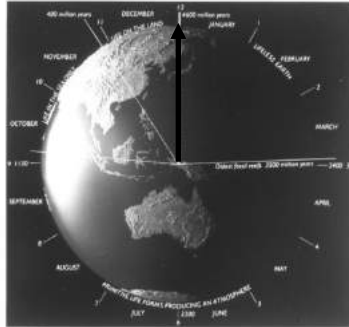


Paleo-biogeography

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

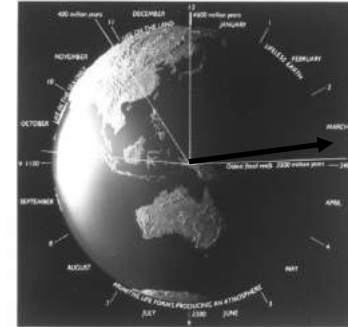


Age of the earth = 1 calendar year
4.6 billion years = 365 days

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

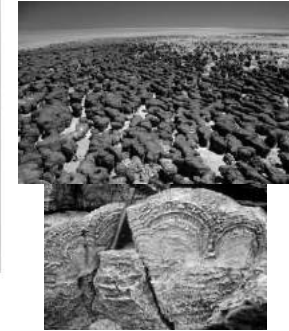
Earth forms at 4.6 bya
= January 1, 12:00 a.m.

Earth Time



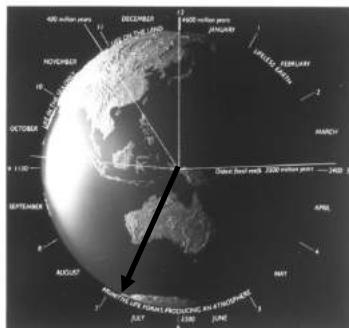
Age of the earth = 1 calendar year
4.6 billion years = 365 days

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



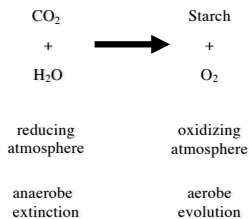
Stromatolites - CaCO_3 ppt by cyanobacteria
= photosynthesis!

Earth Time

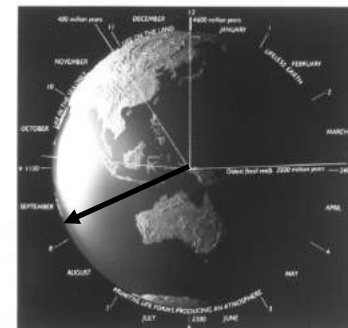


Age of the earth = 1 calendar year
4.6 billion years = 365 days

O_2 accumulates in atmosphere -
2.0 bya
= late July (>1/2 of earth time)

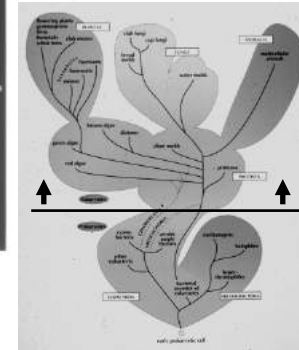


Earth Time

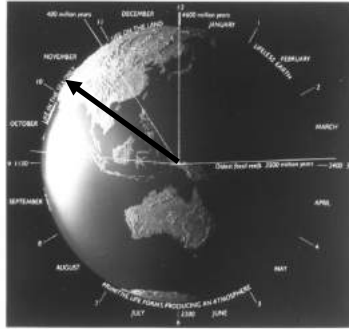


Age of the earth = 1 calendar year
4.6 billion years = 365 days

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



Earth Time



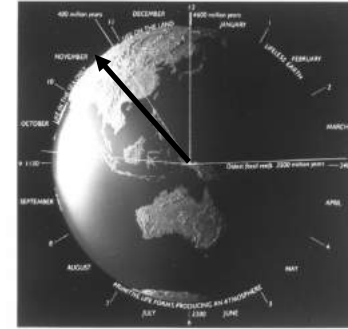
Age of the earth = 1 calendar year
4.6 billion years = 365 days

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



Burgess Shale

Earth Time



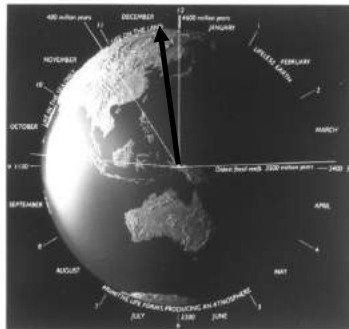
Age of the earth = 1 calendar year
4.6 billion years = 365 days

