BACK = Biodiversity Assessment in the Carboniferous using Kohle - Kugeln (coal balls)

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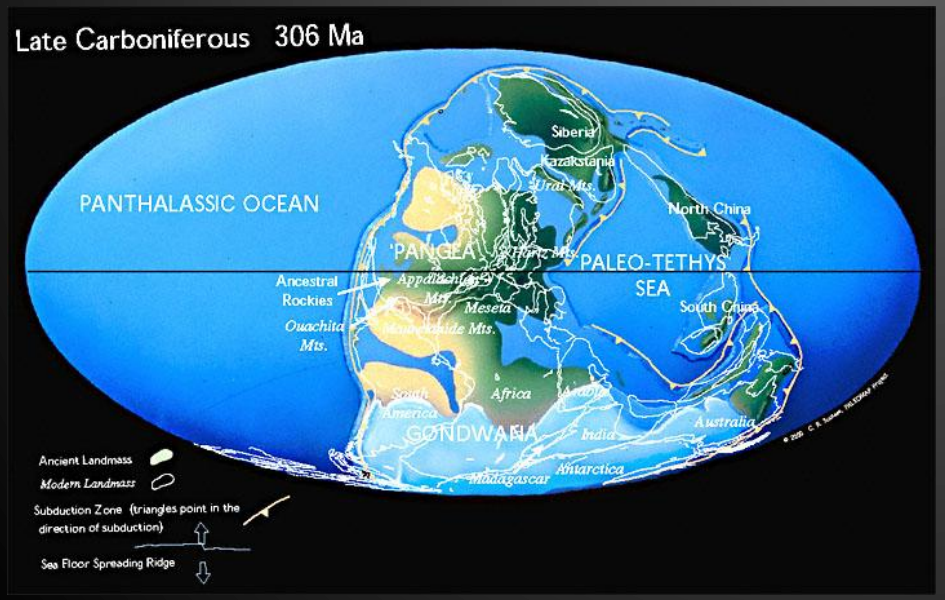
Carboniferous Period

http://taggart.glg.msu.edu/isb200/carbfor.htm



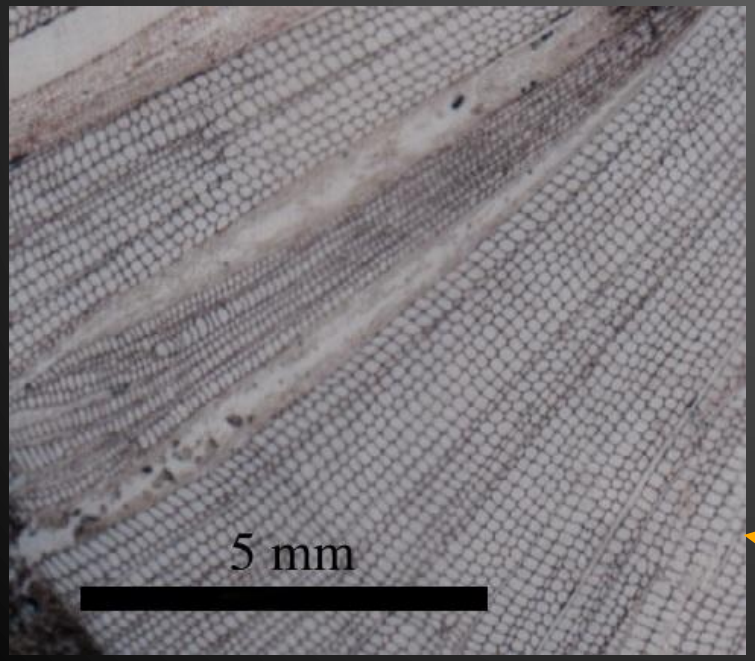
http://www.scotese.com/late.htm

- 359 to 299 Ma
- Much of the historically important coal formed during this age
- Huge insects, advent of the first reptiles
- Glaciation in the polar regions- but wet coal swamps in tropical regions

Q. How do we know about plants of this age?

Coal Ball

- Exceptionally well preserved organic matters through permineralization



- Original plant structures are preserved

Even cell walls!

Observation of the coal balls allows students to think about:

1) What is biodiversity?

2) How much of the world's ancient flora could we expect to understand from examining coal balls?

3) How would we quantitatively assess biodiversity from coal-balls? How specific can we get?

4) Why have the fossil lineages changed so dramatically?

5) How has climate influenced these changes?

6) What uses are there for fossil plants or museum specimens?

How can we observe the microstructures of the coal balls?

Lesson plan

Lesson plan: Coal ball botany

Overview

In this activity, the student will learn about fossil plants contained in coal balls and how plants have responded to climate changes. It integrates the fields of botany, paleobotany, geology and ecology. The activity is scalable and parts could be used for a lab with a mini-lecture to introduce key concepts, while other more in-depth information could be presented in a longer lecture. Furthermore, the activity could be expanded into a term project for an advanced upper division course. The lesson plan follows the learning cycle of engagement, concept introduction, application, and assessment.

