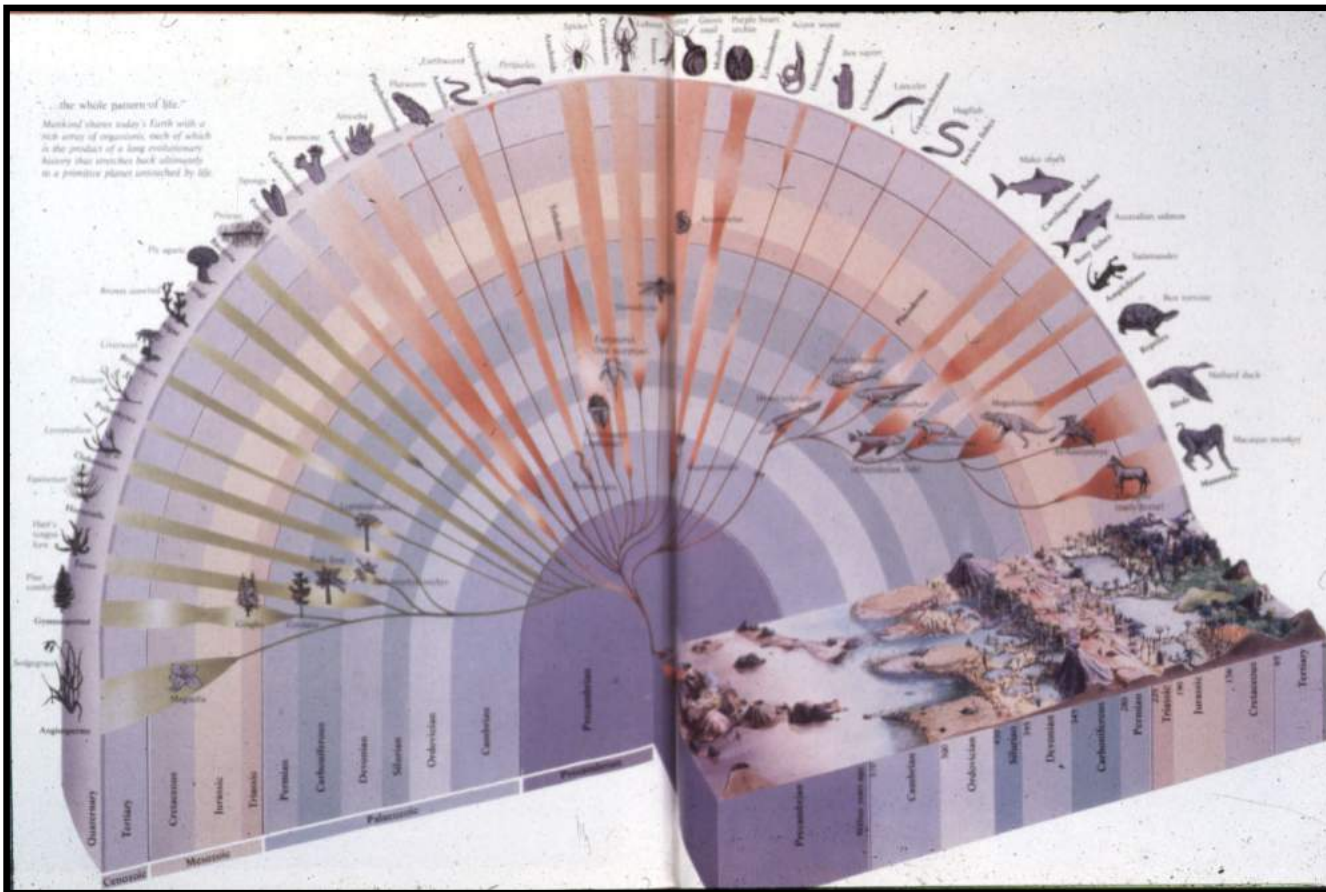
Edith and Tom Taylor on one of their 7
fossil hunting expeditions to Antarctica

Why study fossils?



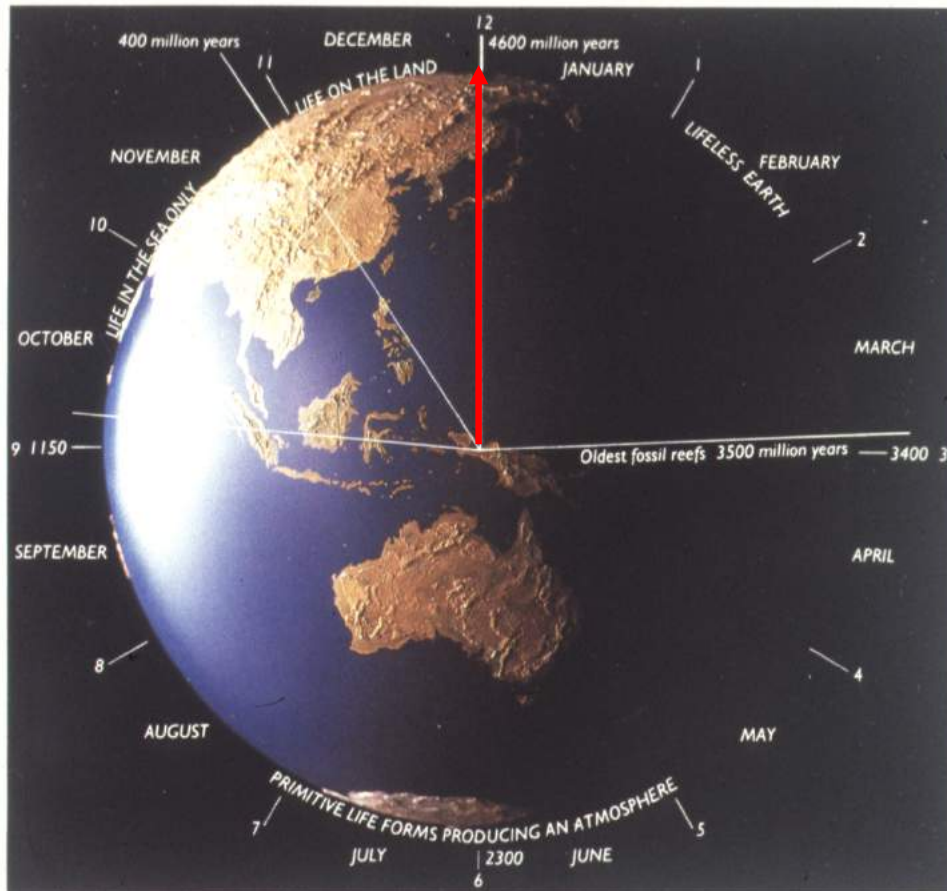
Paleo-biogeography

We will examine the rise of land vegetation and floras and specifically in N. America and the Great Lakes region by using information from paleobiogeography



- paleo floras - plants moving onto land over 400 mya and becoming the dominant set of terrestrial organisms
- modern floras - diversification of land plants and especially flowering plants over the last 100 my
- ice age events (Pleistocene - last 2.5 my) and the assembly of vegetation and flora in Great Lakes region during recent times (Holocene)

Earth Time



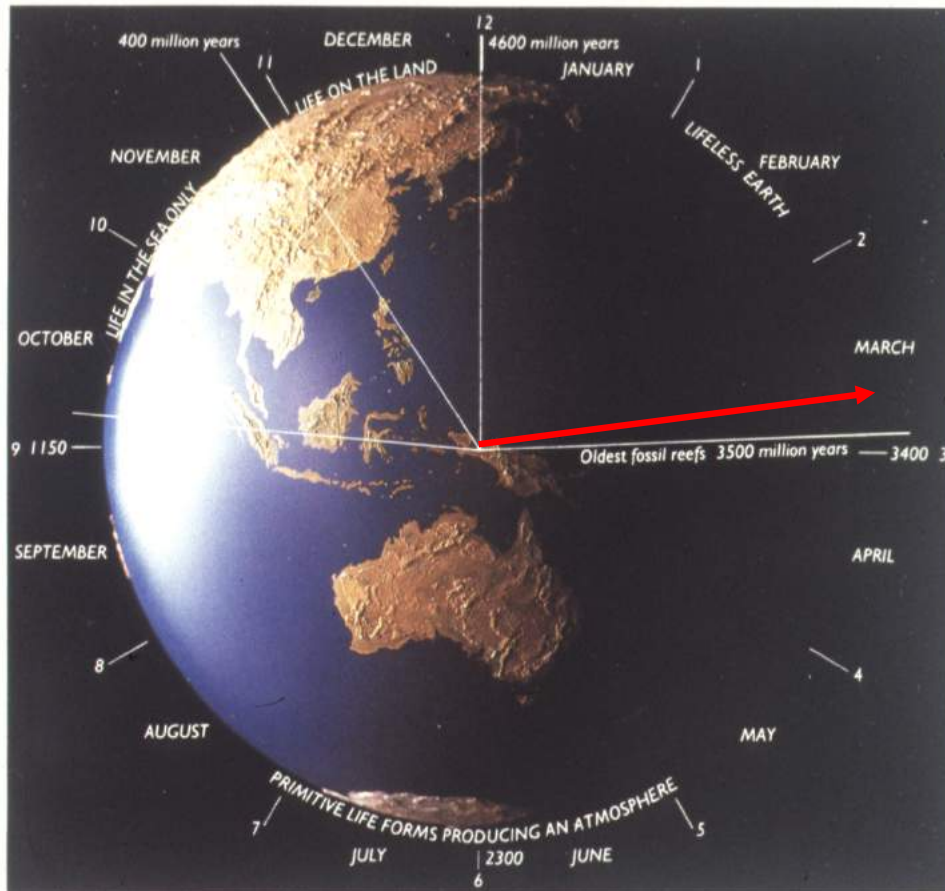
A different perspective before taking a look at the rise and fall of floras and faunas through time . . .

Earth forms at 4.6 bya
= January 1, 12:00 a.m.

Age of the earth = 1 calendar year
4.6 billion years = 365 days

Earth Time

First evidence of life? - 3.8 bya
Oldest fossils, cyanobacteria- 3.5 bya
= late March (1/4 of earth time)

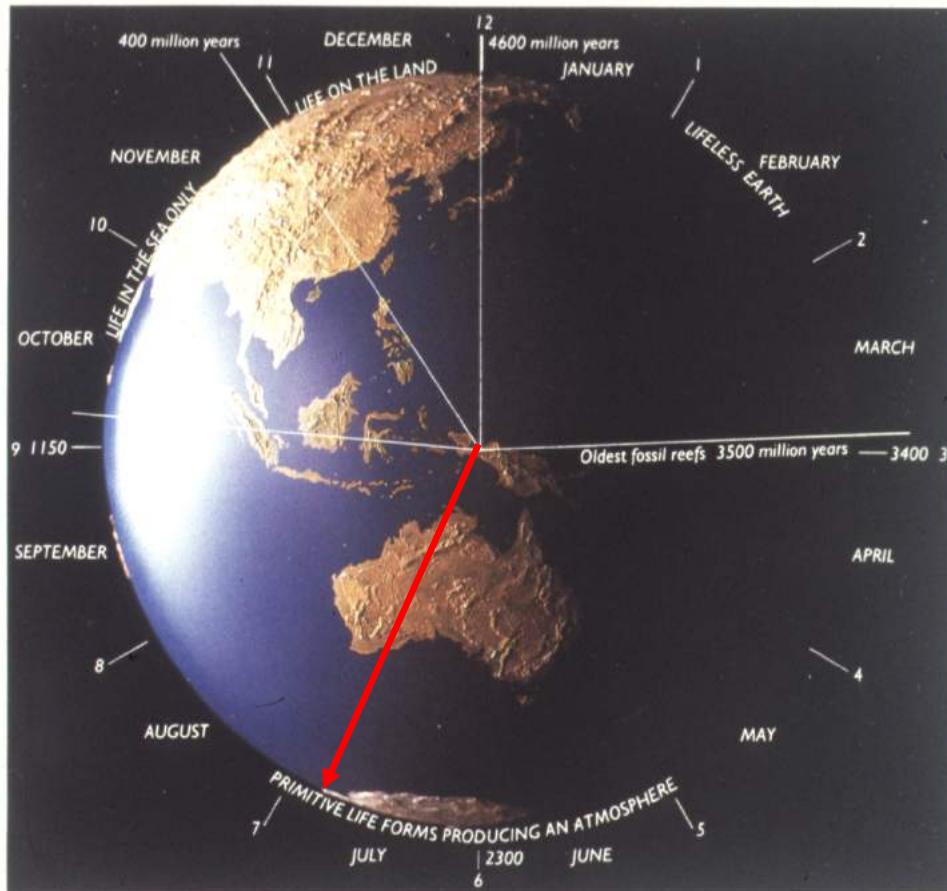


Age of the earth = 1 calendar year
4.6 billion years = 365 days



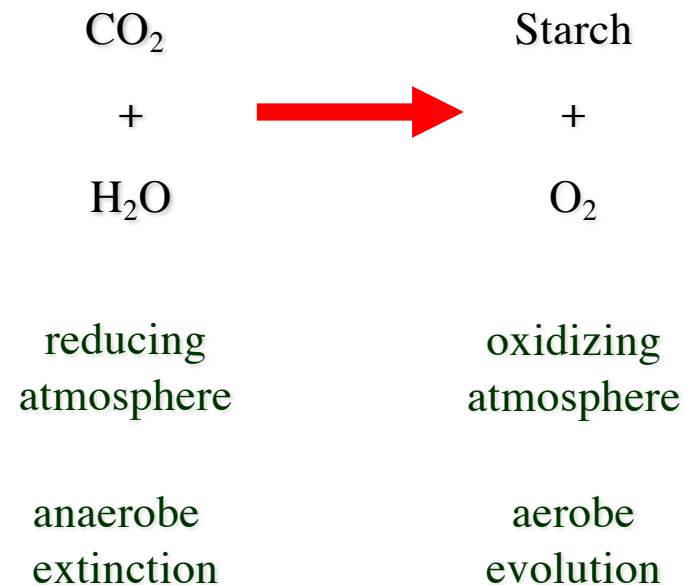
Stromatolites - CaCO_3 ppt by cyanobacteria
= photosynthesis!

Earth Time

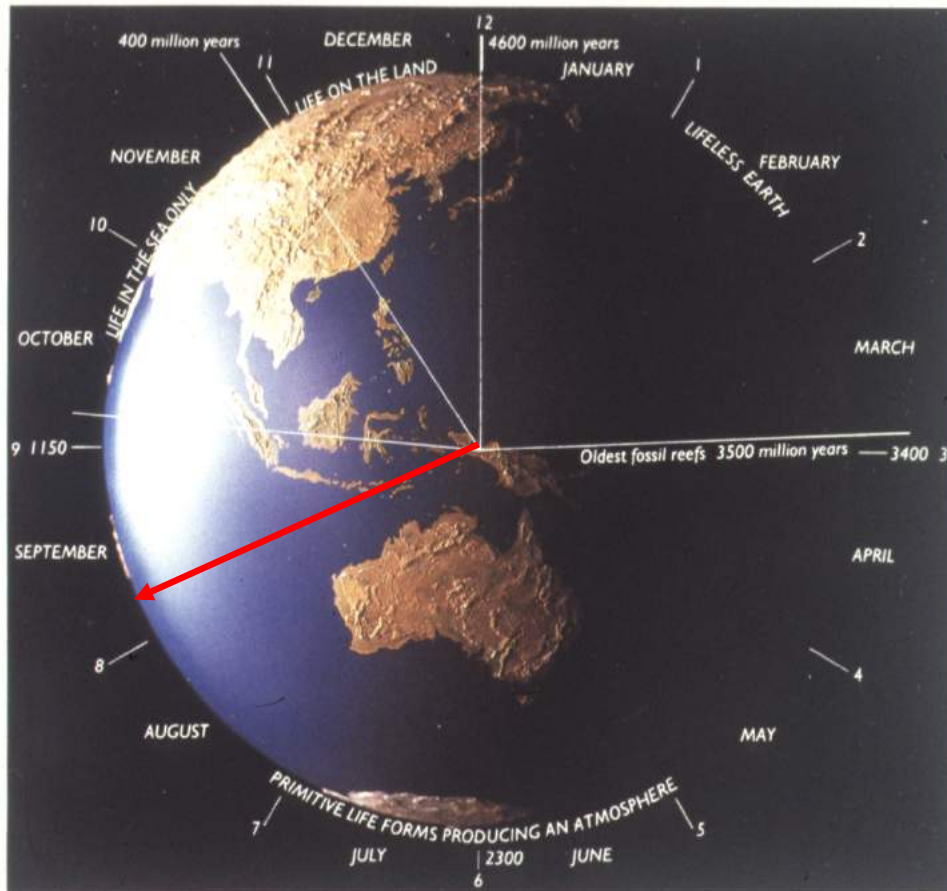


Age of the earth = 1 calendar year
4.6 billion years = 365 days

O₂ accumulates in atmosphere -
2.0 bya
= late July (>1/2 of earth time)