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



Spore Tetrad

Earth Time

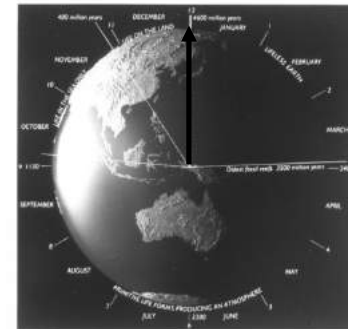


Age of the earth = 1 calendar year
4.6 billion years = 365 days

First flowering plant - 127 mya =
December 22



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

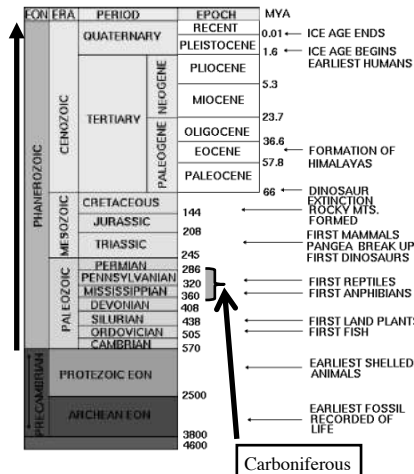


Periods will be the important part of the geological time scale to reference changes in vegetation, flora, fauna

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

Extant Land Plants



"bryophytes"
mosses



Lycopodiophyta
club mosses



Pinophyta
gymnosperms



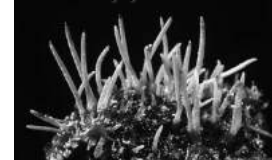
Polypodiophyta
ferns and horsetails



Magnoliophyta
angiosperms

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



spikemoss

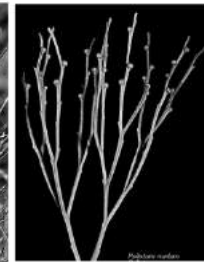


quillwort

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

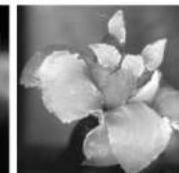


ginkgo

Extant Land Plants



Amborella male flower



Amborella female flower



Fruits



Water Lily (*Nymphaea odorata*)

Magnoliophyta - angiosperms, flowering plants

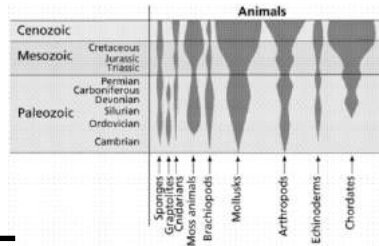
- 275,000 – 400,000 species
- tremendous adaptive radiation on land
- seed plants with seeds encased in ovary

Extinct Land Plants - the Fossil Record



Cambrian Period (540 - 505 mya)

- most phyla of animals seen except chordates – all marine

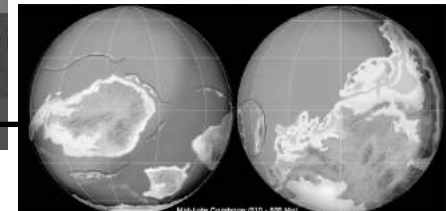


Extinct Land Plants - the Fossil Record

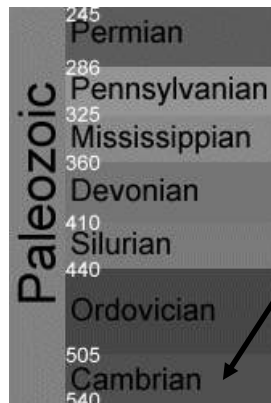


Cambrian Period (540 - 505 mya)

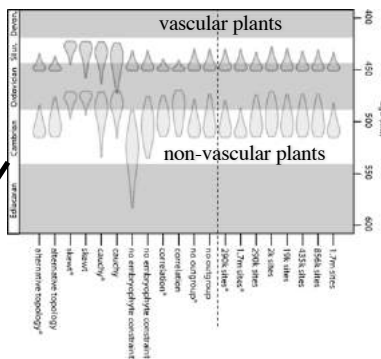
- most phyla of animals seen except chordates – all marine
- lime secreting algae in marine water
- fungi diversifying (starting at about 600 mya)
- no life on land!