Objectives

Content & concepts

- learn what a coal ball fossil is
- prepare a coal ball peel
- identify fossil plants in the coal ball peel
- learn about climate change in the past and how it mirrors modern climate change events
- species diversity
- species richness
- sampling bias/ strategies
- museum records and databases
- plate tectonics
- evolutionary change

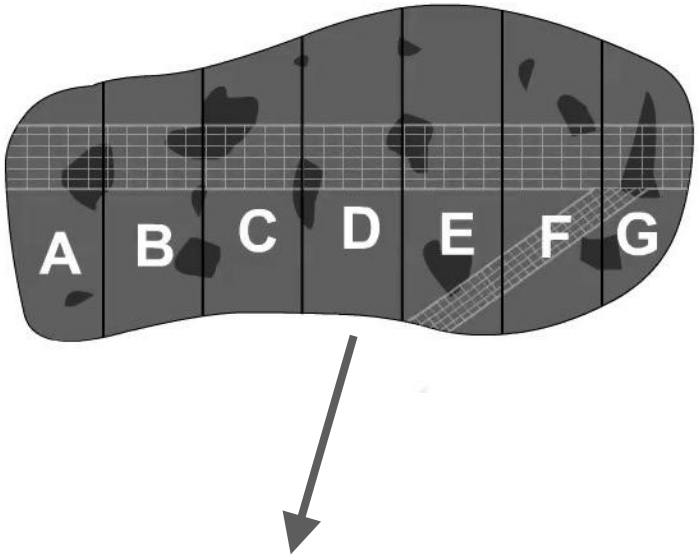
Skills

- Sampling design
- Identification/ familiarity with taxa commonly found in the coal swamp
- Create and manipulate spreadsheets
- Apply metrics and models to interpret data
- Hypothesis testing
- Critical evaluation of assumptions and biases in data collection and analysis
- Synthesize results & draw inferences
- Use of databases (Arctos, GBIF, Paleographic mapping service, etc.)

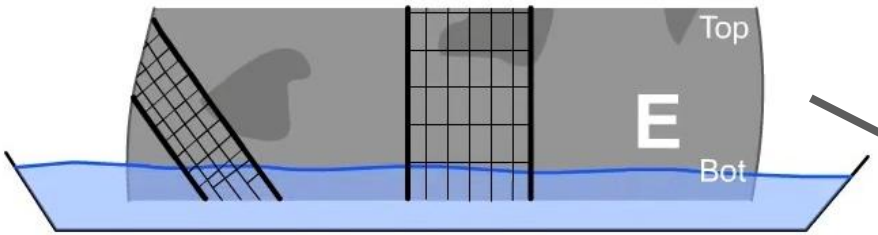
- provides background for teachers
- objectives, materials, protocol
- inquiry questions for students