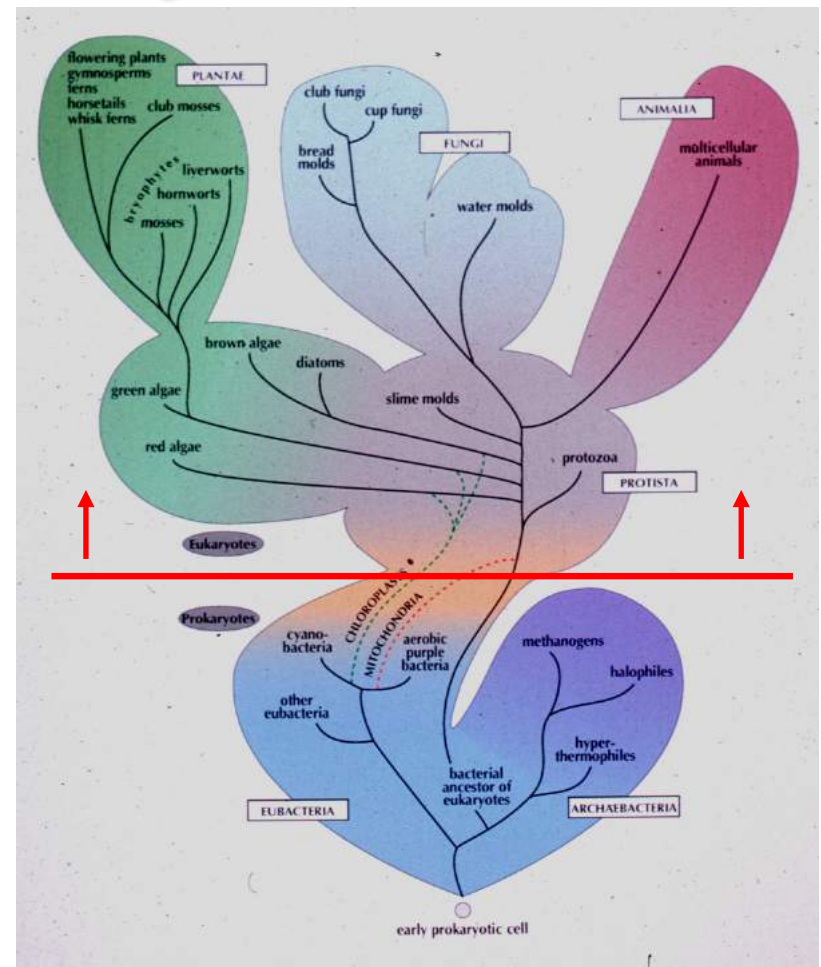


Earth Time

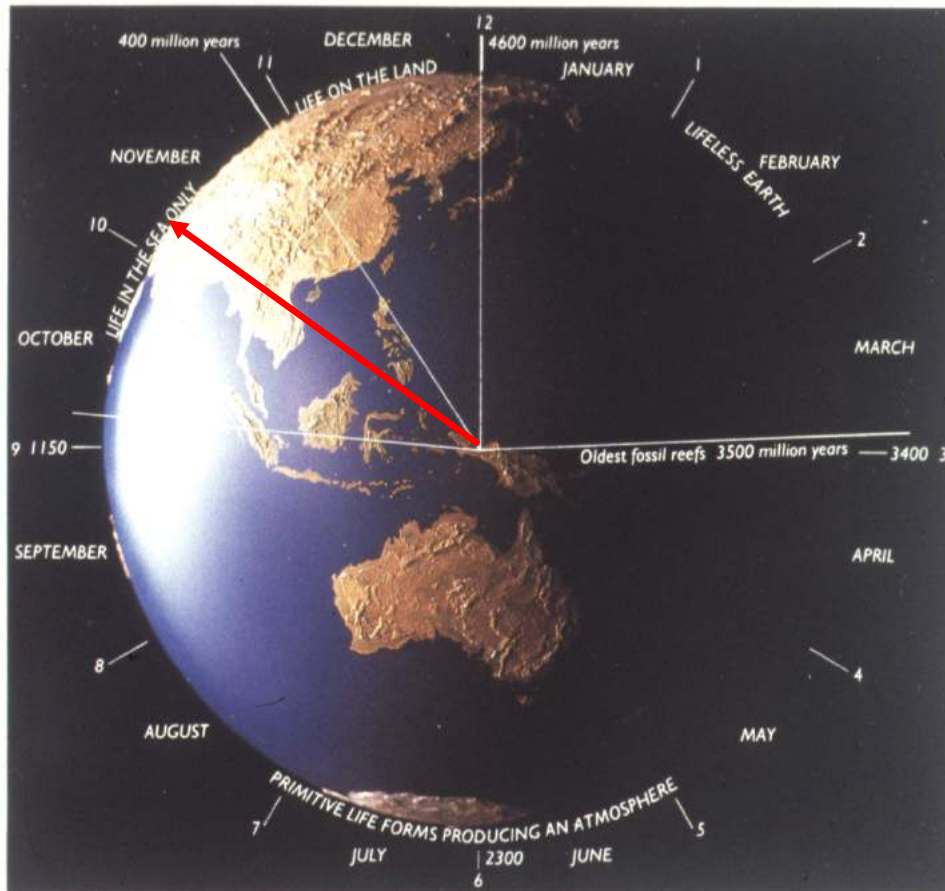


Age of the earth = 1 calendar year
4.6 billion years = 365 days

First eukaryotes - 1.5 bya
= early September (2/3 of earth time gone)



Earth Time



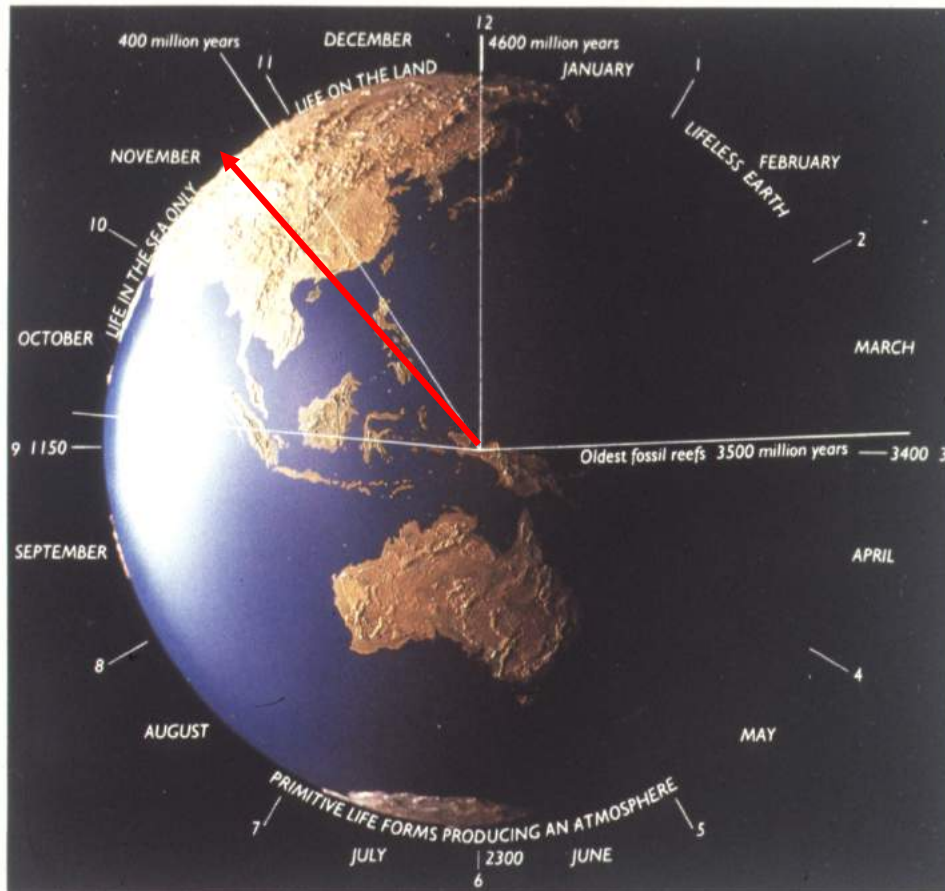
Age of the earth = 1 calendar year
4.6 billion years = 365 days

First abundant fossils in Cambrian
“explosion” - 560 million ya
Many phyla of animals
= early November



Burgess Shale

Earth Time



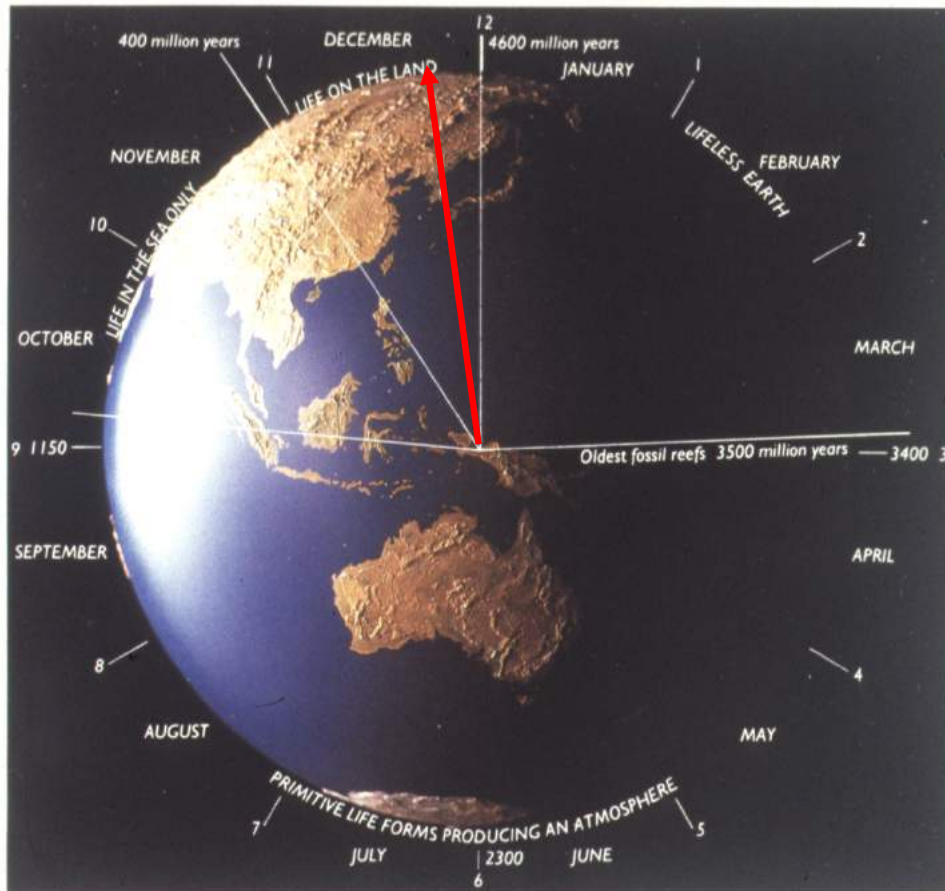
Age of the earth = 1 calendar year
4.6 billion years = 365 days

First land life in Ordovician - 460 mya (a liverwort?)
= November 15 (7/8ths of earth time gone!)

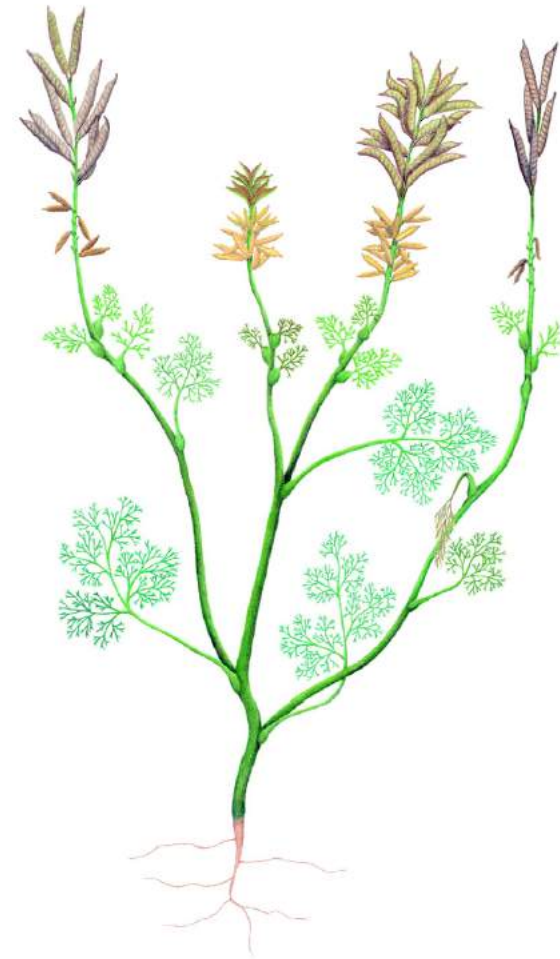


Spore Tetrad

Earth Time

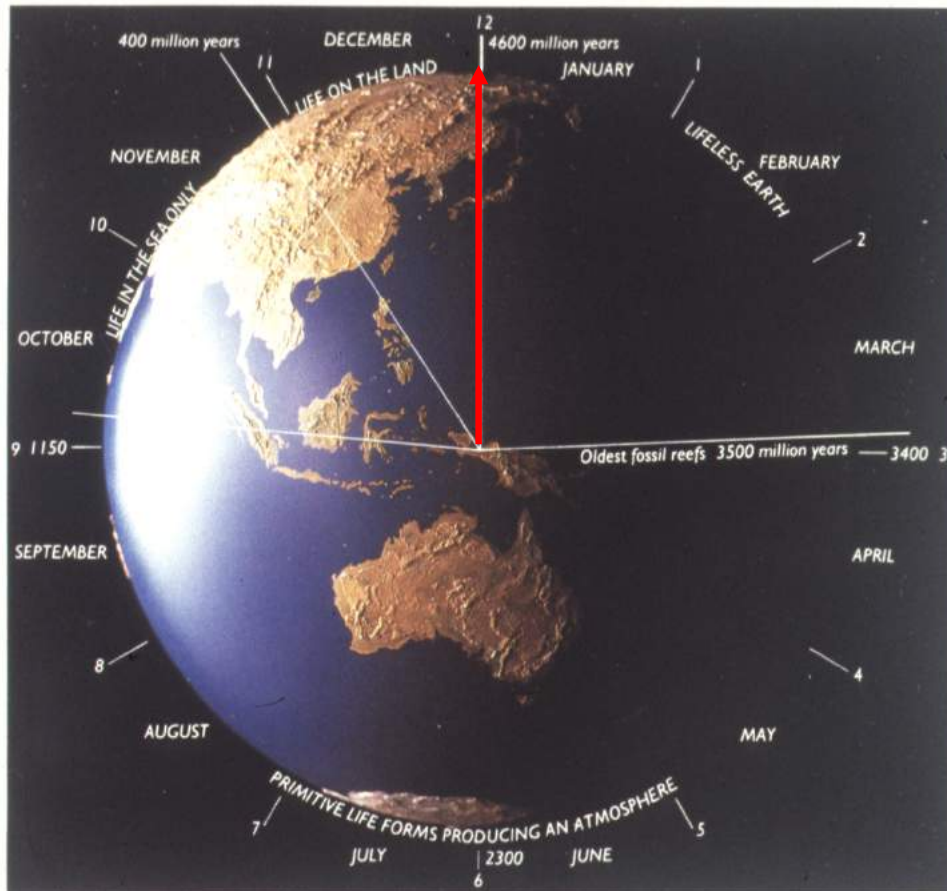


First flowering plant - 127 mya =
December 22



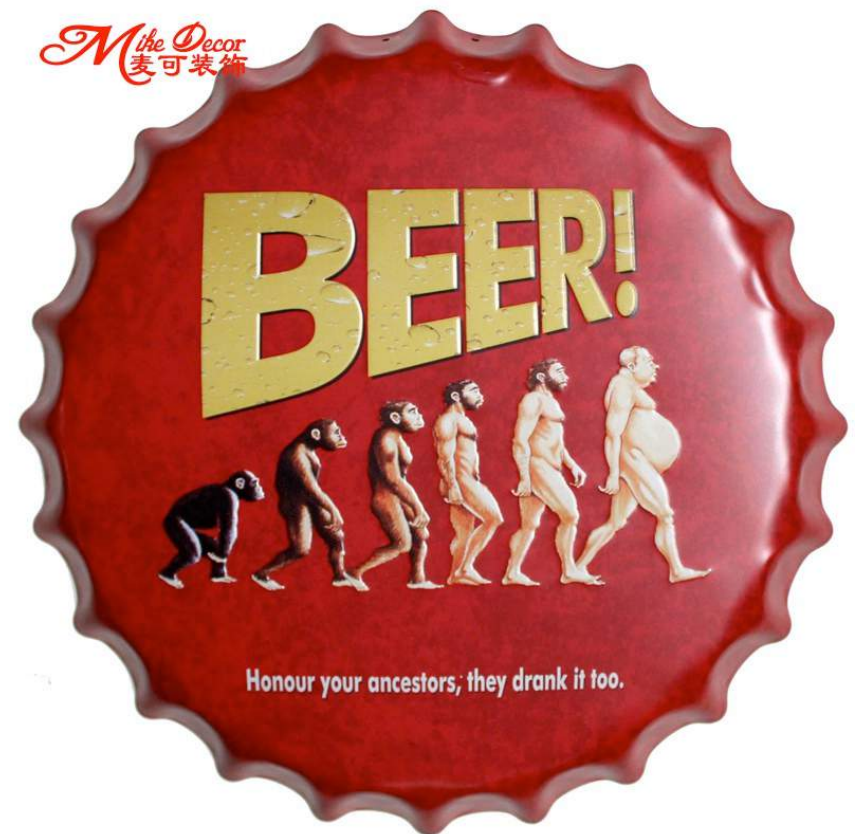
Age of the earth = 1 calendar year
4.6 billion years = 365 days

Earth Time



Age of the earth = 1 calendar year
4.6 billion years = 365 days

Earliest civilization of *Homo sapiens* and assembling of Great Lakes flora - 13,000 ya
= December 31, 11:59 p.m.



Geological Time Scale - the Fossil Record

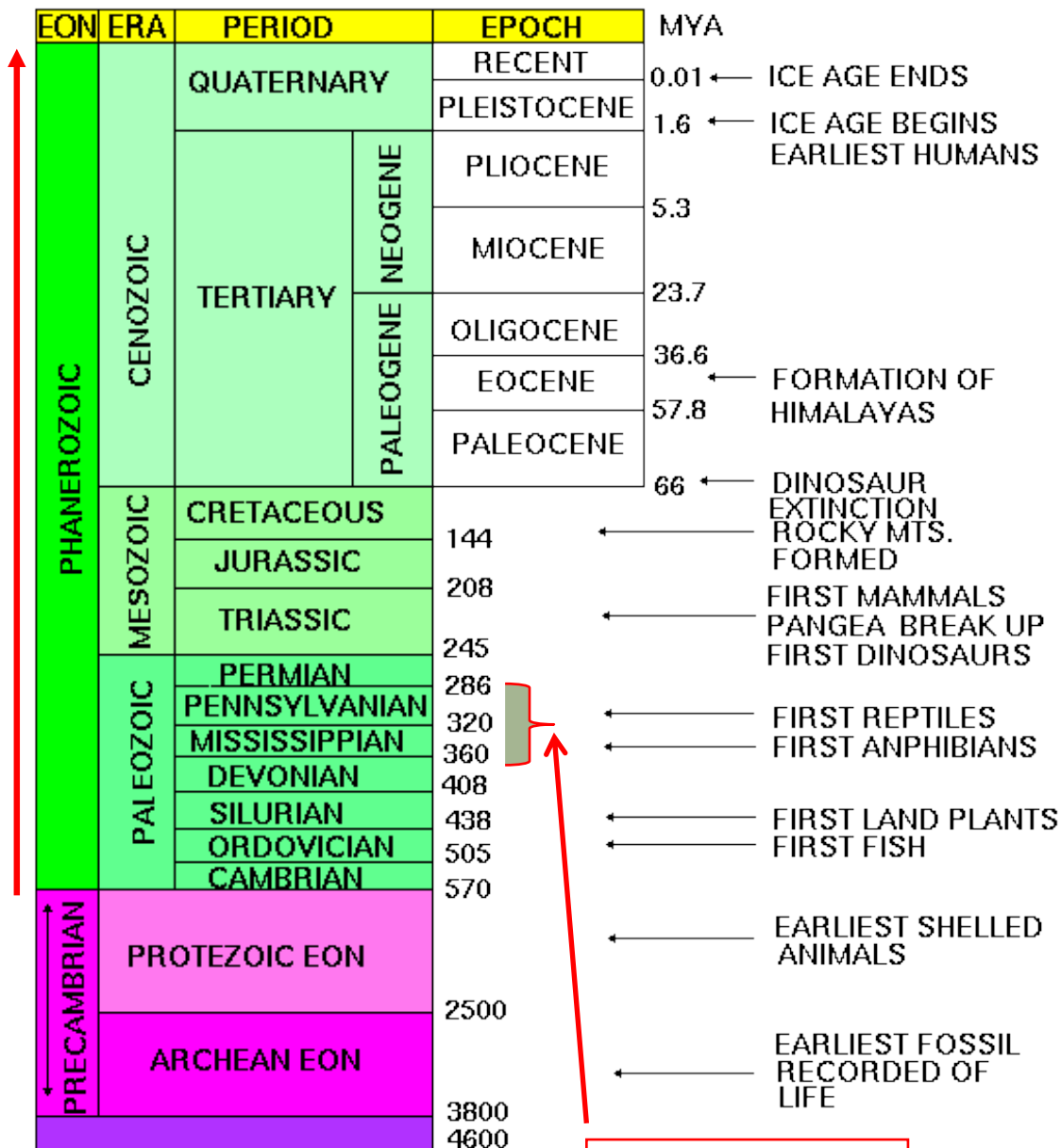


Periods will be the important part of the geological time scale to reference changes in vegetation, flora, fauna