Extinct Land Plants - the Fossil Record



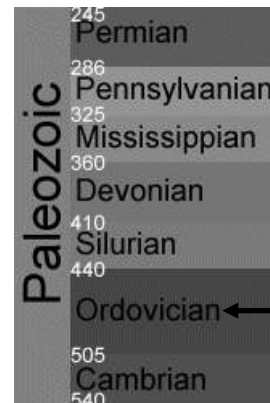
Cambrian Period (540 - 505 mya)



- molecular clock - life on land!

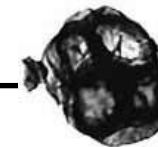
Morris et al. 2018. The timescale of early land plant evolution. Proc Natl Acad Sci USA.

Extinct Land Plants - the Fossil Record



Ordovician Period (505 - 440 mya)

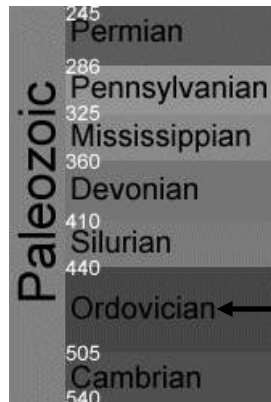
- jawed fish diversifying in oceans
- complex green algae in marine water
- First evidence of land life at 460 mya



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

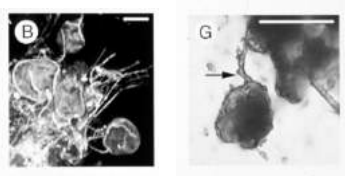
Found worldwide in shales that were deposited at the marine-terrestrial interface

Extinct Land Plants - the Fossil Record



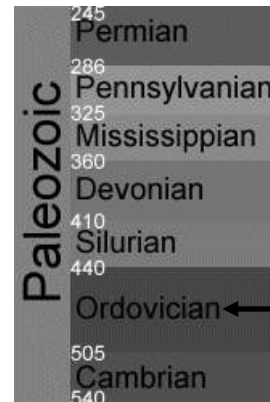
Ordovician Period (505 - 440 mya)

- Other evidence of land life



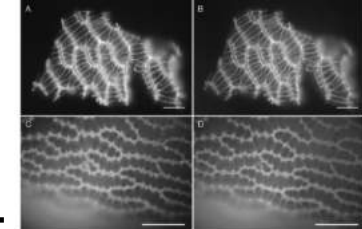
Glomales fungi seen in 460 my Wisconsin rock. Glomales today form important arbuscular mycorrhizal associations with some liverworts and hornworts and many vascular plants. Symbiosis!

Extinct Land Plants - the Fossil Record



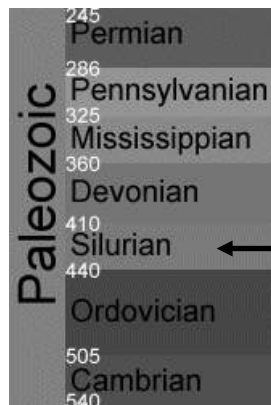
Ordovician Period (505 - 440 mya)

- Other evidence of land life



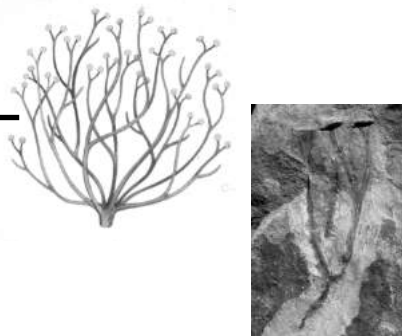
"Sphagnum" moss seen in 455 my Wisconsin rock - 2nd diverging lineage of bryophytes

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

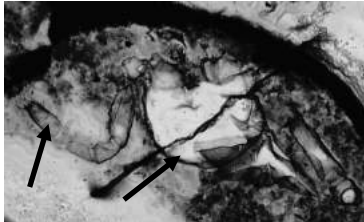


Silurian view

Silurian Period (440 - 410 mya)