The Coal Ball Acetate Peel Technique

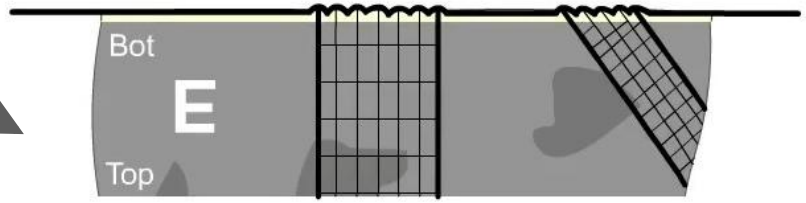
1. slice a coal ball



2. Soak in 5% HCl

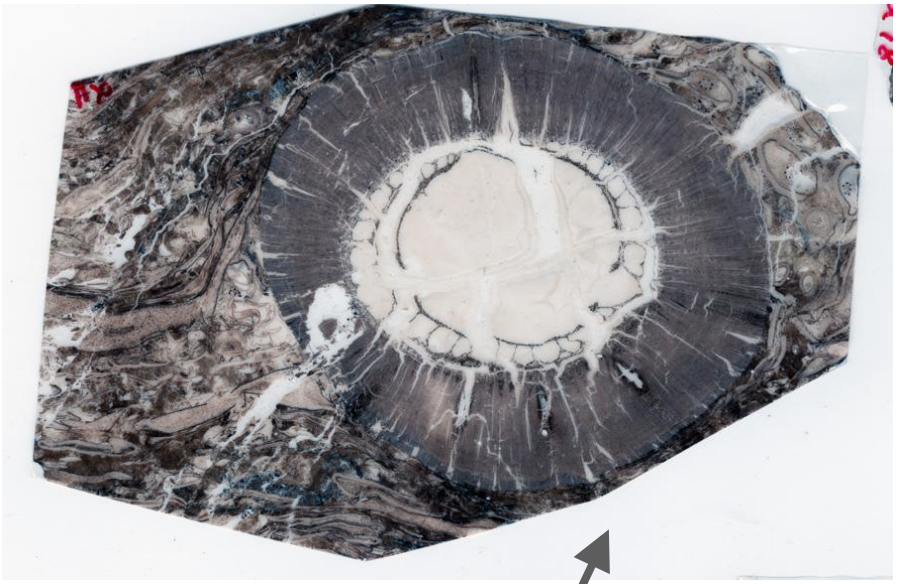


rotate



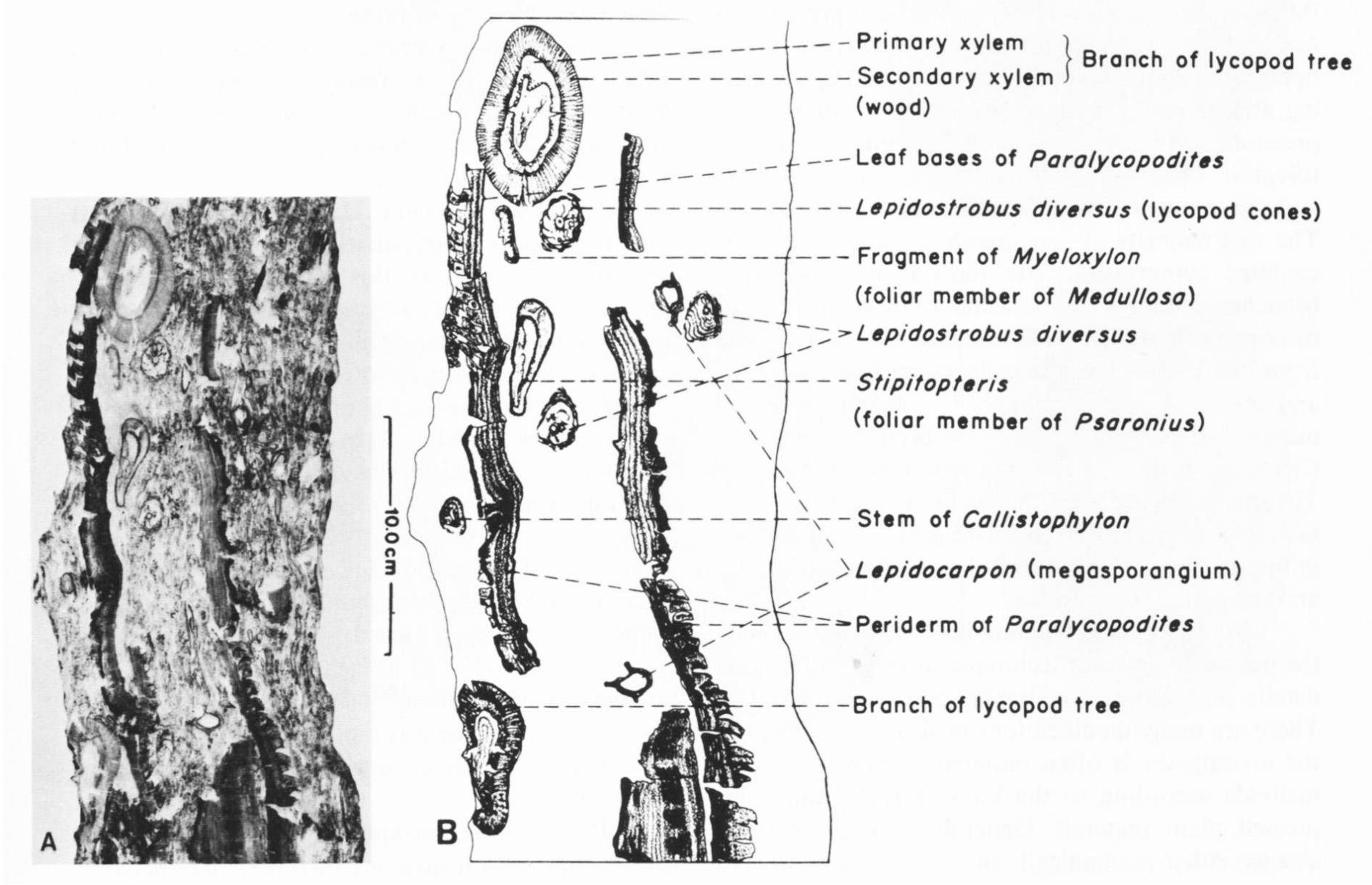
3. Flood with acetone, overlay an acetate sheet

4. Peel



http://www.biology.ualberta.ca/facilities/multimedia/uploads/botany/peel1.swf

Example of Plant Composition of a Coal Ball



From Stewart, W.N. and G.W. Rothwell (1993)

Major Plants Groups in Coal Balls

Ferns, lycopods and horsetails:

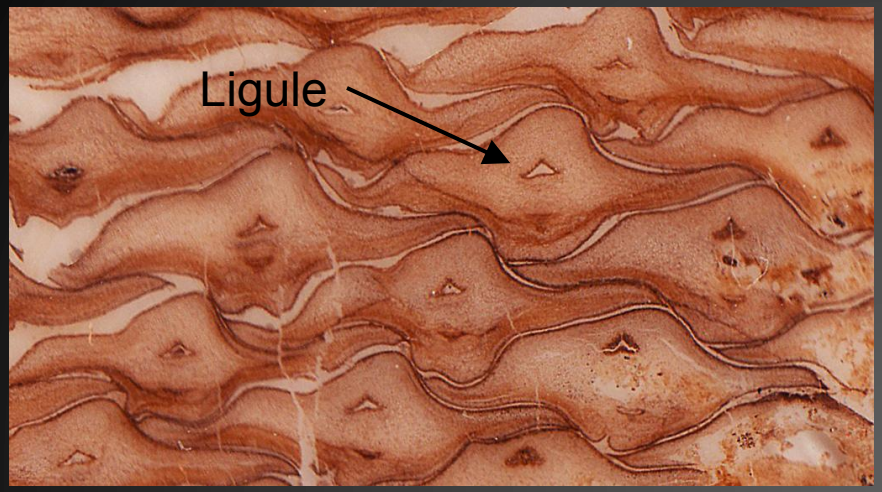
- Lycopods
- Horsetails
- Marattialean ferns
    - Leptosporangiate fern
- Progymnosperms

Seed plant lineages:

- Seed ferns
- Gymnosperms

Landscape of the peat swamp of the Springfield Coal (Middle Pennsylvanian: 300 million years ago)