Know

1. the **sequence** of the Periods,
2. the general **time** in million of years,
3. and important **events, plant and animal groups**

Geological Time Scale - the Fossil Record



Please, Easy On My Pliable Quads

Three Juicy Creatures

Campbell's Ordinary Soups Develop Carbohydrates Permanently

Carboniferous

Extant Land Plants



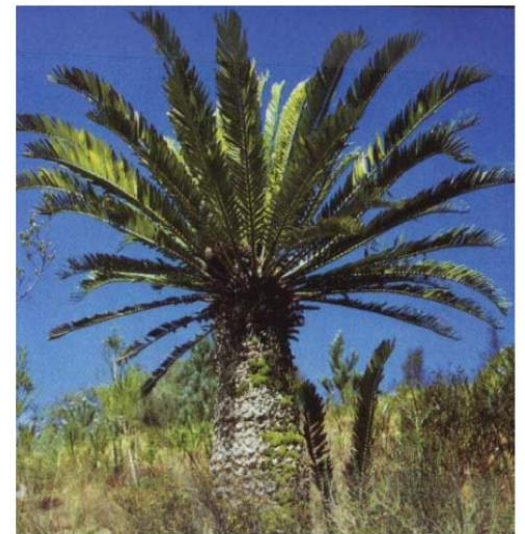
“bryophytes”
mosses



Lycopodiophyta
club mosses



Pinophyta
gymnosperms



Magnoliophyta
angiosperms



Polypodiophyta
ferns and horsetails



Extant Land Plants

Anthocerotophyta hornworts



Marchantiophyta liverworts



Bryophyta
mosses



“bryophytes”

- 16,000 species
- nonvascular plants, least specialized land plants, gametophyte dominant
- comprising 3 phyla)

Extant Land Plants



club moss



quillwort



spikemoss

Lycopodiophyta - lycopods

- 1,150 species
- vascular plants, least specialized vascular plants
- sporophyte dominant; free sporing
- comprising 3 families

Extant Land Plants



Polypodiophyta – ferns

- the ferns, horsetails, whisk ferns
- 11,000 species
- diverse in habit and habitat
- spores produced in specialized sporangia

Extant Land Plants

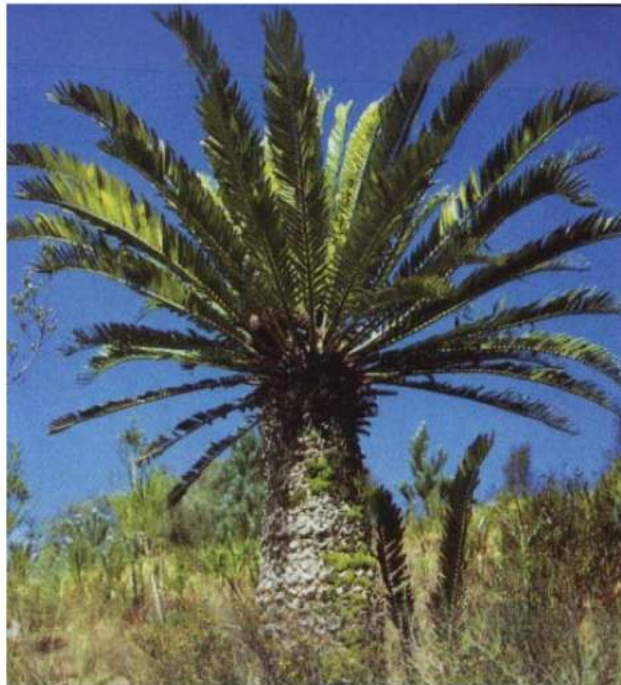
Pinophyta - gymnosperms

- 870 species
- seed plants but seeds naked or exposed
- often divided into 4 phyla

gnetophytes



conifers



cycads



ginkgo

Extant Land Plants



Amborella male flower



Amborella female flower



Fruits



Water Lily (*Nymphaea odorata*)

Magnoliophyta - angiosperms, flowering plants

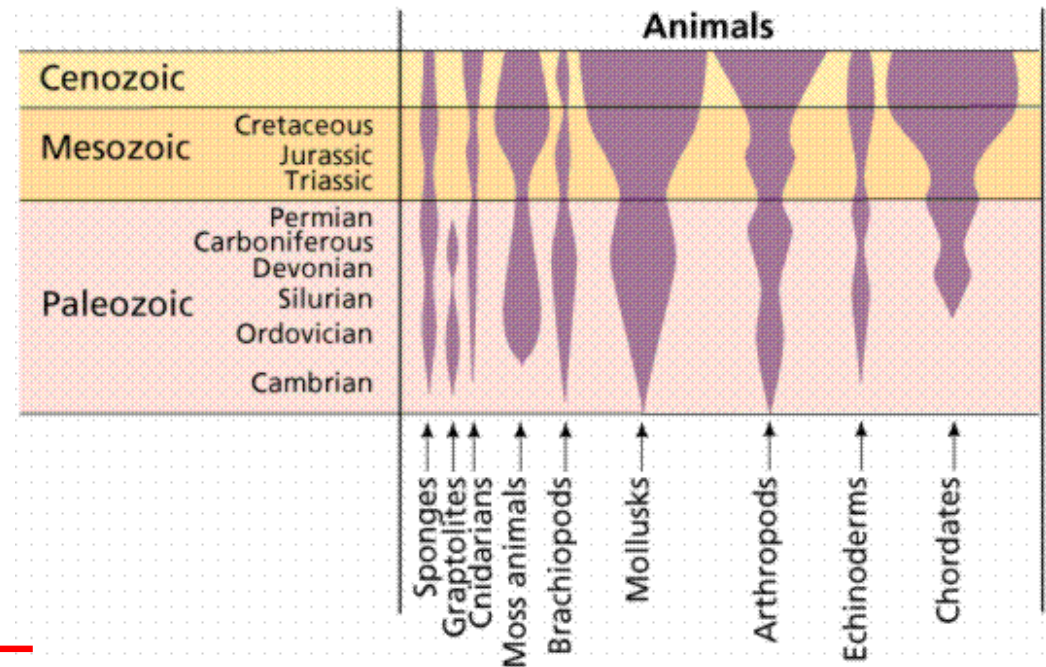
- 275,000 – 400,000 species
- tremendous adaptive radiation on land
- seed plants with seeds encased in ovary

Extinct Land Plants - the Fossil Record



Cambrian Period (540 - 505 mya)

- most phyla of animals seen except chordates – **all marine**

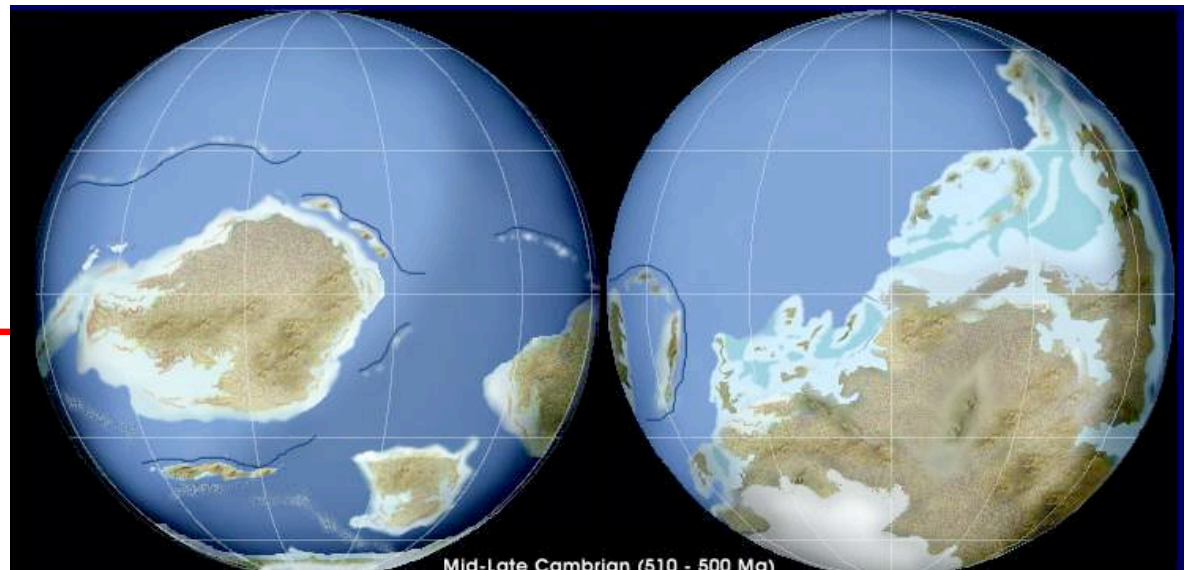


Extinct Land Plants - the Fossil Record

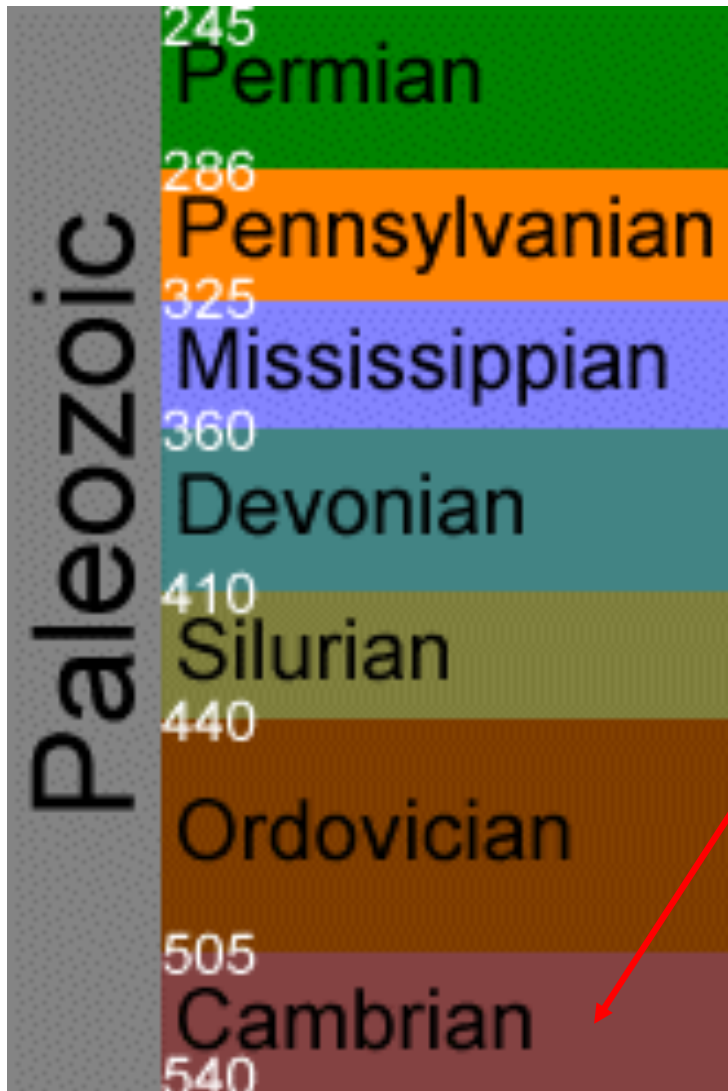


Cambrian Period (540 - 505 mya)

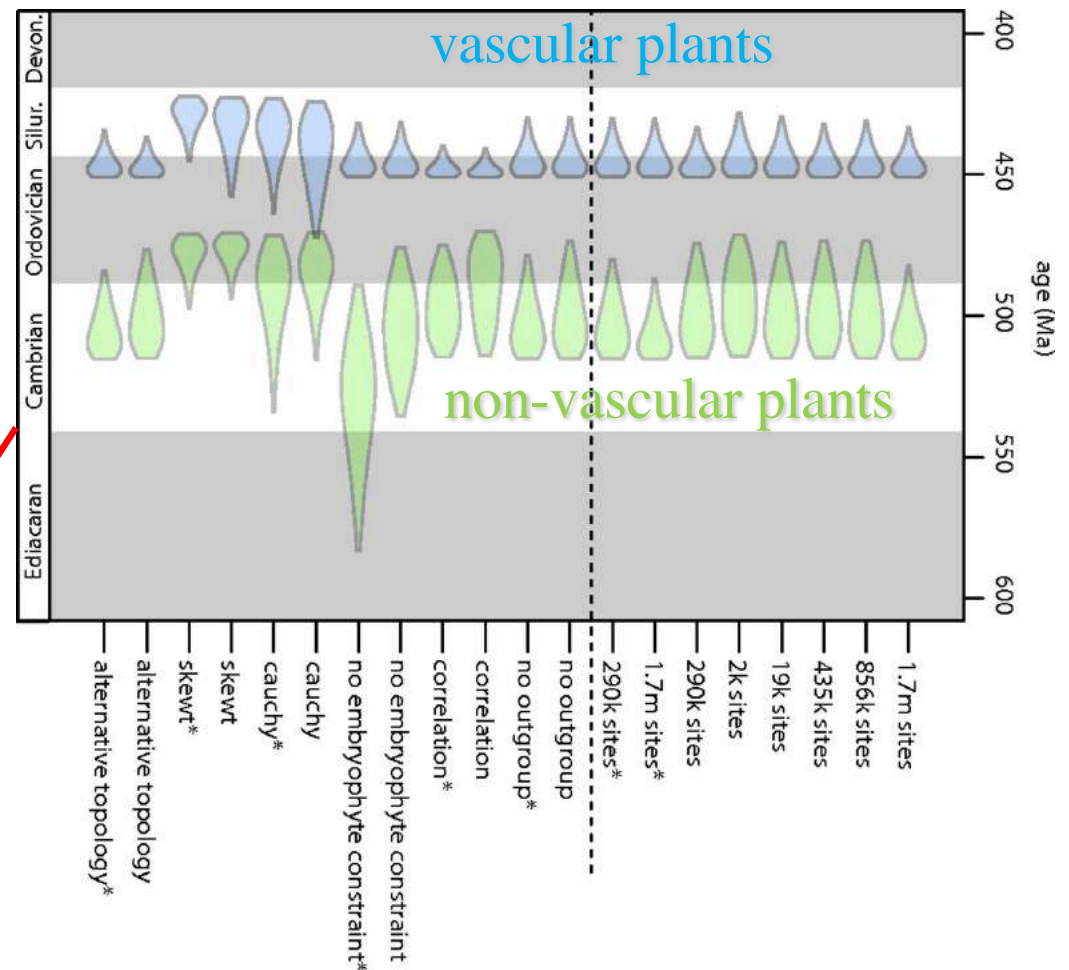
- most phyla of animals seen except chordates – **all marine**
- lime secreting algae in marine water
- fungi diversifying (starting at about 600 mya)
- **no life on land!**



Extinct Land Plants - the Fossil Record



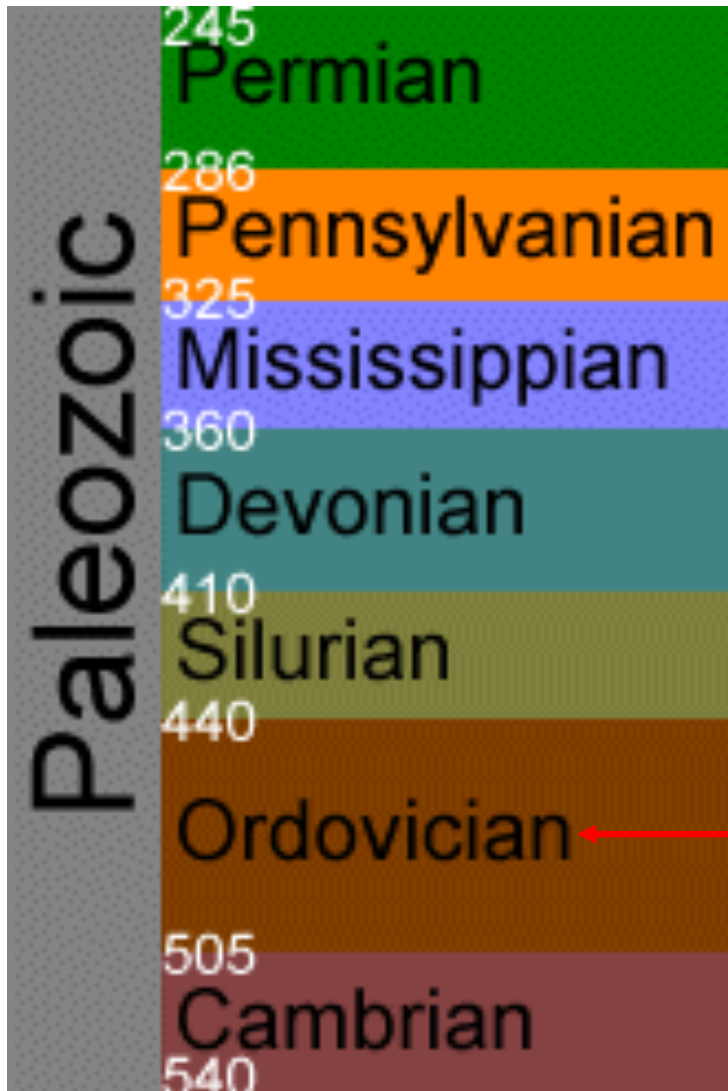
Cambrian Period (540 - 505 mya)



- molecular clock - life on land!

Morris et al. 2018. The timescale of early land plant evolution. Proc Natl Acad Sci USA.