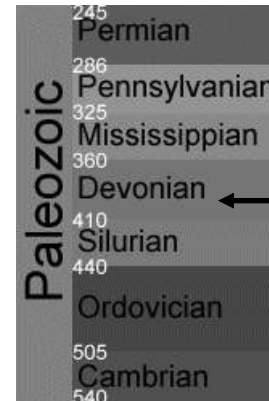
Late Silurian is also the first occurrence of land animals - arachnids, centipedes

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



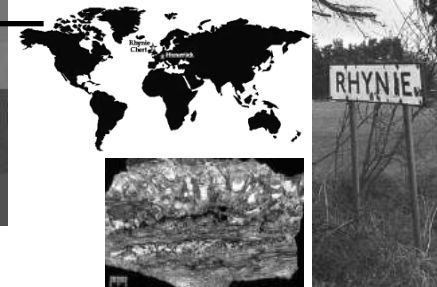
Trigonotarbid Spider in chert

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)



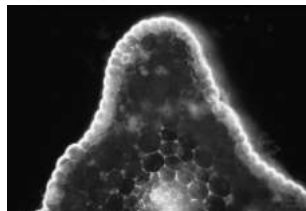
Extinct Land Plants - the Fossil Record

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

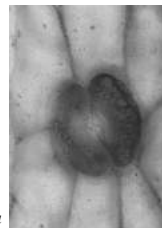
Early Devonian Period (410 - 390 mya)

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



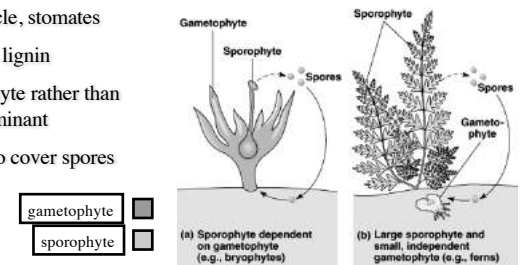
Extinct Land Plants - the Fossil Record

- 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:



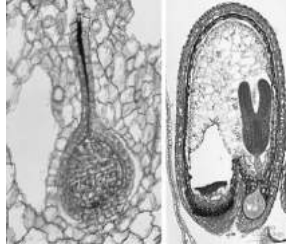
Extinct Land Plants - the Fossil Record

- 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

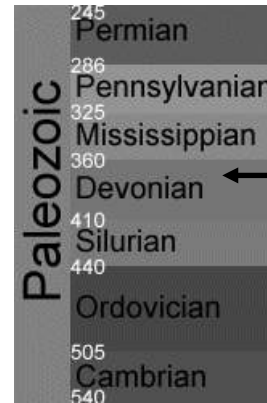
Early Devonian Period (410 - 390 mya)

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



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

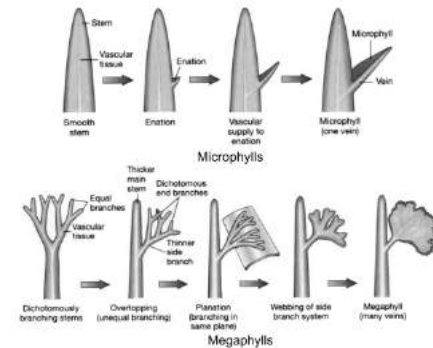
Extinct Land Plants - the Fossil Record



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



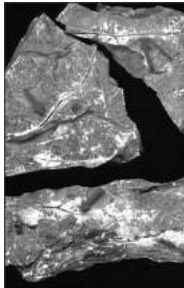
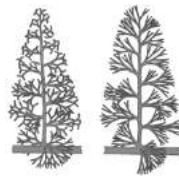
Extinct Land Plants - the Fossil Record

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



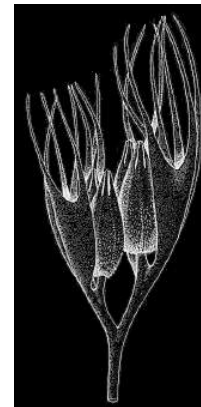
Gillespiea

Extinct Land Plants - the Fossil Record

Late Devonian Period (390 - 360 mya)