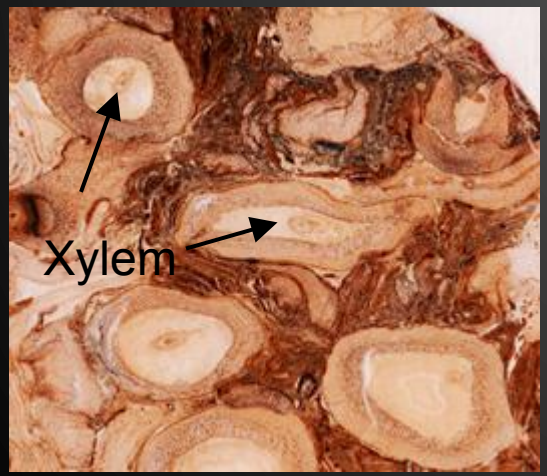
Lycopods



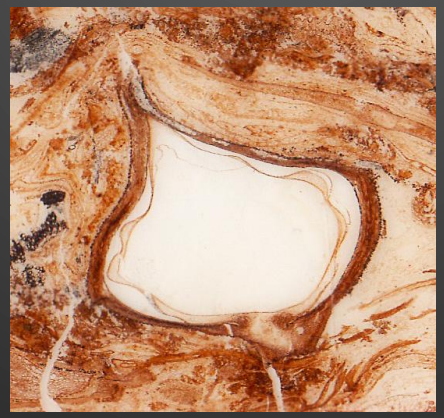
Lepidophloios leaf cushions, xs (Coal ball)

Lepidostrobus cone, xs (Coal ball)

Lycopodium venustulum, extant

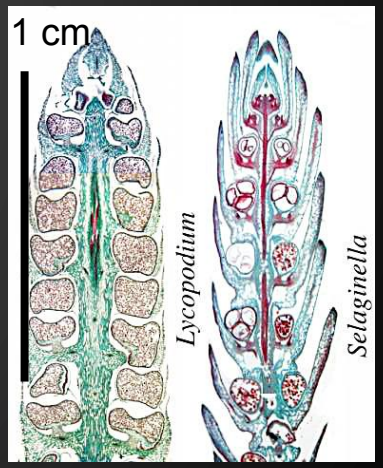


Stigmaria rootlets, xs (Coal ball)

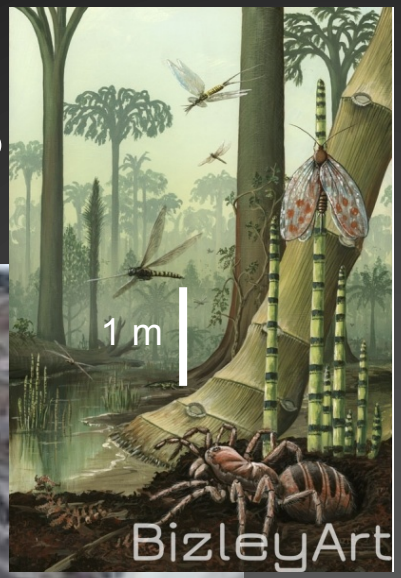


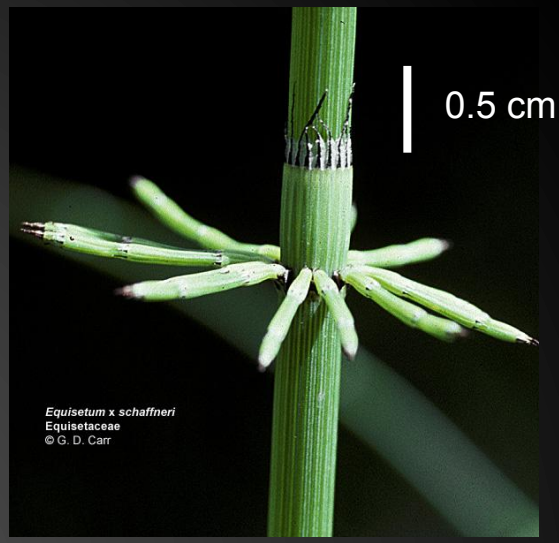
Lepidocarpon sporangium, xs (Coal ball)

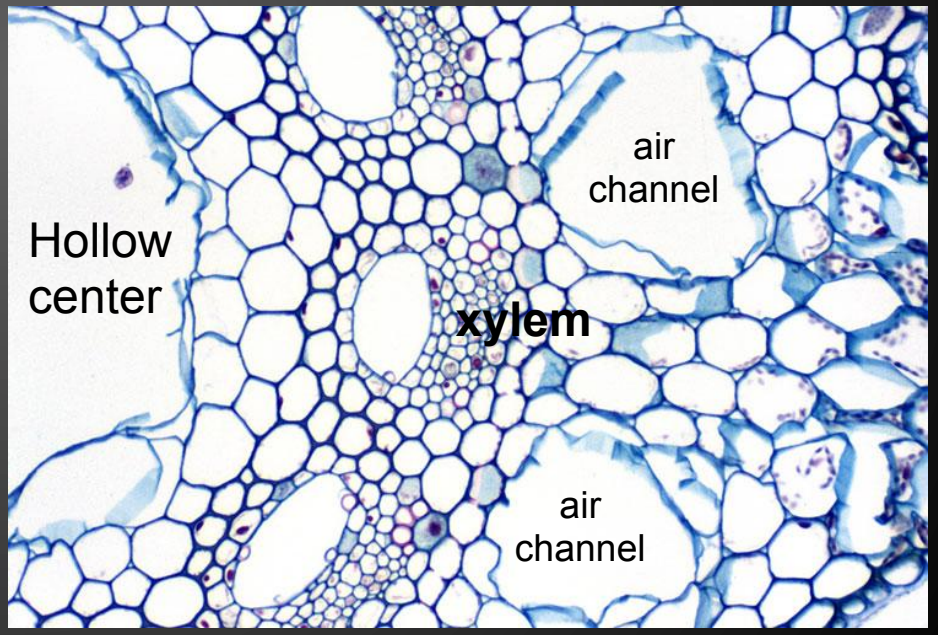
Lycopodium sporangium, xs (extant)