Extinct Land Plants - the Fossil Record



Ordovician Period (505 - 440 mya)

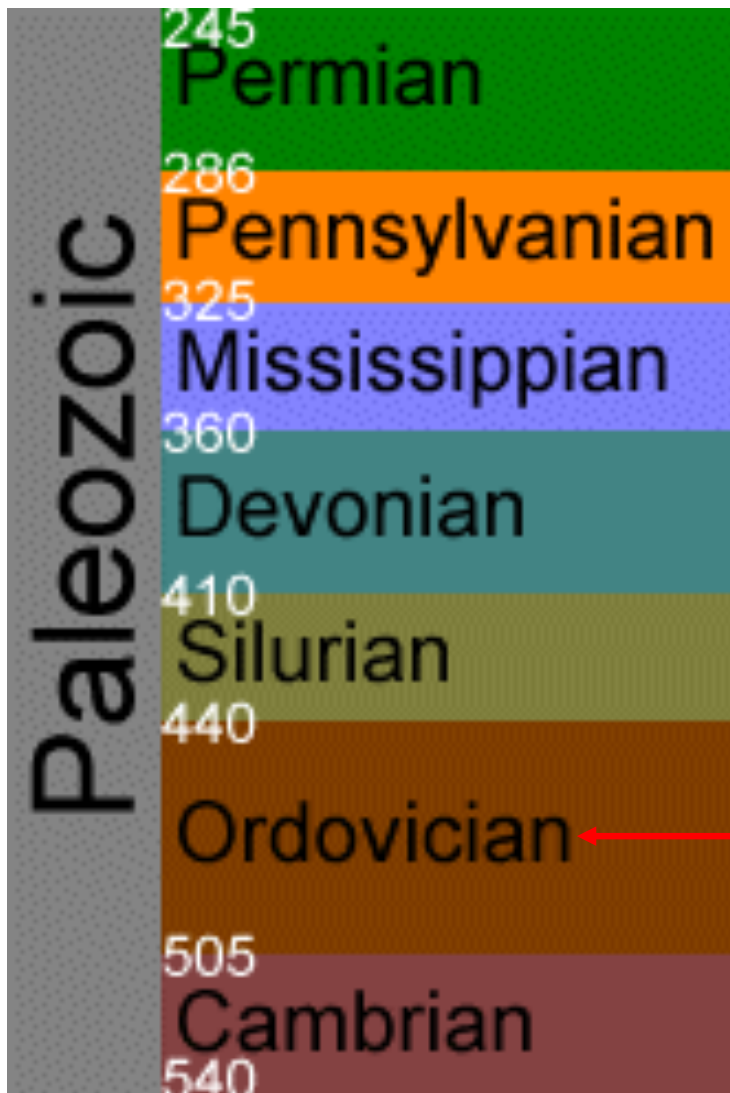
- jawed fish diversifying in oceans
- complex green algae in marine water
- **First evidence of land life at 460 mya**



Microfossils of spores with **sporopollenin** (degradation resistant material like lignin) and similar to modern day bryophytes such as liverworts

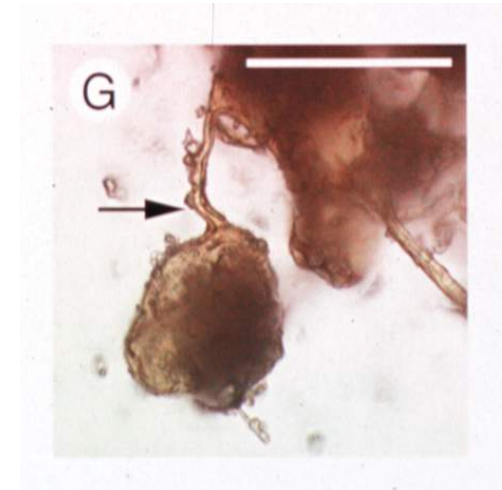
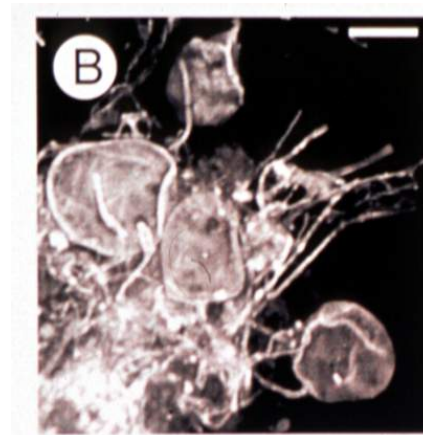
Found worldwide in shales that were deposited at the marine-terrestrial interface

Extinct Land Plants - the Fossil Record



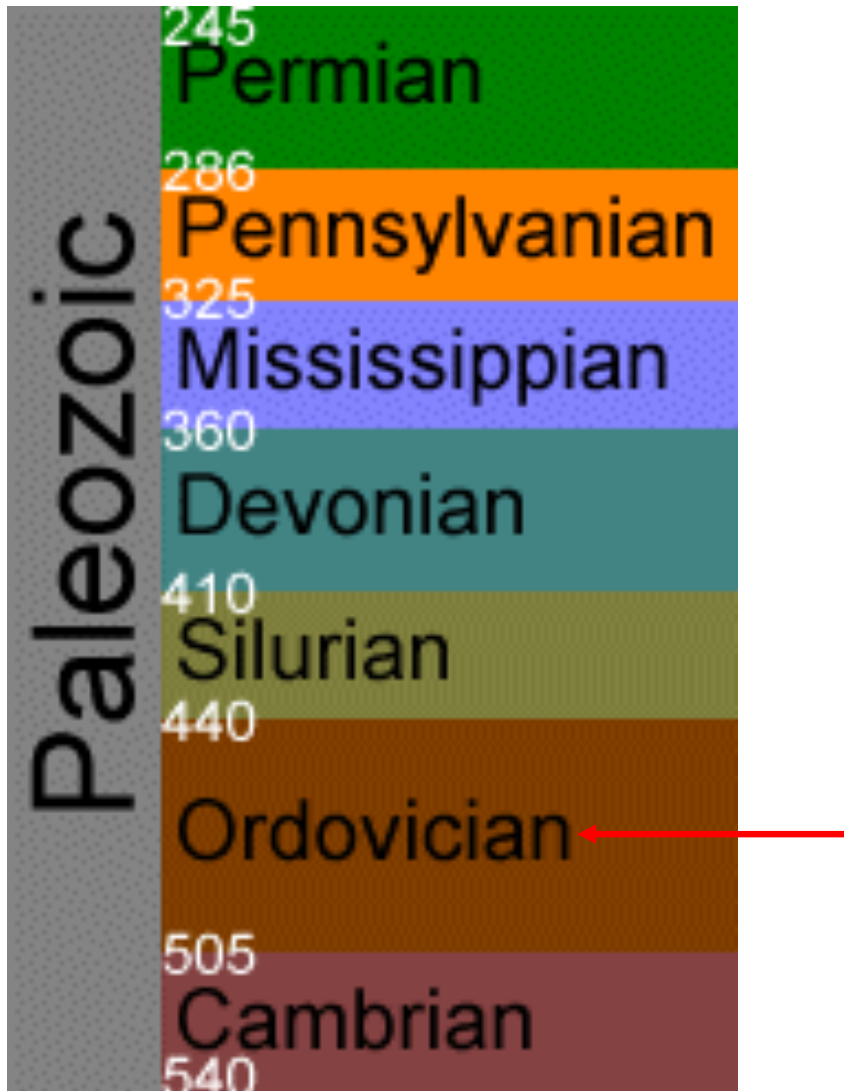
Ordovician Period (505 - 440 mya)

- Other evidence of land life



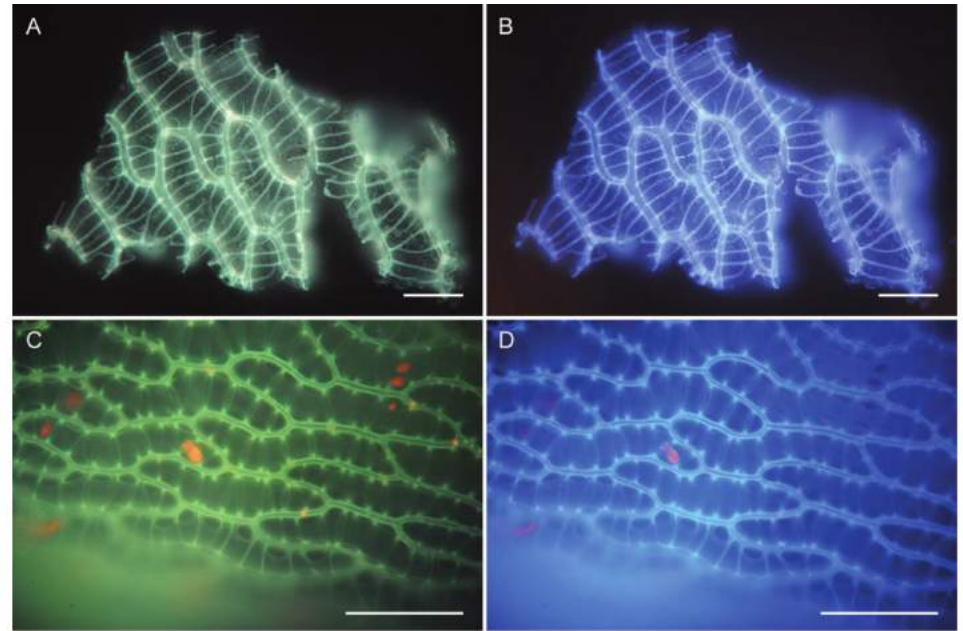
Glomales fungi seen in 460 my Wisconsin rock. Glomales today form important arbuscular **mycorrhizal** associations with some liverworts and hornworts and many vascular plants. **Symbiosis!**

Extinct Land Plants - the Fossil Record



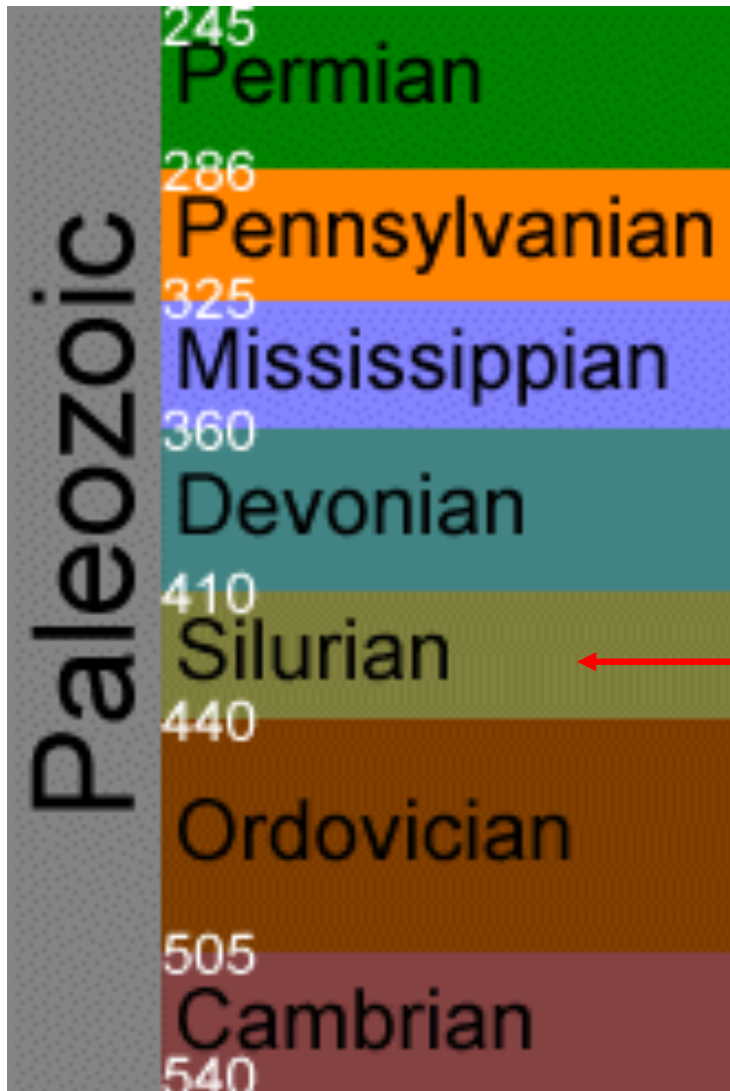
Ordovician Period (505 - 440 mya)

- Other evidence of land life



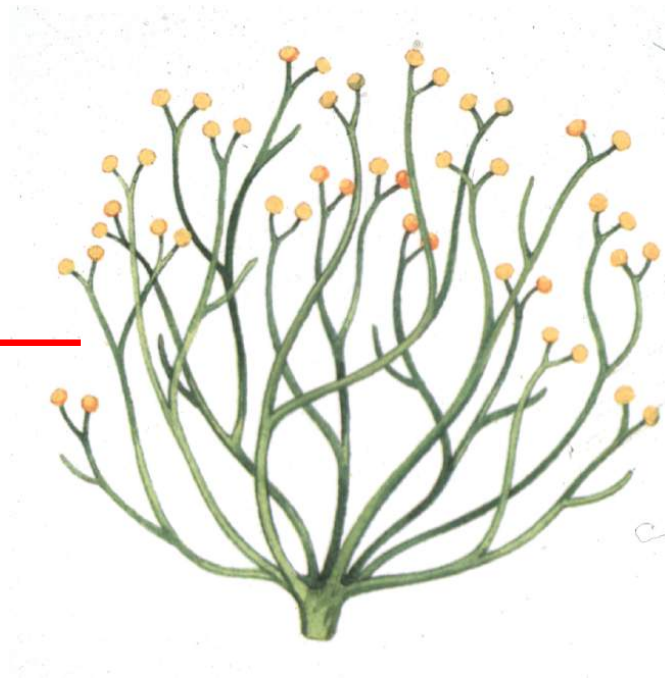
“Sphagnum” moss seen in 455 my
Wisconsin rock - 2nd diverging lineage
of bryophytes

Extinct Land Plants - the Fossil Record

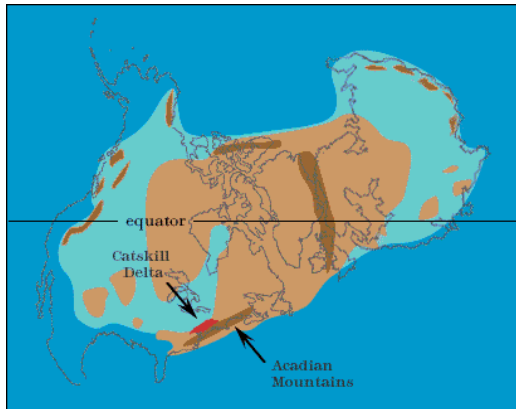


Silurian Period (440 - 410 mya)

Cooksonia fossils are seen in the mid Silurian growing close to water



Extinct Land Plants - the Fossil Record



Euramerica

Silurian Period (440 - 410 mya)

Cooksonia fossils are seen in the mid Silurian growing close to water

- very simple, stick-like, leafless plants but sporophyte dominant
- roots never seen
- terminal flat sporangia (spore producing structures)
- primitive vascular or possibly non-vascular
- first seen in Euramerica (tropical setting) and later in Australia



Extinct Land Plants - the Fossil Record

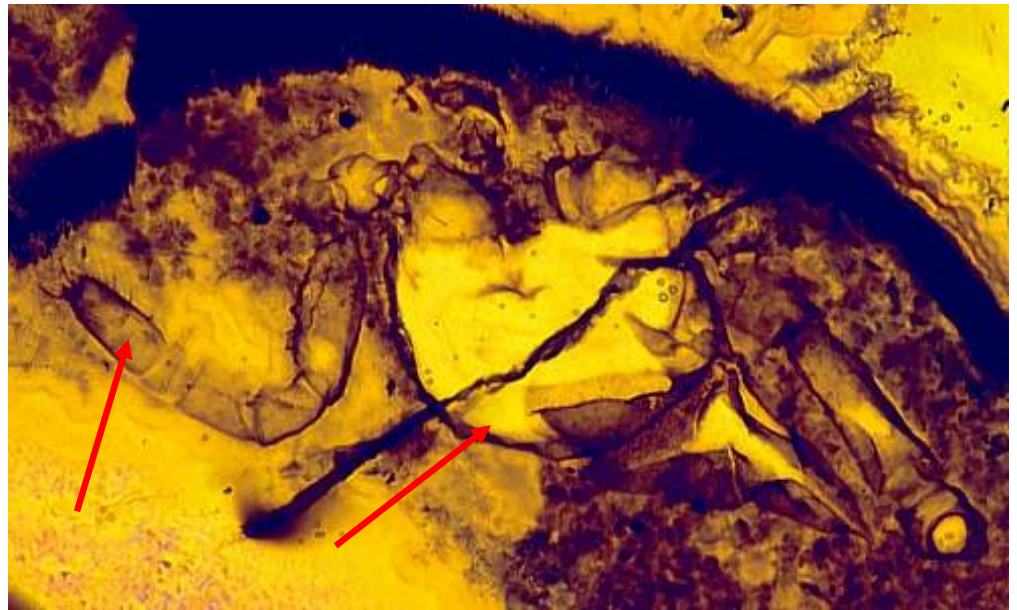


Silurian view

Silurian Period (440 - 410 mya)

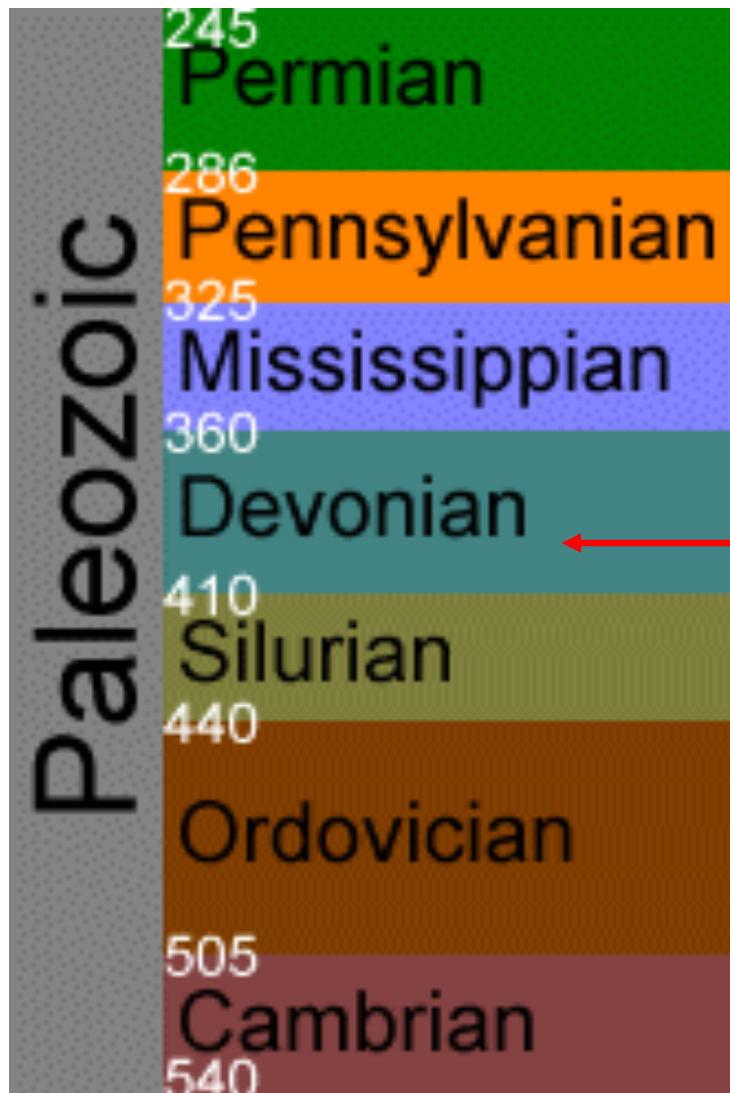
Late Silurian is also the first occurrence of land animals - arachnids, centipedes

Predators and thus indicate that there were unknown herbivores - **community** of plants, herbivores and carnivores!