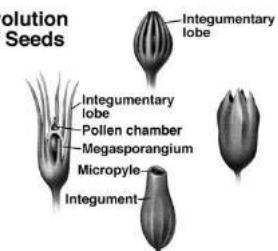
First "seeds" - "seed fern" lineage

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



Archaeosperma

Evolution of Seeds



Extinct Land Plants - the Fossil Record



Ichthyostega

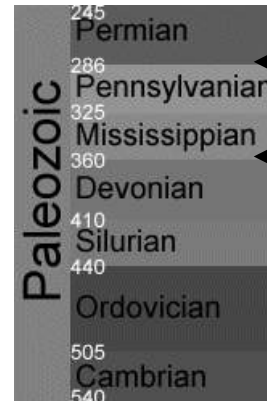
Late Devonian Period (390 - 360 mya)

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



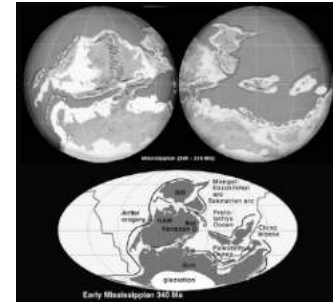
Hynerpeton

Extinct Land Plants - the Fossil Record



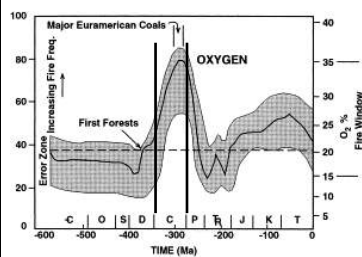
Carboniferous Period (360 - 286 mya)

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

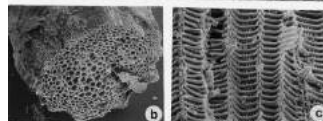


Extinct Land Plants - the Fossil Record

Carboniferous Period (360 - 286 mya)



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



Lower Carboniferous lycopod 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

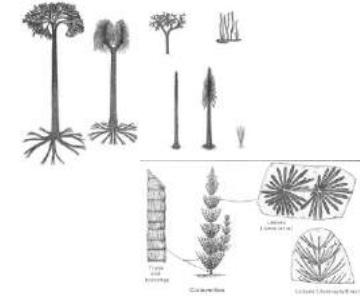
Hylonomus, primitive reptile, leaping after an insect in a coal swamp of Nova Scotia



Extinct Land Plants - the Fossil Record

Carboniferous Period (360 - 286 mya)

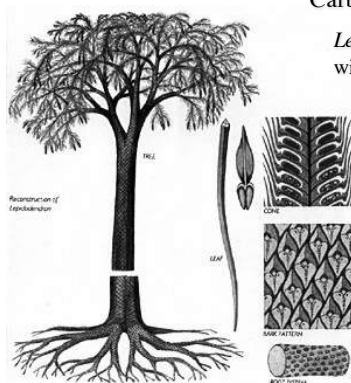
The tropical equatorial coal swamps were dominated by a diversity of lycopsids (lycopod lineage) and horsetails (fern lineage)



Extinct Land Plants - the Fossil Record

Carboniferous Period (360 - 286 mya)

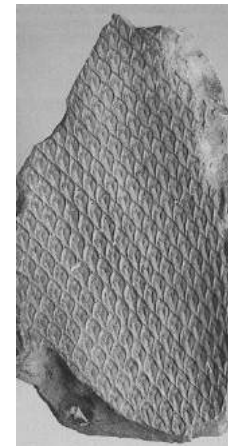
Lepidodendron (lycopod) was 30 m tall with 1 meter long “microphyll” leaves



Extinct Land Plants - the Fossil Record

Carboniferous Period (360 - 286 mya)

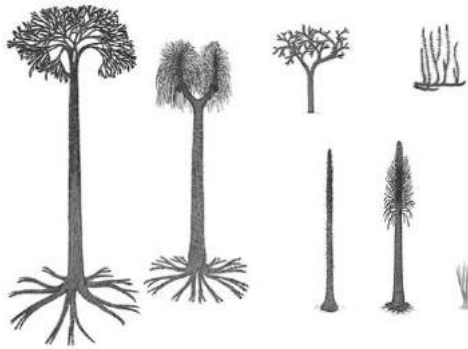
The scaly bark of *Lepidodendron* is distinctive as a fossil



Extinct Land Plants - the Fossil Record

Carboniferous Period (360 - 286 mya)