Horsetails





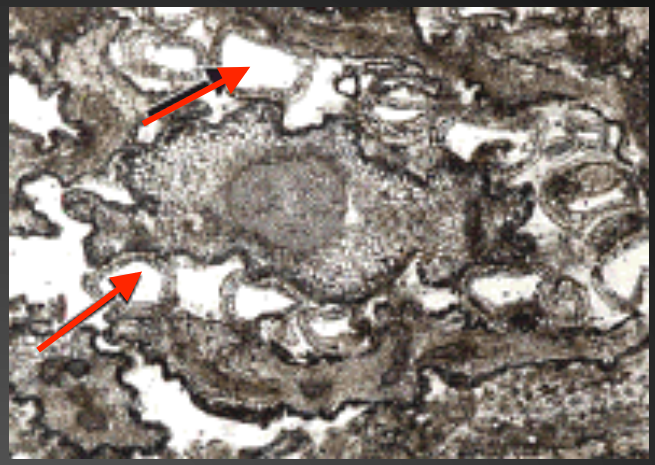


Calamites stem xs (Coal ball)

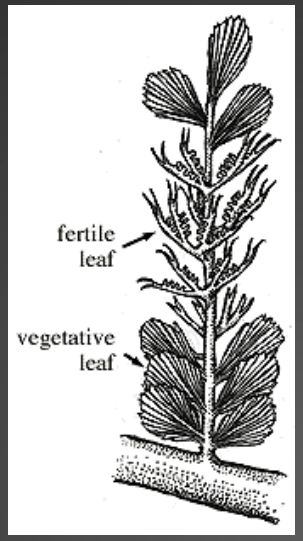
Extant *Equisetum* stem xs

Progymnosperms

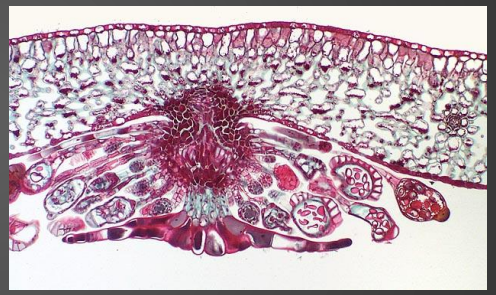
- *Callixylon*



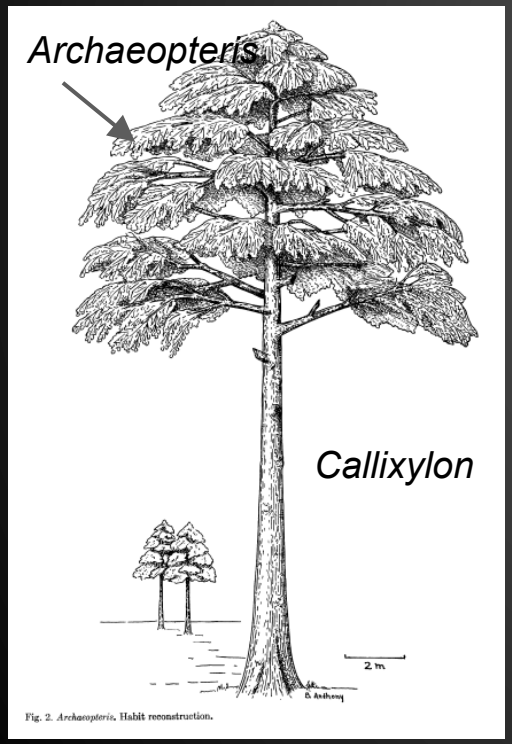
Cecropsis leaf xs, sporangia at arrows (Rothwell)



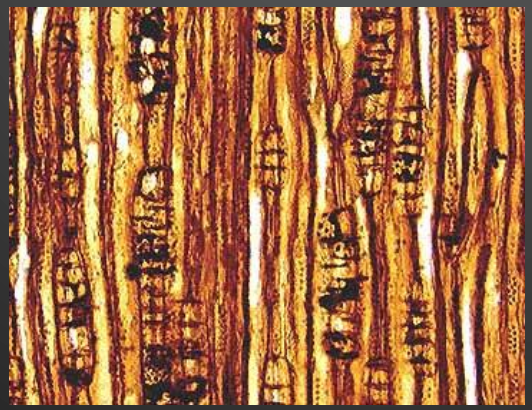
Archaeopteris



Fern leaf, xs with cluster of sporangia



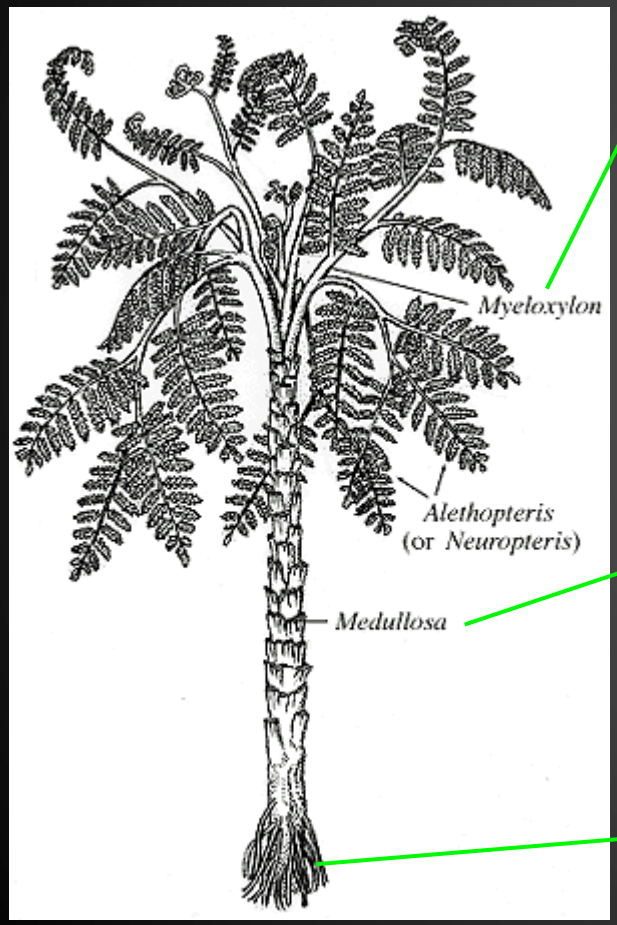
Archaeopteris
(from Beck 1962)