Trigonotarbid Spider in chert

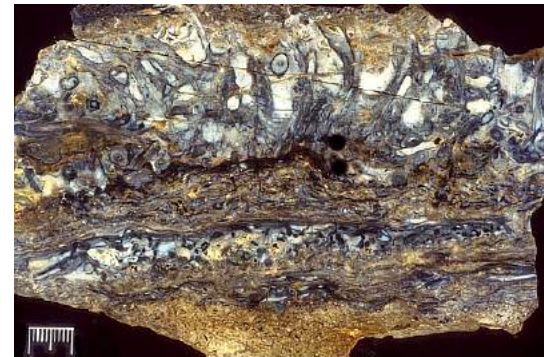
Extinct Land Plants - the Fossil Record



Early Devonian Period (410 - 390 mya)

The 'greening' of the earth

Abundant and exquisite fossils known from chert fossil beds in Rhynie, northern Scotland (tropical Euramerica)



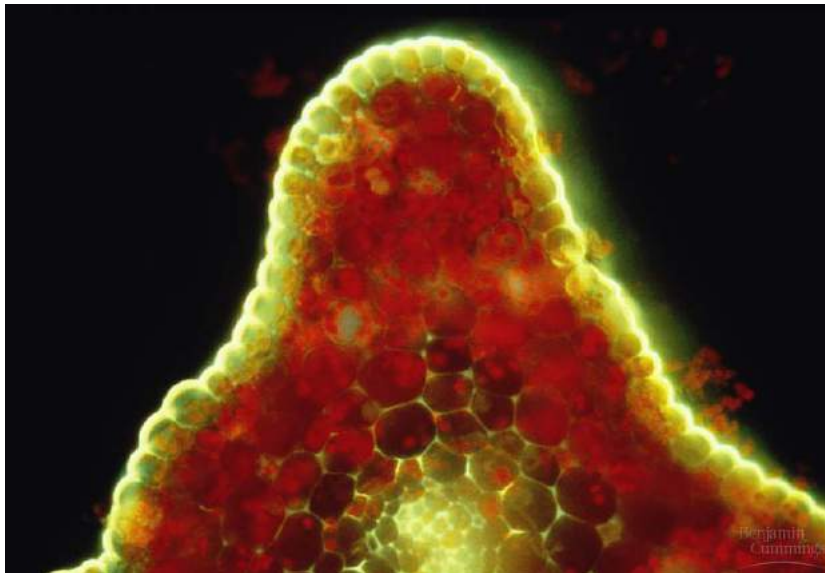
Extinct Land Plants - the Fossil Record

- underground (root) and above ground photosynthetic stem
- rhizoids (water uptake)
- primitive leaves
- internal transport - vascular tissue
- epidermis, cuticle, stomates

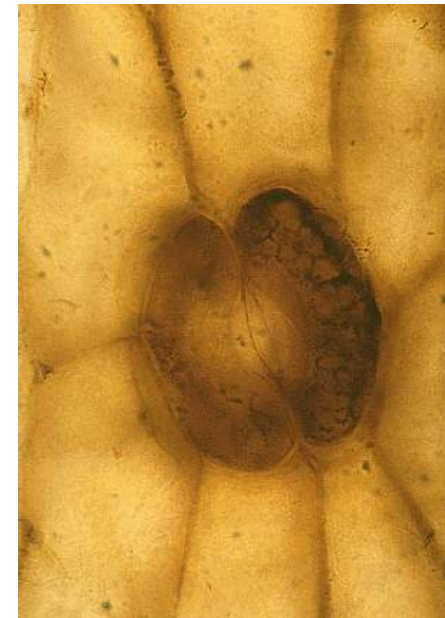
Early Devonian Period (410 - 390 mya)

The Early Devonian lasted some 30 million years after the first appearance in mid-Silurian of simple land plants

During this interval the critical features of **land plant survival** evolved:

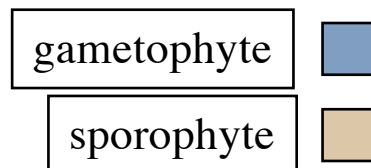


Rhynia



Extinct Land Plants - the Fossil Record

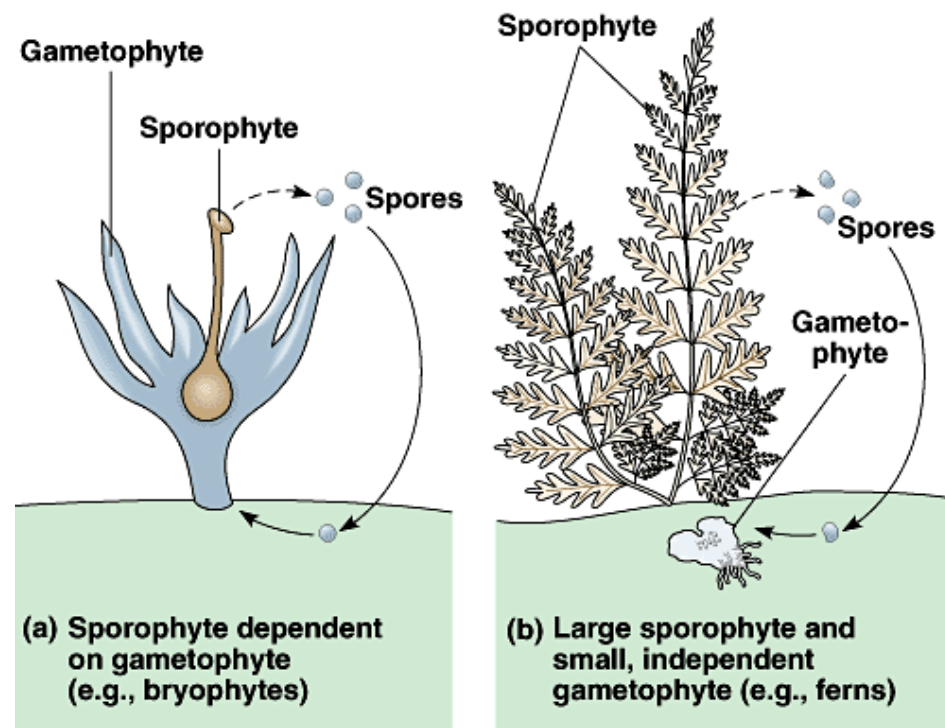
- underground (root) and above ground photosynthetic stem
- rhizoids (water uptake)
- primitive leaves
- internal transport - vascular tissue
- epidermis, cuticle, stomates
- support tissue - lignin
- shift to sporophyte rather than gametophyte dominant
- sporopollenin to cover spores for protection



Early Devonian Period (410 - 390 mya)

The Early Devonian lasted some 30 million years after the first appearance in mid-Silurian of simple land plants

During this interval the critical features of **land plant survival** evolved:



Extinct Land Plants - the Fossil Record

- underground (root) and above ground photosynthetic stem
- rhizoids (water uptake)
- primitive leaves
- internal transport - vascular tissue
- epidermis, cuticle, stomates
- support tissue - lignin
- shift to sporophyte rather than gametophyte dominant
- sporopollenin to cover spores for protection
- more complex embryo

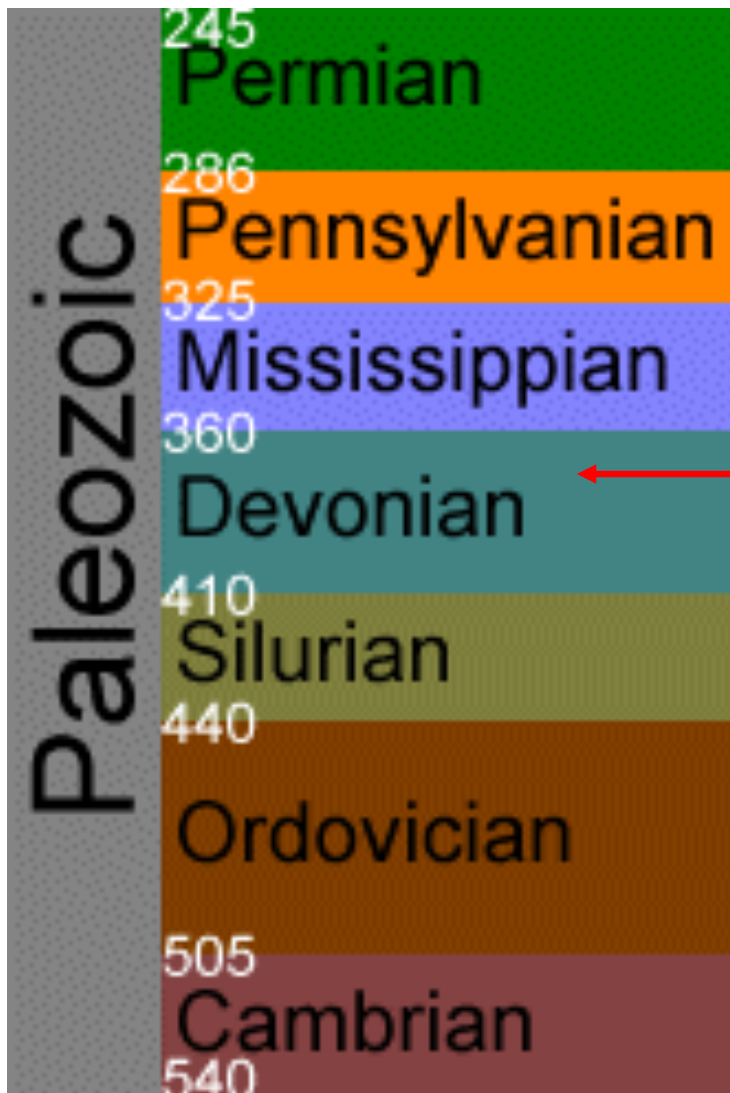
Early Devonian Period (410 - 390 mya)

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During this interval the critical features of **land plant survival** evolved:



Extinct Land Plants - the Fossil Record



Late Devonian Period (390 - 360 mya)

First “**progymnosperms**” - believed to be ancestors of seed plants

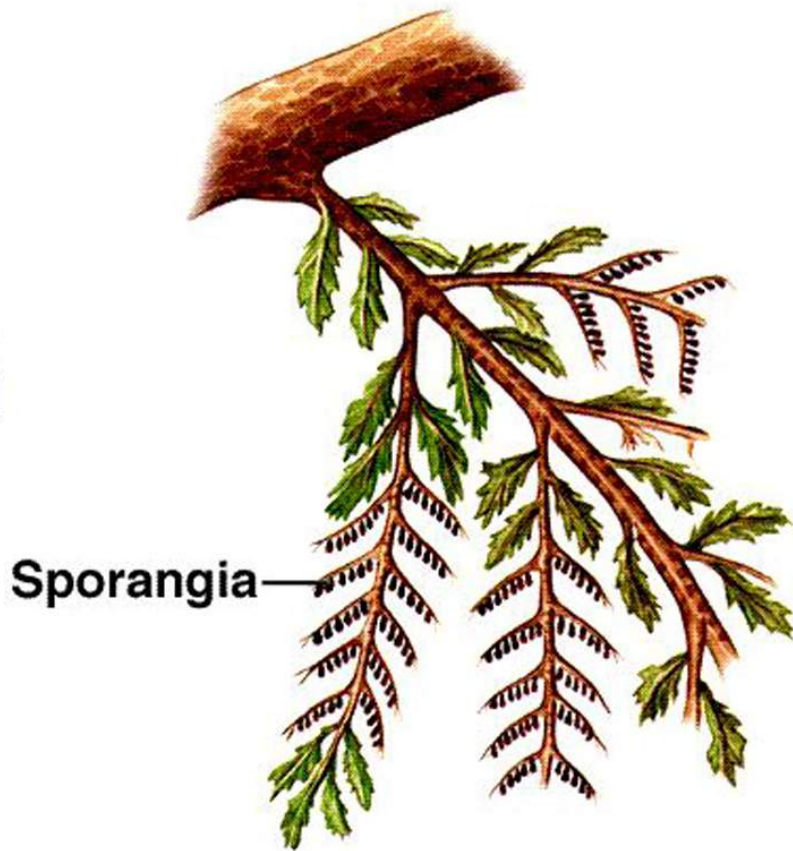


Archaeopteris

Extinct Land Plants - the Fossil Record

Late Devonian Period (390 - 360 mya)

First “**progymnosperms**” - free sporing like ferns but trees like gymnosperms; **first forests**



Archaeopteris

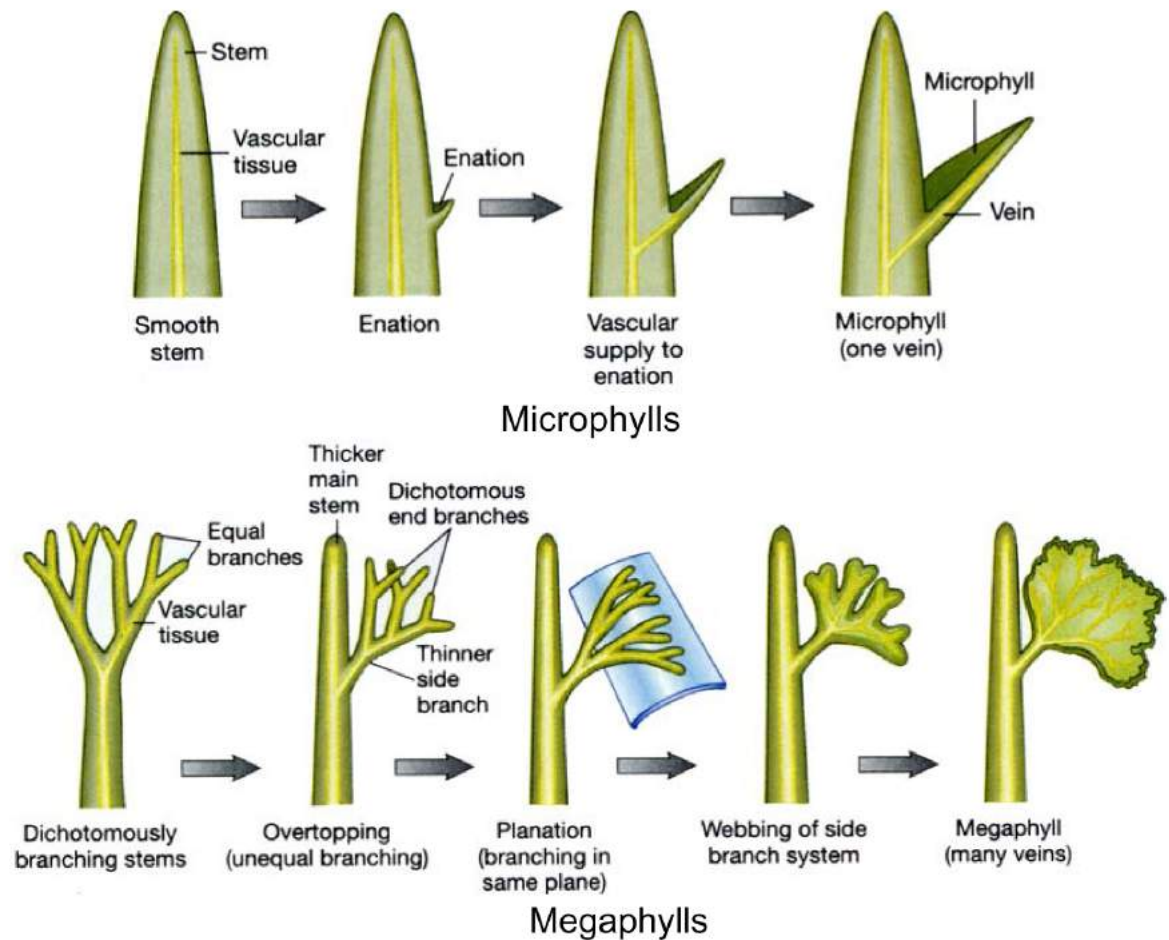
Extinct Land Plants - the Fossil Record



Archaeopteris

Late Devonian Period (390 - 360 mya)

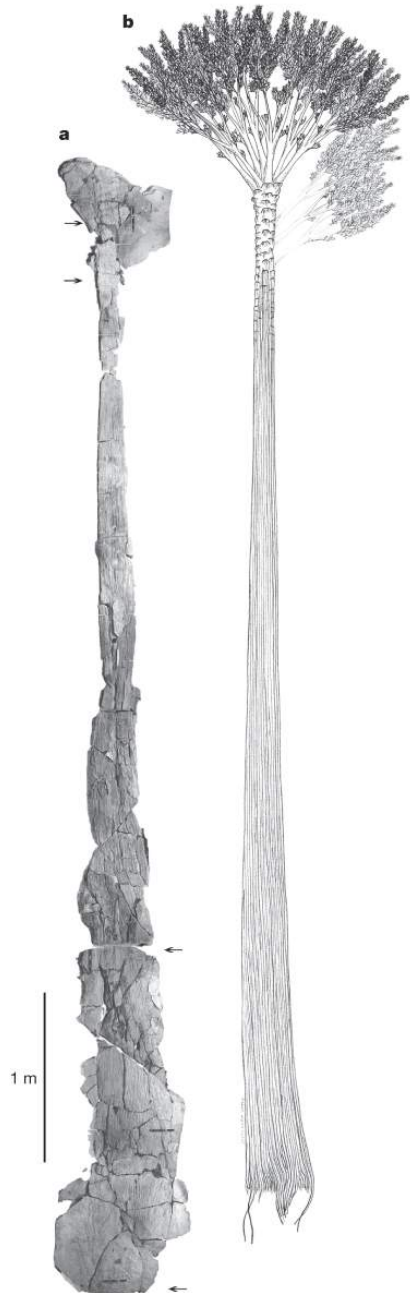
First complex leaves - megaphylls



Extinct Land Plants - the Fossil Record

Late Devonian Period (390 - 360 mya)

Eospermatopteris trunks from New York recently connected to *Wattieza* fern like crown. 385 my old **forests** of at least 8m tall trees with primitive root systems.