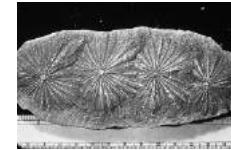
Lepidodendron, along with *Sigillaria*, were large; but other lycopsids were herbaceous and even viney



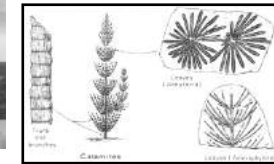
Extinct Land Plants - the Fossil Record

Carboniferous Period (360 - 286 mya)

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



Annularia

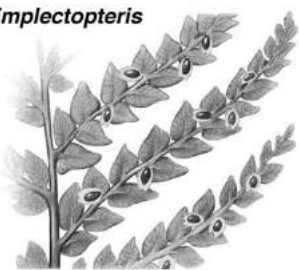


Extinct Land Plants - the Fossil Record

Carboniferous Period (360 - 286 mya)

"Seed ferns" continue to diversify

Emplectopteris



Seed fern fossils - 320 mya

Extinct Land Plants - the Fossil Record

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*



Medullosa



Seed fern fossils - 320 mya

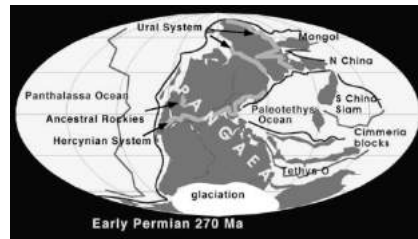
Extinct Land Plants - the Fossil Record



Permian Period (286 - 245 mya)

At the end of the Paleozoic, Pangaea begins to coalesce

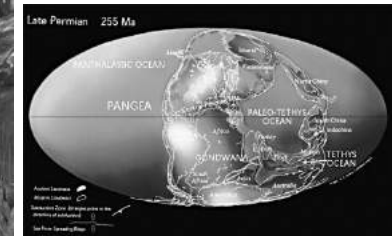
Tethys Sea forms and allows for provincial floras to develop



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

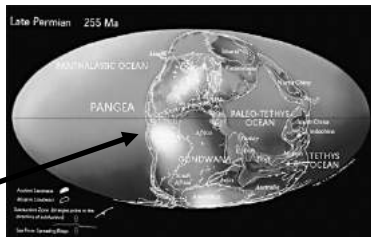
Angarar (Northern Hemisphere)

- *Cordaites* conifers
- Northern hemisphere mainly

Permian Period (286 - 245 mya)

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

Continental - mid continent aridity first seen

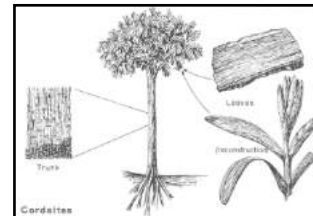


Extinct Land Plants - the Fossil Record

Permian Period (286 - 245 mya)

Possible forerunners to modern conifers beginning to be seen with fossils such as *Cordaites* 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)

- *Cordaites* conifers
- Northern hemisphere mainly

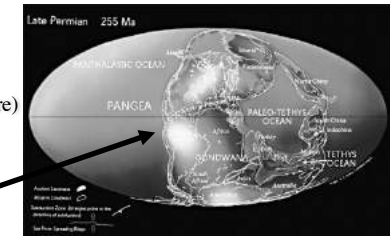
Gondwana (Southern Hemisphere)

- 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

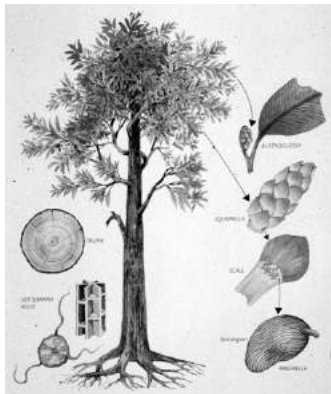
Permian Period (286 - 245 mya)

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)

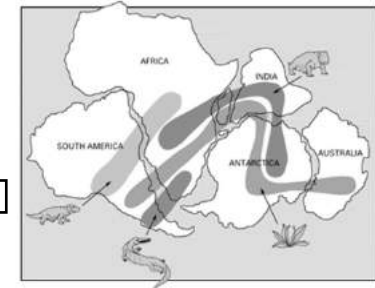
Remember! Wegener described both plant and animal fossil examples supporting his theory — he believed that this biogeographic data was the strongest evidence for his theory

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