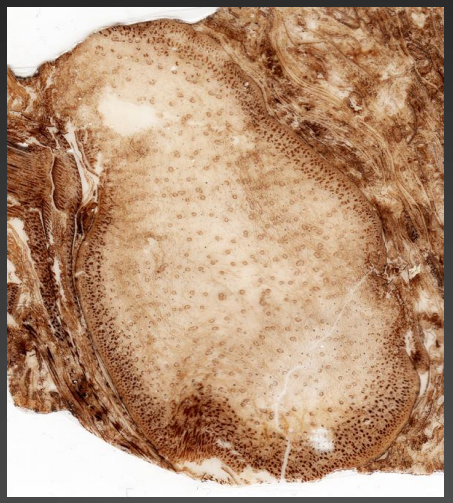
Callixylon wood, ls
http://www.ucmp.berkeley.edu

Pinus wood, ls
http://www.photographersdirect.com

Seed Ferns - *Medullosa*

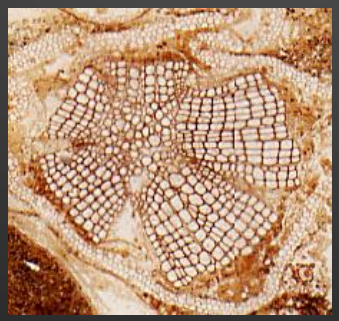


http://www.ucmp.berkeley.edu/IB181/VPL/MedCyc/MedCyc2.html



Myeloxylon petiole, xs

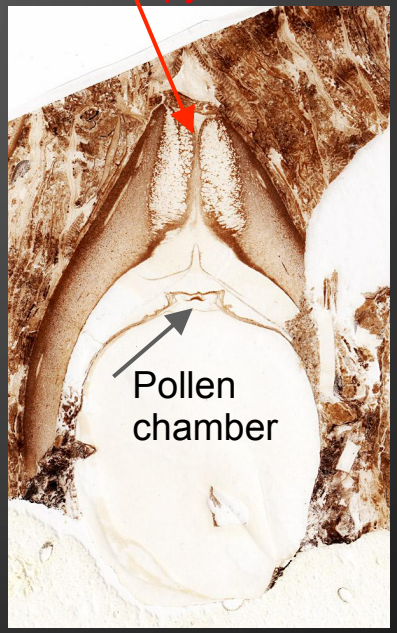
Medullosa stem, xs



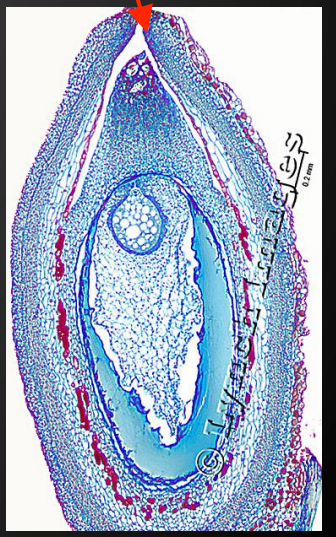
Medullosa root, xs

Extant relatives: Conifers

Pine



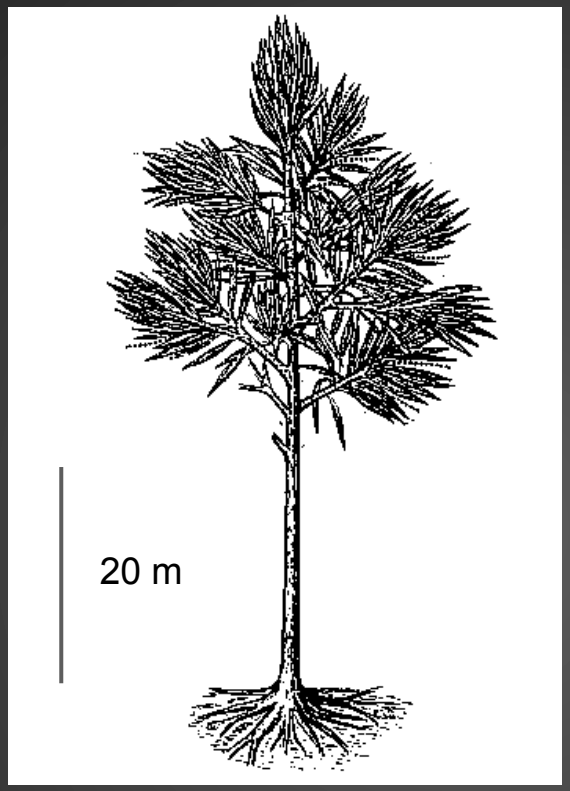
Pachytesta seed, ls



Pine ovule, ls

Gymnosperms - Cordaites

Cordaites stem, ls
pith septations



http://www.ucmp.berkeley.edu/seedplants/cordaitales/cordaites.gif

Extant conifer relative: Spruce

Cordaites stem, xs
pith septations

Stephanospermum fronds, Mazon Creek nodule, Field Museum

Mitrospermum, cordaite seed, ls

Gymnosperm seed ls

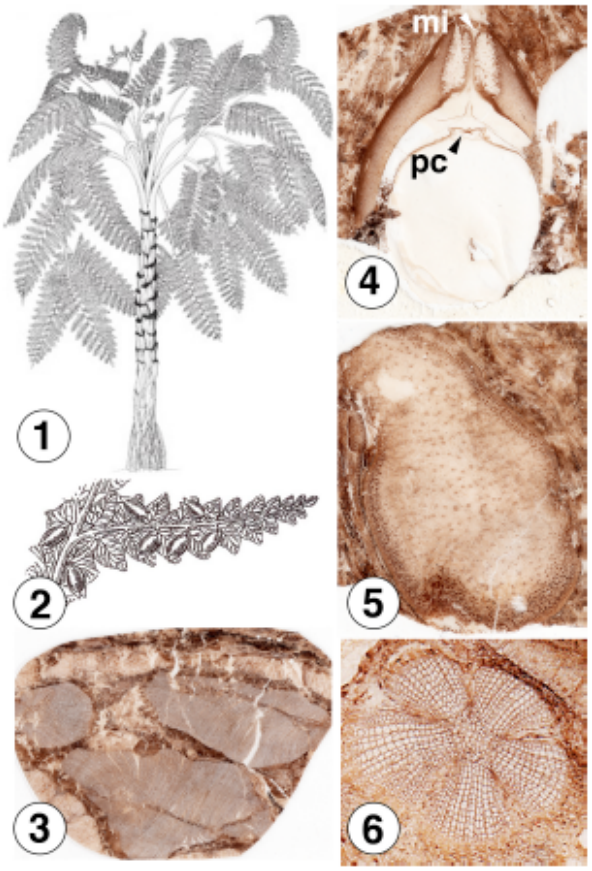
Field Guide

- includes description on general habit
- fossil and extant diversity
- illustrations of commonly found coal ball plant remains

Seed ferns (Pteridosperms)

Characteristics: The seed ferns were a group of seed-producing plants with large fronds that, superficially, resembled the leaves of ferns (hence their name!). The leaves of these plants were known prior to the discovery of their seed-bearing nature. In some species, the frond-like leaves could be more than 20 