Extinct Land Plants - the Fossil Record

Late Devonian Period (390 - 360 mya)

First **true ferns** - free sporing with complex sporangia & megaphylls



Protopteridium

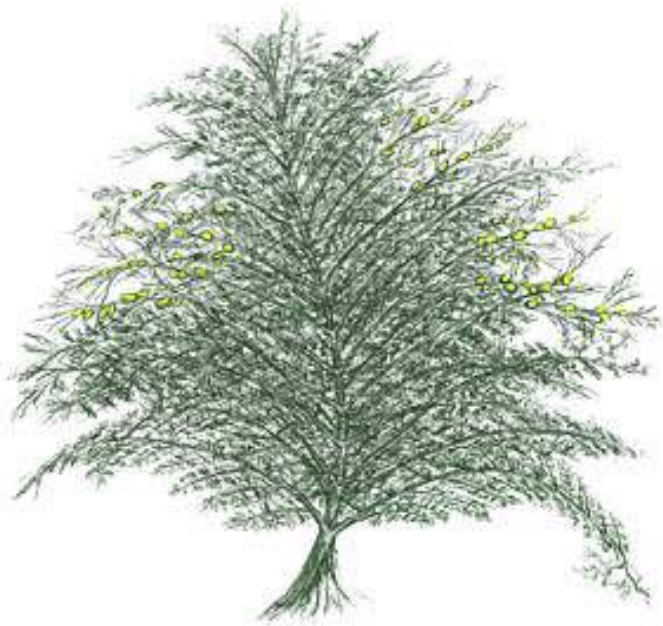
*Pteridium -
Bracken fern*



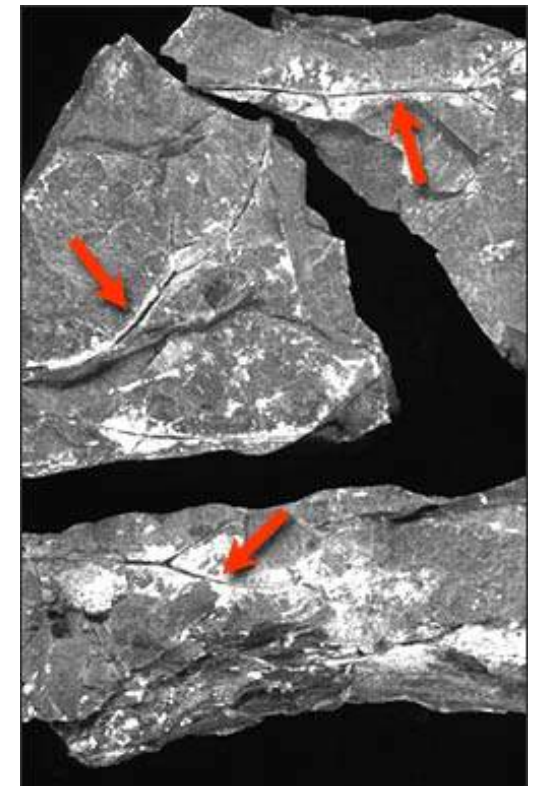
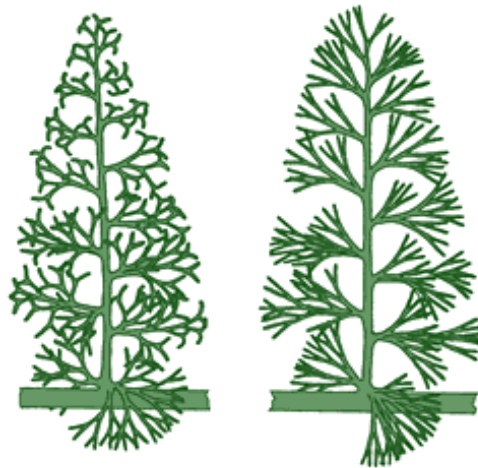
Extinct Land Plants - the Fossil Record

Late Devonian Period (390 - 360 mya)

Rhacophyton and the rarer *Gillespiea* were understory ferns in the *Archaeopteris* forests. *Rhacophyton* produced enough biomass, that the first records of **forest fires** are seen in the Catskill fossil sites

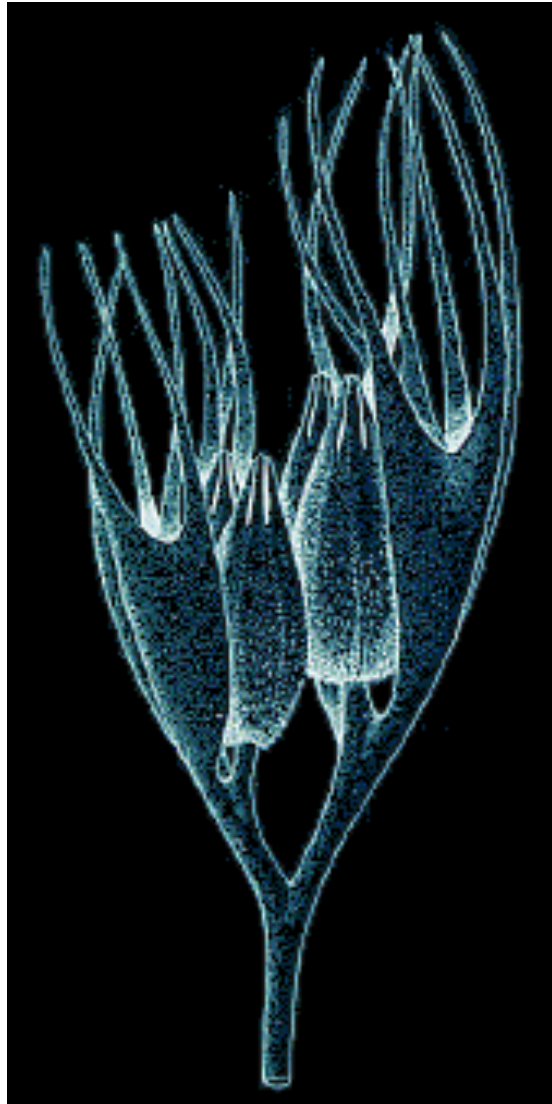


Rhacophyton



Gillespiea

Extinct Land Plants - the Fossil Record



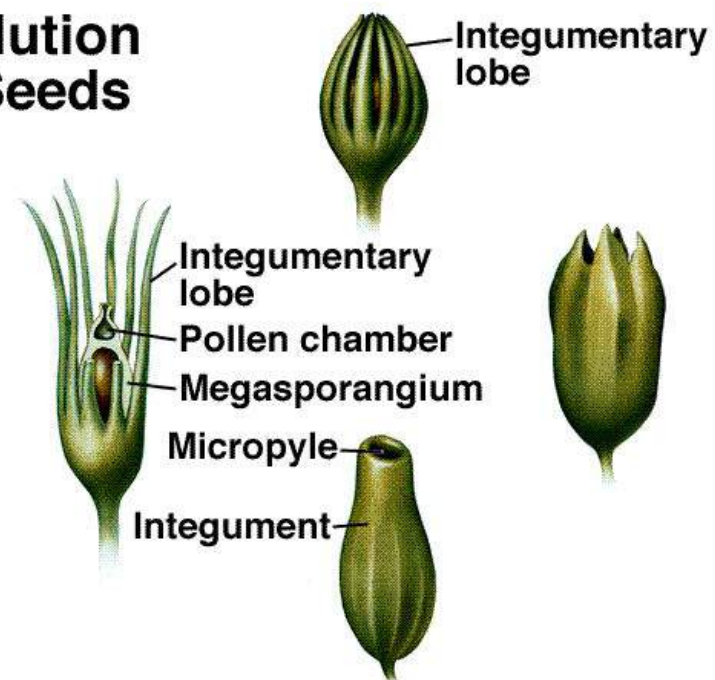
Archaeosperma

Late Devonian Period (390 - 360 mya)

First “**seeds**” - “seed fern” lineage

Plants fern-like with dissected compound leaves, but produce naked seeds (embryo within protective coverings)

Evolution of Seeds



Extinct Land Plants - the Fossil Record



Ichthyostega

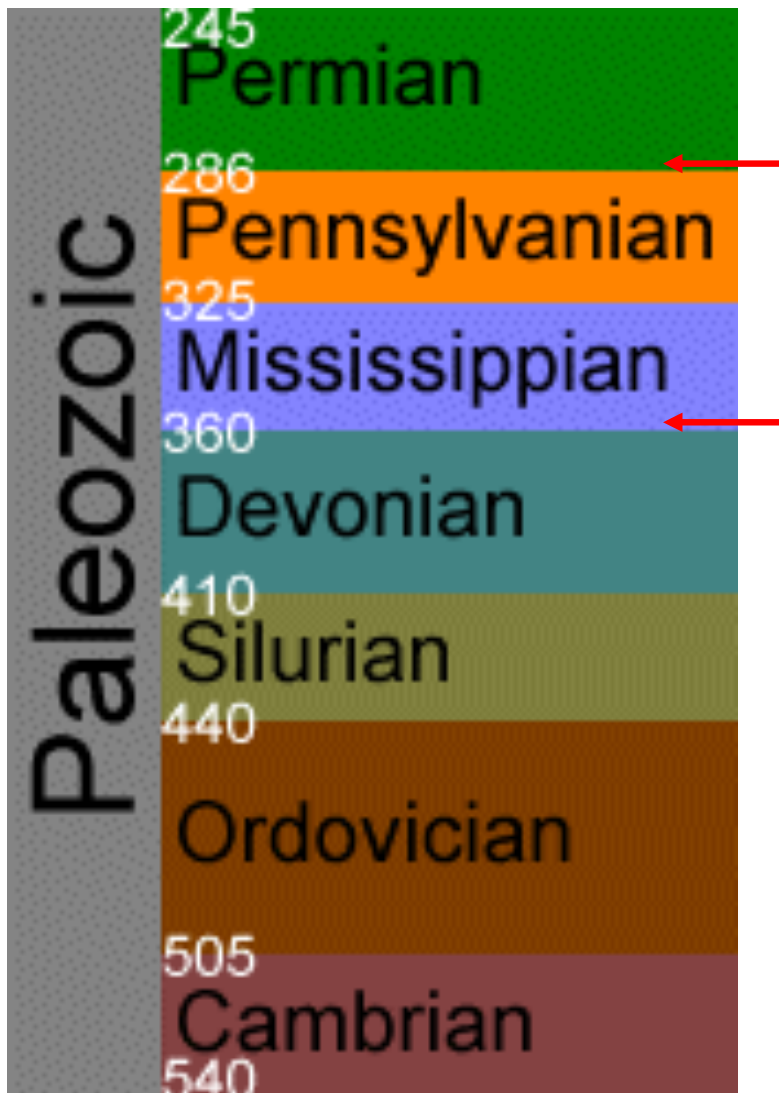
Late Devonian Period (390 - 360 mya)

- Great diversity of plants in warm, wet climate and **no apparent provincialism** yet seen - worldwide
- **Arthropods** diversify and first **amphibians** seen by late Devonian



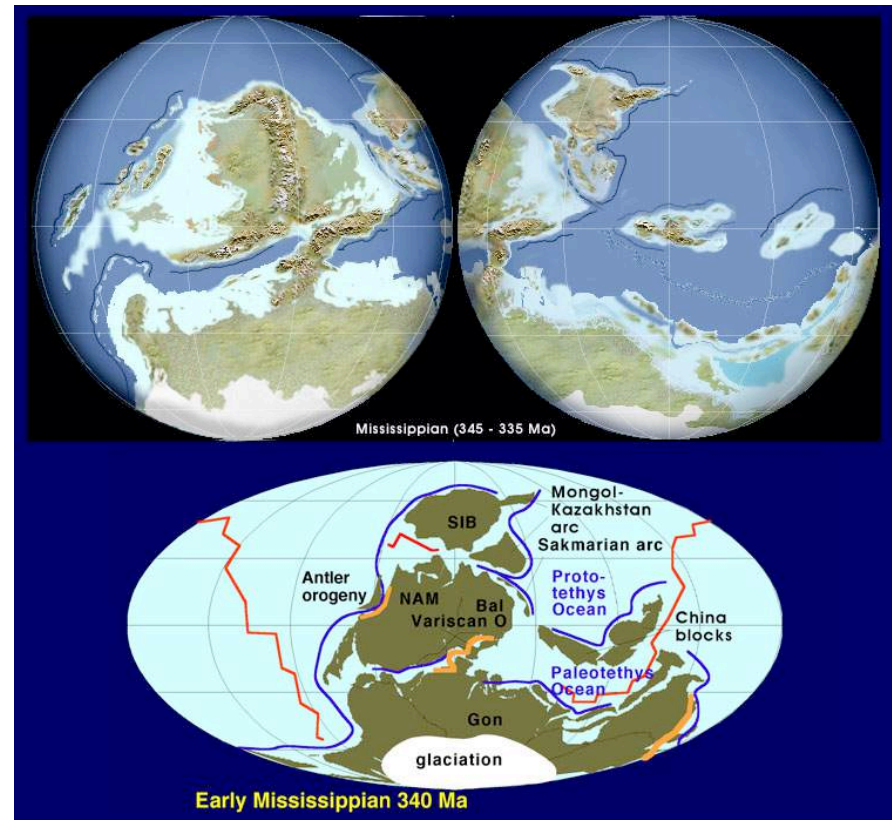
Hynerpeton

Extinct Land Plants - the Fossil Record



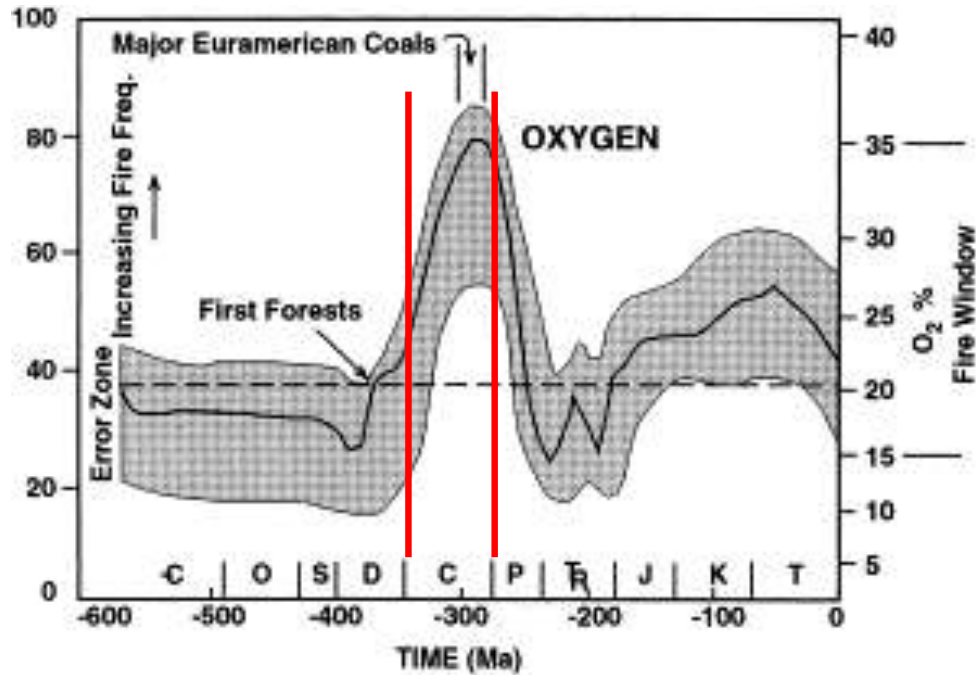
Carboniferous Period (360 - 286 mya)

- **Provincialism** seen due to global cooling
- Ice sheets at South Pole (due to CO₂ decrease via plants?) and tropical forests at equator

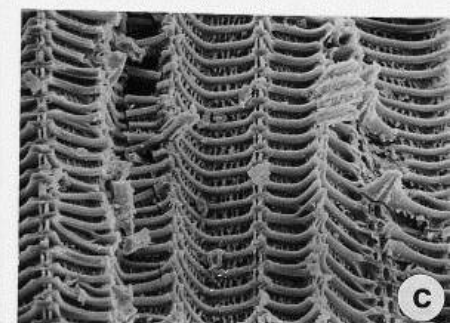
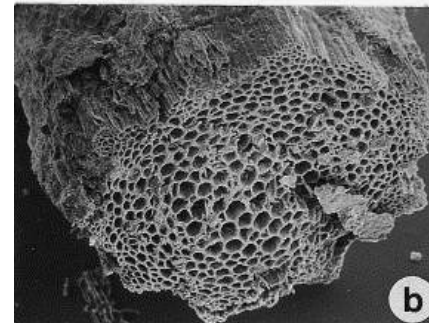
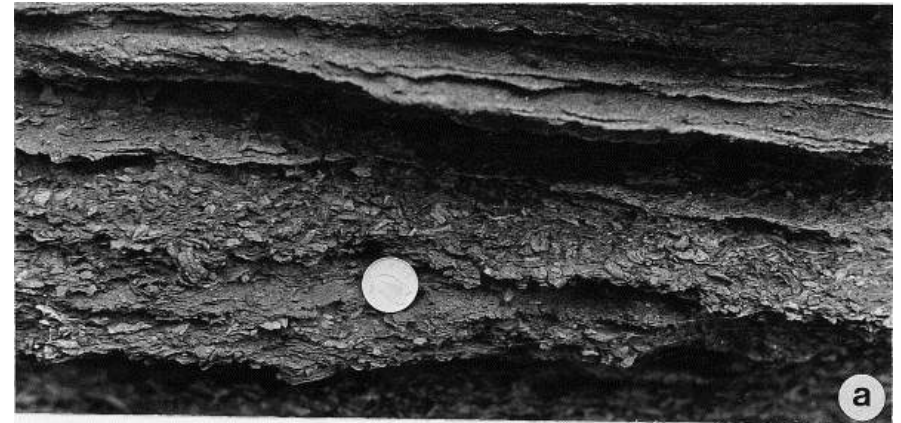


Extinct Land Plants - the Fossil Record

Carboniferous Period (360 - 286 mya)



- **extensive forests** increased O₂ levels worldwide and saw greatest incidence of fire



Lower Carboniferous
lycopsid charcoal fossils

Extinct Land Plants - the Fossil Record

Carboniferous Period (360 - 286 mya)



The equatorial “coal” forests were the site for the diversification of insects . . .