feet (7 m) in length. Trees have been found to be of two major growth forms: short, upright, free-standing forms, perhaps 15 feet (3 m) in height, and taller forms that were not self-supporting, but that formed tangles or thickets in which they leaned on one another and the large fronds were intertwined, lending support to the weak trunks.

Seed ferns were a diverse group of plants and so had many different kinds and sizes of reproductive organs. Their seeds ranged from small, perhaps the size of a modern "field pea", to quite large, roughly the size of, or even a little larger than, an avocado seed.



1. *Medullosa* whole plant reconstruction showing frond-like leaves, stem and roots (after Taylor & Taylor 199).

2. Fertile frond showing seeds of the *Pachytesta* type.

3. *Callixylon* stem cross-section showing multiple steeles with wood.

4. *Pachytesta* seed, longitudinal section. Showing micropyle (mi) and pollen chamber (pc). Typical of hydrasperman reproduction.

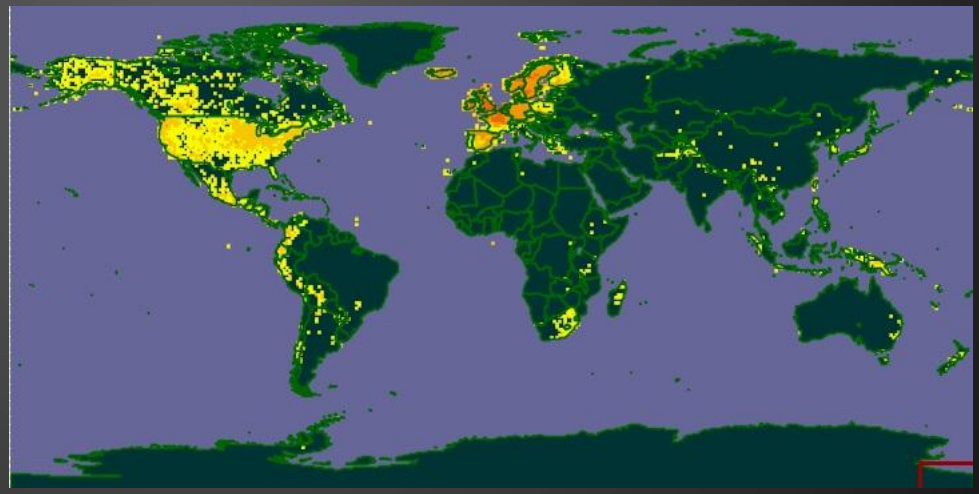
5. *Myeloxylon* cross section of petiole showing numerous scattered vascular bundles.

6. *Medullosa* root cross section.

Linking the Past with the Present

Using museum databases we can find images and distribution maps for extant plant lineages:

Equisetum

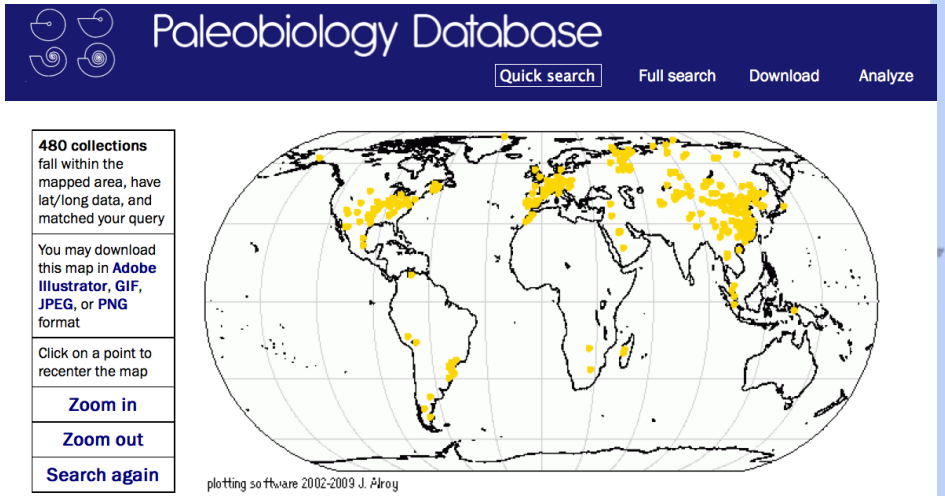


ARCTOS (http://arctos.database.museum)