Extinct Land Plants - the Fossil Record



Carboniferous Period (360 - 286 mya)

. . . and the first appearance of **reptiles**

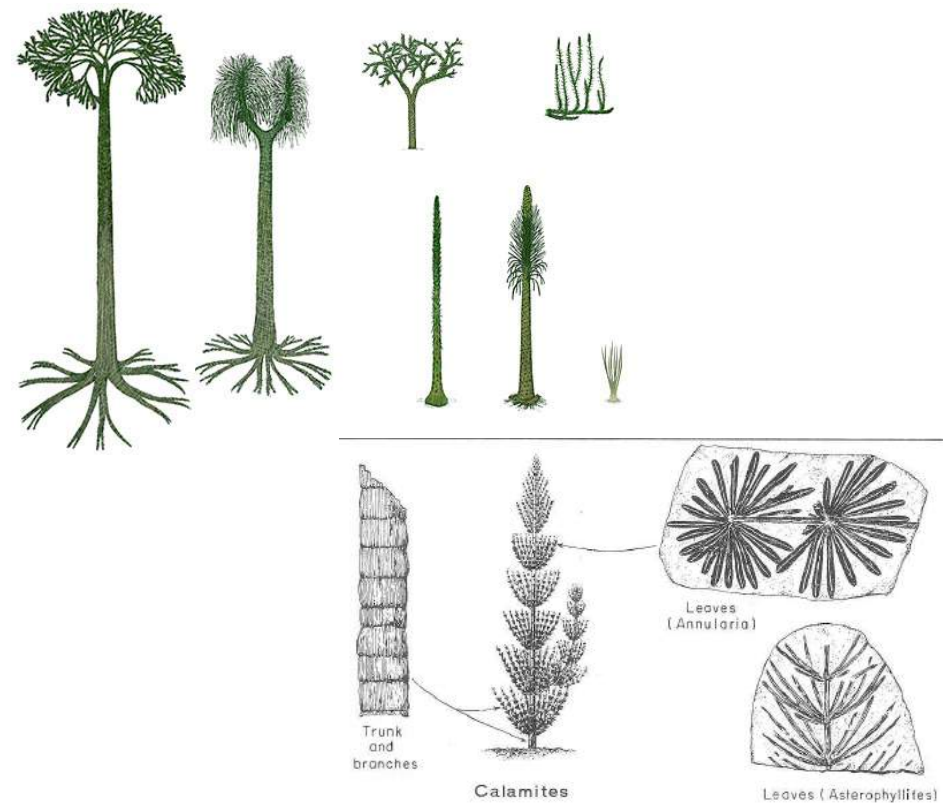
Hylonomus, primitive reptile, leaping after an insect in a coal swamp of Nova Scotia

Extinct Land Plants - the Fossil Record



Carboniferous Period (360 - 286 mya)

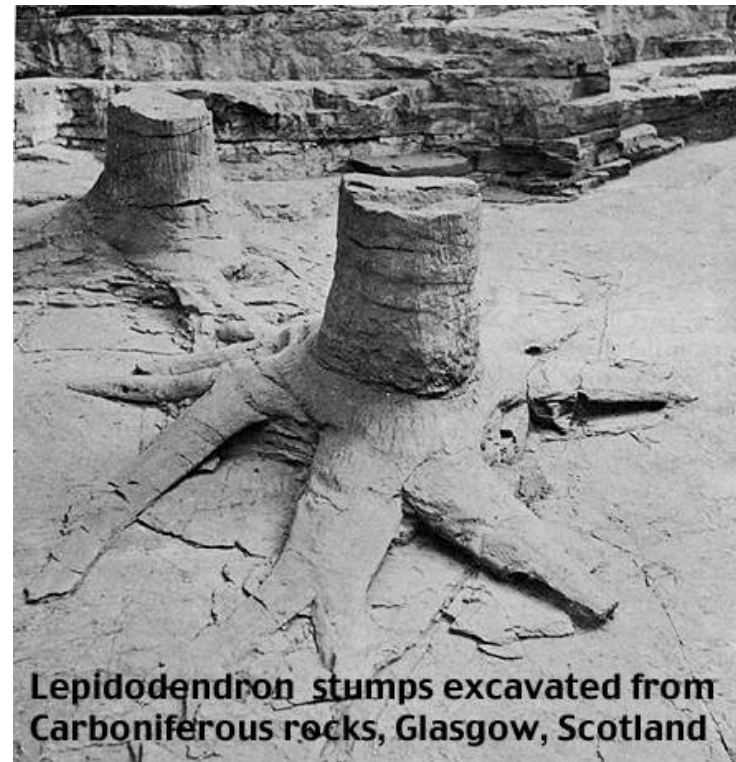
The tropical equatorial coal swamps were dominated by a diversity of **lycopsids** (lycopod lineage) and **horsetails** (fern lineage)



Extinct Land Plants - the Fossil Record

Carboniferous Period (360 - 286 mya)

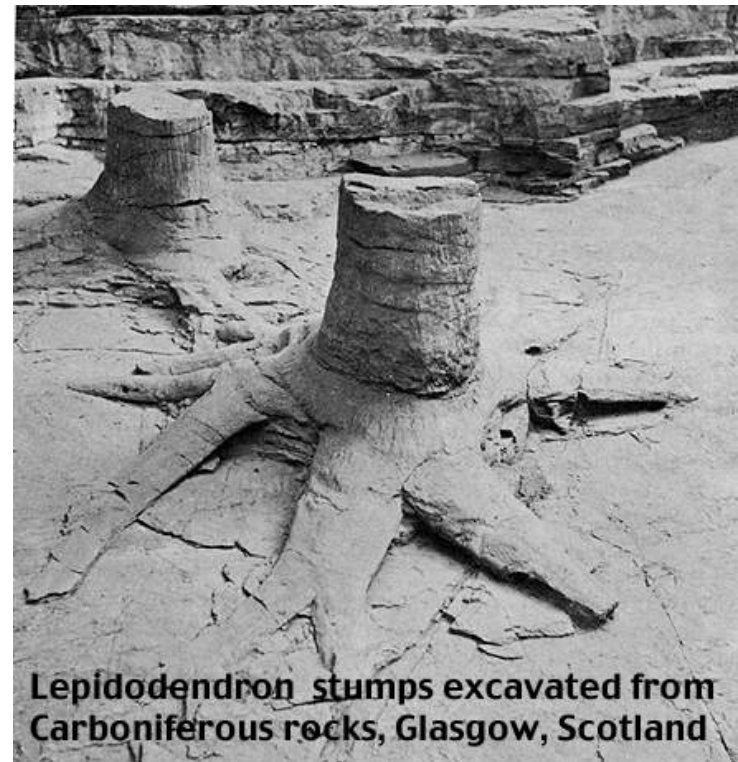
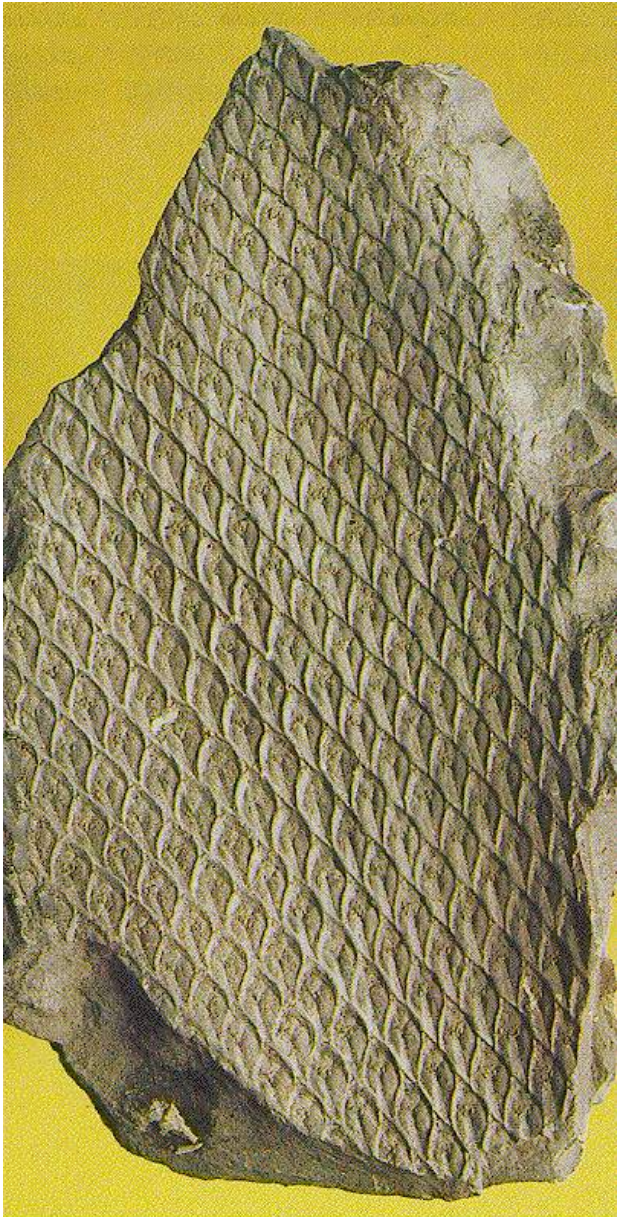
Lepidodendron (lycopod) was 30 m tall with 1 meter long “microphyll” leaves



Extinct Land Plants - the Fossil Record

Carboniferous Period (360 - 286 mya)

The scaly bark of *Lepidodendron* is distinctive as a fossil

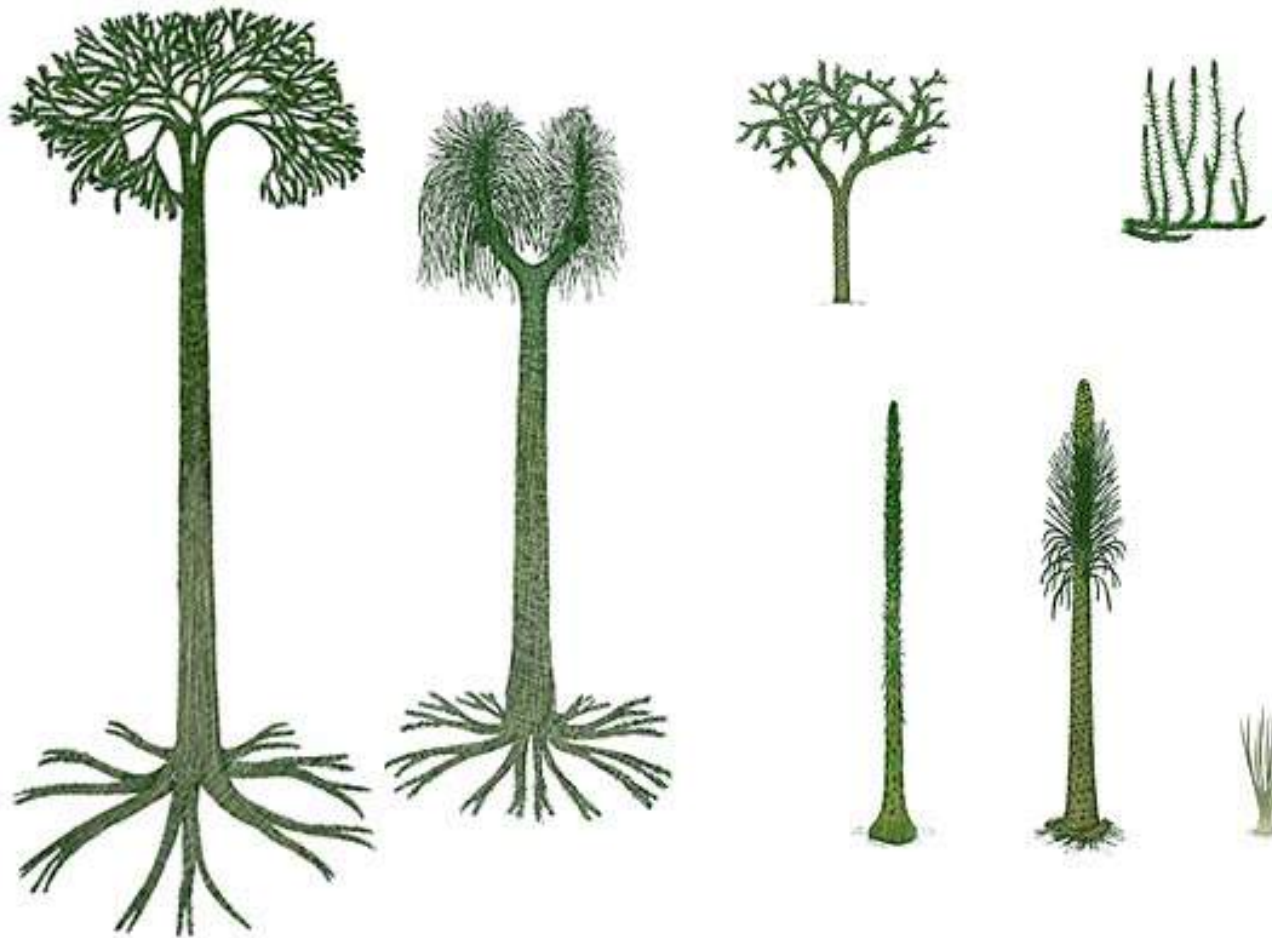


Lepidodendron stumps excavated from Carboniferous rocks, Glasgow, Scotland

Extinct Land Plants - the Fossil Record

Carboniferous Period (360 - 286 mya)

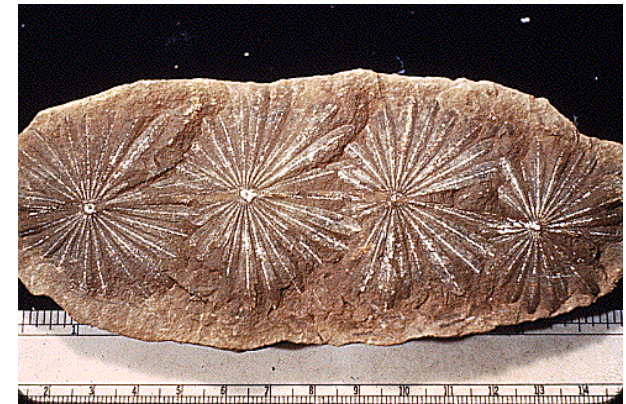
Lepidodendron, along with *Sigillaria*, were large; but other lycopsids were herbaceous and even viney



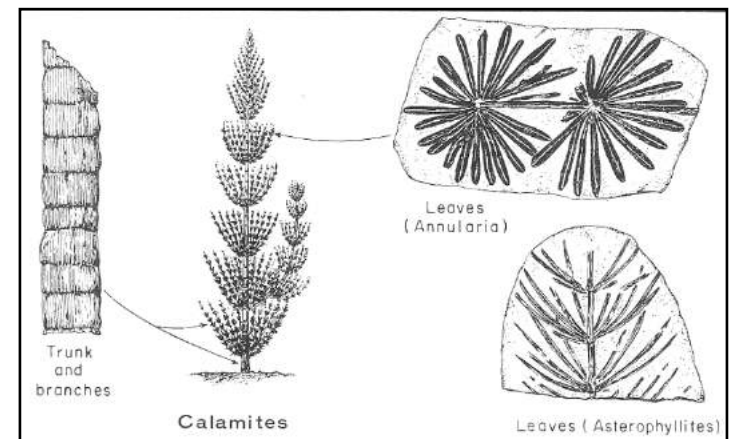
Extinct Land Plants - the Fossil Record

Carboniferous Period (360 - 286 mya)

Calamites was the dominant large tree-like horsetail (sphenopsid); but other smaller horsetails covered the ground



Annularia

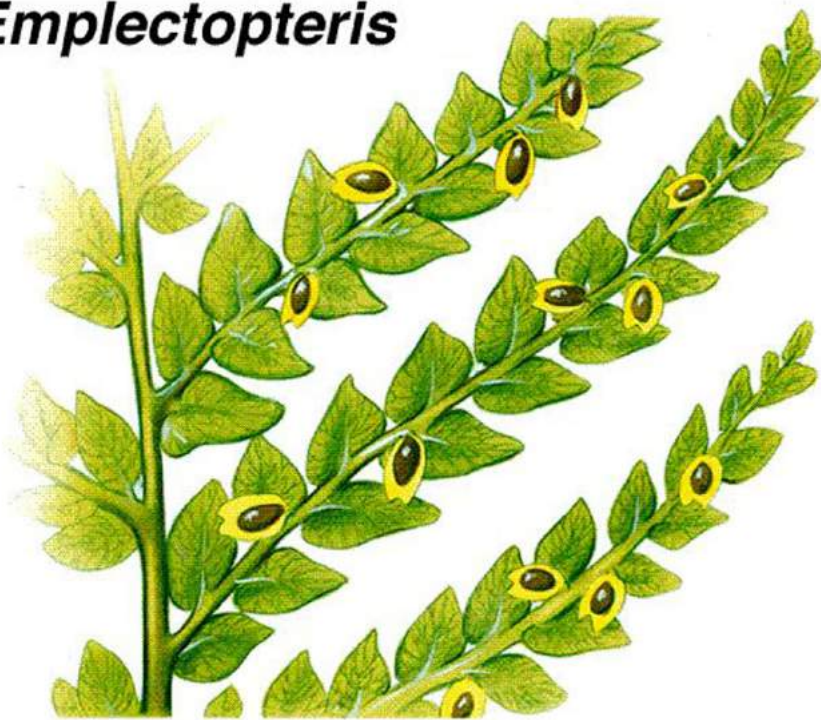


Extinct Land Plants - the Fossil Record

Carboniferous Period (360 - 286 mya)

“Seed ferns” continue to diversify

Emplectopteris



Seed fern fossils - 320 mya

Extinct Land Plants - the Fossil Record



Medullosa

Carboniferous Period (360 - 286 mya)

“Seed ferns” continue to diversify

First indication of **insect pollination** -
insect movement of male pollen
(microgametophyte) to egg in female
gametophyte in *Medullosa*



Seed fern fossils - 320 mya

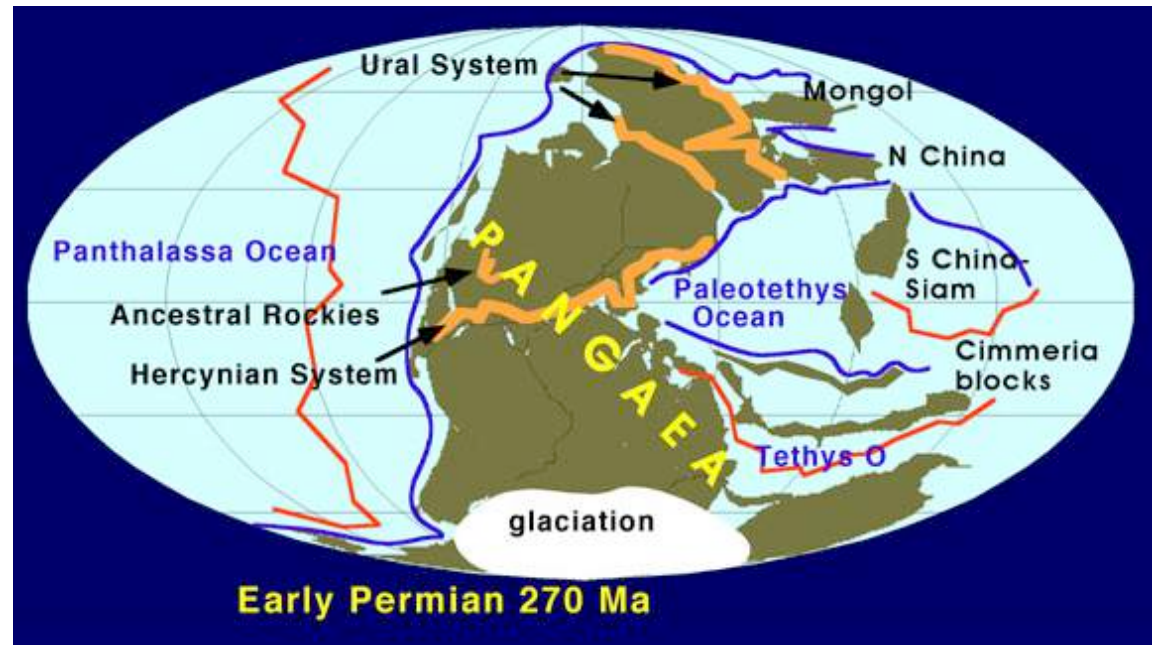
Extinct Land Plants - the Fossil Record



Permian Period (286 - 245 mya)

At the end of the Paleozoic, **Pangaea** begins to coalesce

Tethys Sea forms and allows for provincial floras to develop

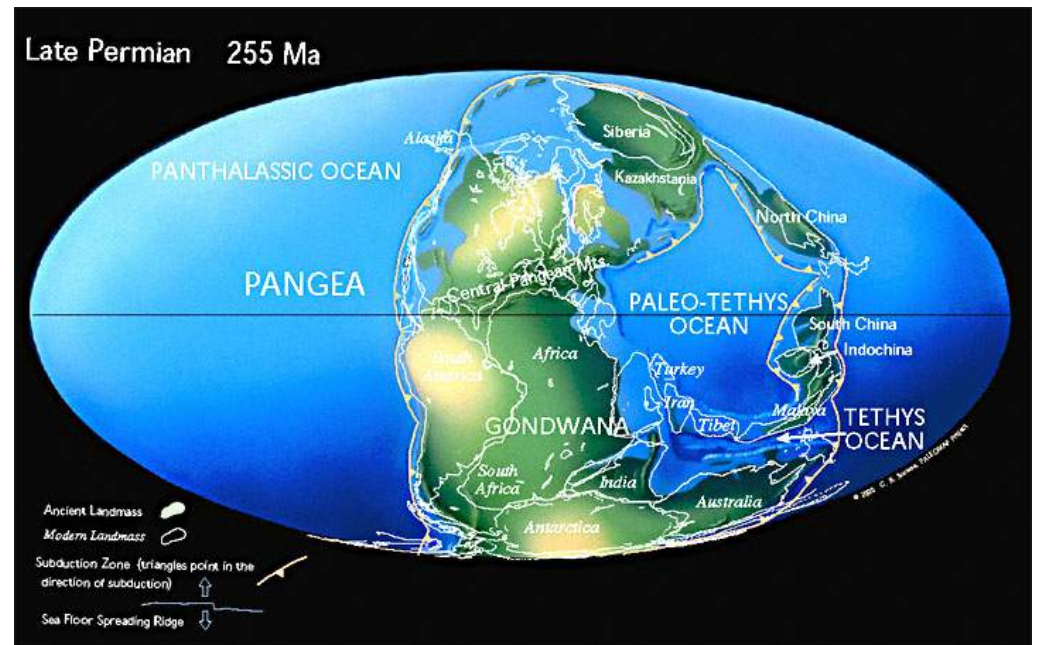
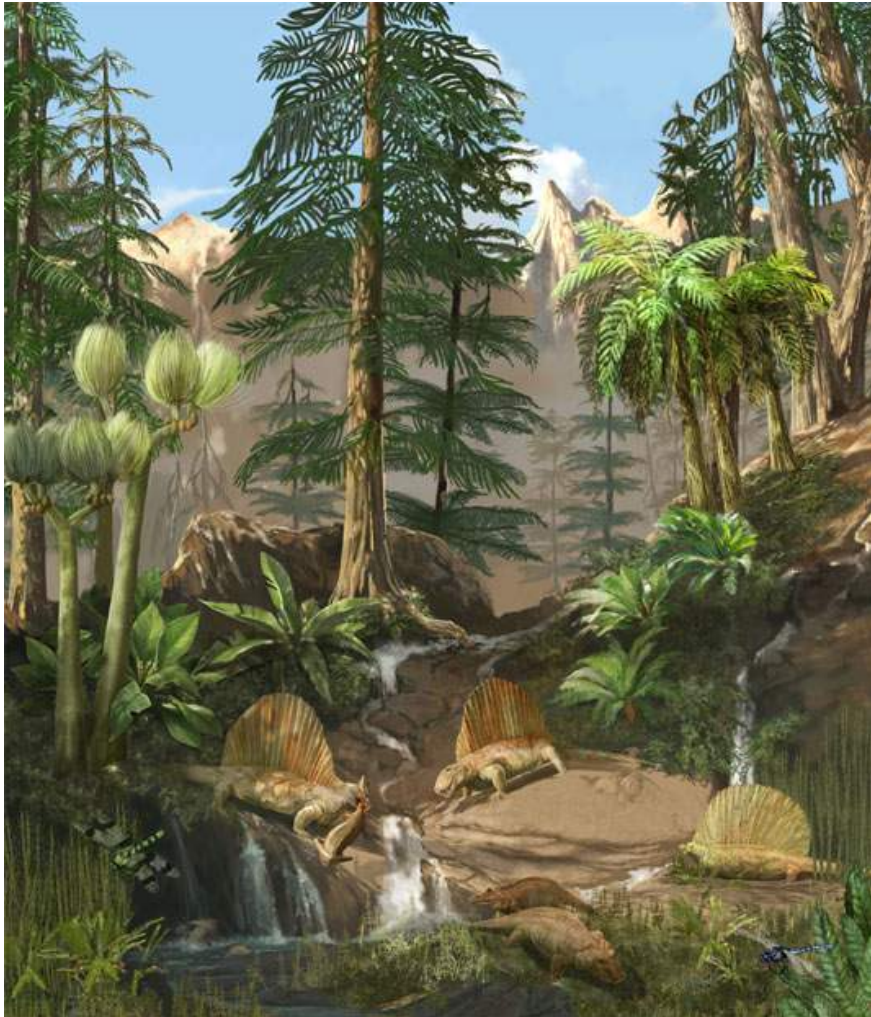


Extinct Land Plants - the Fossil Record

Permian Period (286 - 245 mya)

Herbivorous insects and reptiles diversify

Lycopods and sphenopsids still dominate, but true ferns, “seed ferns”, ginkgophytes, cycadophytes, and cone bearing gymnosperms begin to replace them



Extinct Land Plants - the Fossil Record

Cathaysia (equatorial)

- Rich, rain-forest
- Seed ferns, lycopsids, sphenopsids

Angaran (Northern Hemisphere)

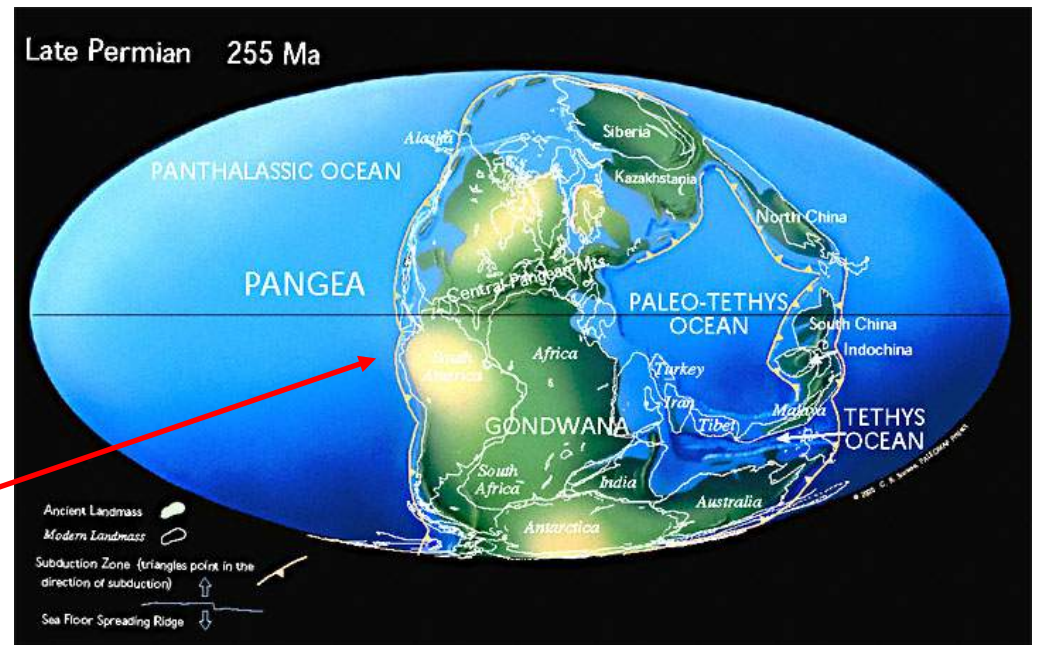
- *Cordaite* conifers
- Northern hemisphere mainly

Continentality - mid continent aridity first seen



Permian Period (286 - 245 mya)

3 provincial floras develop in response to continentality and still separated land masses

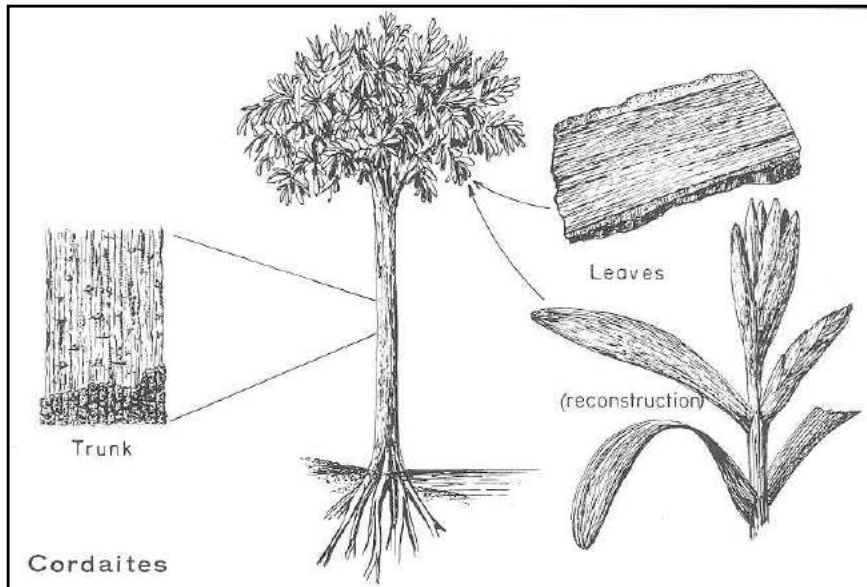


Extinct Land Plants - the Fossil Record

Permian Period (286 - 245 mya)

Possible forerunners to modern conifers beginning to be seen with fossils such as *Cordaite*s with cones

Fossilized trunks common around *Welwitschia* sites in the Namib Desert region



Extinct Land Plants - the Fossil Record



Permian Period (286 - 245 mya)

Delnortea abbottii – large seed ferns from the oil rich shales of central Texas [collected in Abilene State Park]



Extinct Land Plants - the Fossil Record

Cathaysia (equatorial)

- Rich, rain-forest
- Seed ferns, lycopsids, sphenopsids

Angarar (Northern Hemisphere)

- *Cordaite* conifers
- Northern hemisphere mainly

Gondwana (Southern Hemisphere)

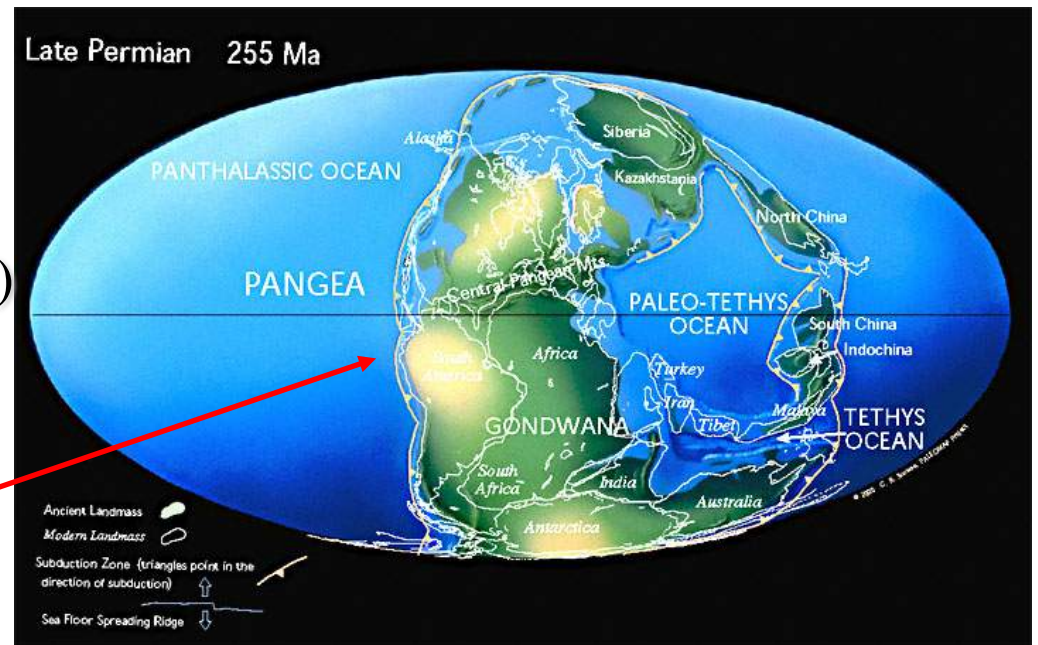
- Glossopterids

Continentality - mid continent aridity first seen



Permian Period (286 - 245 mya)

3 provincial floras develop in response to continentality and still separated land masses



Extinct Land Plants - the Fossil Record

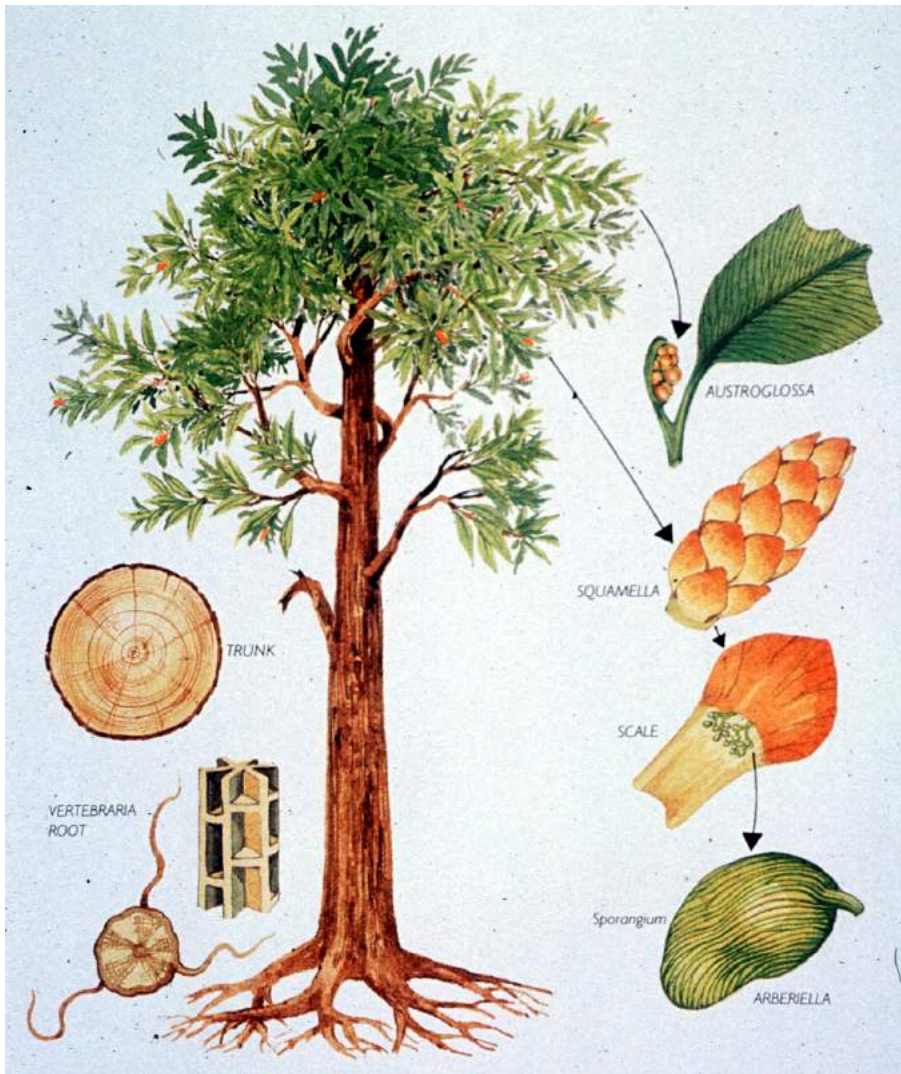
Permian Period (286 - 245 mya)

South of the tropical flora dominated by lycopsids, sphenopsids, and seed ferns existed the **Glossopterid** flora

- Big trees with net-veined leaves
- **Seed** bearing (derived from female gametophyte) and **pollen** forming (from male gametophyte)

Biogeographically ties together flora of Gondwana

“Gond” = site in India where Glossopterid fossils first seen
“Gondwana” = “land of Gond”



Extinct Land Plants - the Fossil Record

Permian Period (286 - 245 mya)

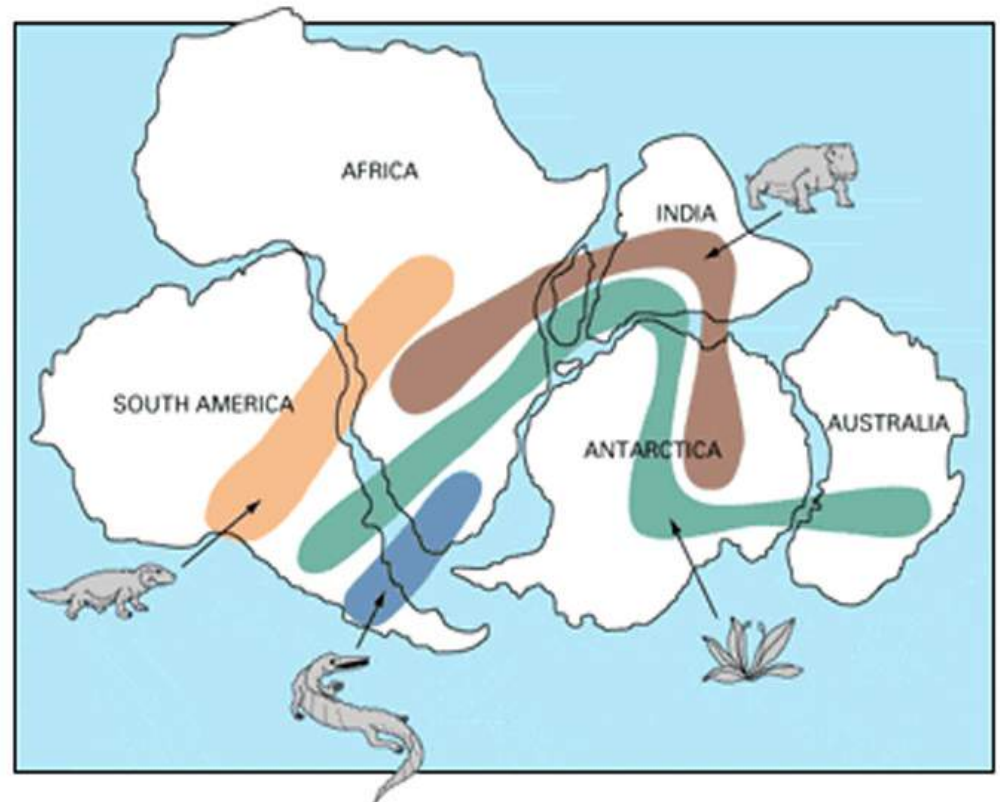
Remember! Wegener described both plant and animal fossil examples supporting his theory — he believed that this biogeographic data was the strongest evidence for his theory

Glossopteris - Permian seed plants

Mesosaurus - Permian freshwater reptile

Cynognathus - Triassic land reptile

Lystrosaurus - Triassic land reptile



Extinct Land Plants - the Fossil Record

End of the Paleozoic Era (245 mya)

By the end of Permian and the Paleozoic Era, land life had seen:

- terrestrial green algae
- Bryophytes
- early non-vascular and vascular lineages
- Lycopodiophyta
- Pteridophytes (ferns and allies)
- Progymnosperms (free sporing)
- Early seed plants including Glossopterids, seed ferns, conifers, cycadophytes, ginkgophytes