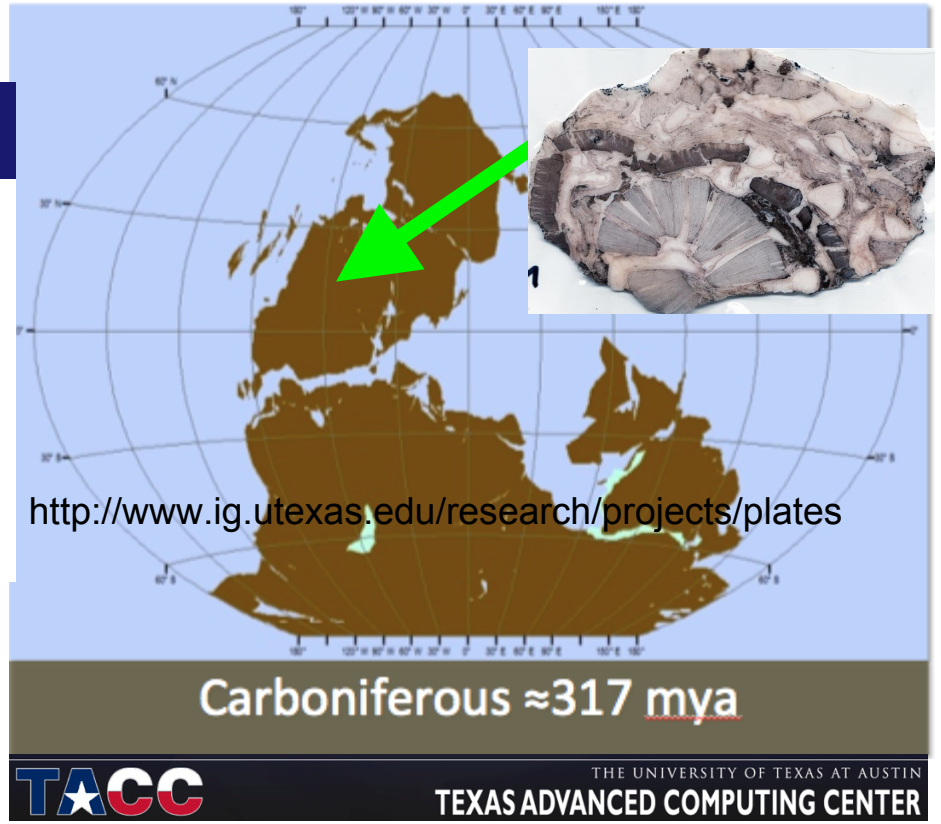
GBIF (http://www.gbif.org)

Linking the Past with the Present

1) **Fossil localities**
(*Pecopteris* - coal ball marratialean tree fern foliage)



2) **Where was it in the past?**



3) **Compare the distribution with extant species!** (*Angiopteris* - tree fern) from Arctos, GBIF

Linking the Past with the Present

Questions for students:

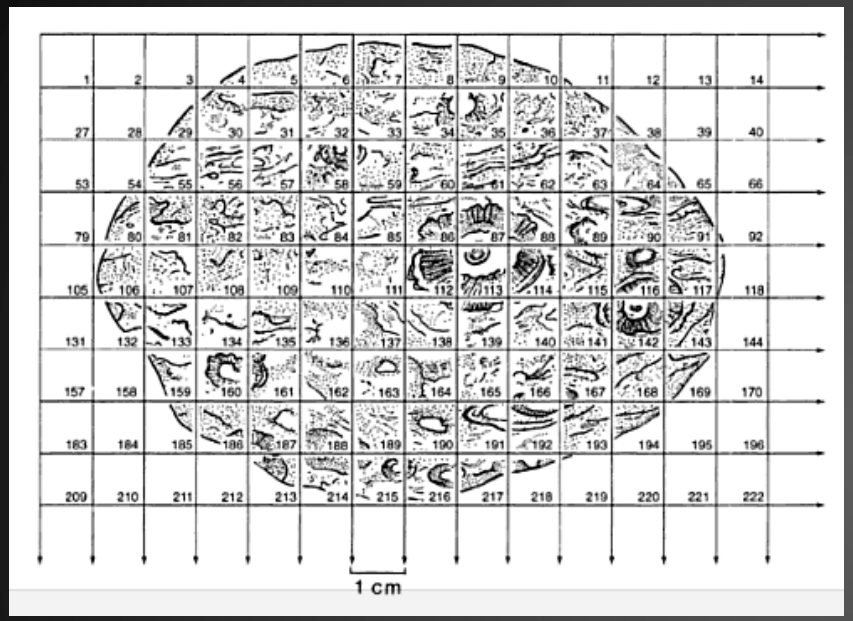
1) Where do the extant relatives of the fossilized species occur? Do they inhabit similar climates?

2) Do the extant relatives of fossilized species have the same distribution as the coal balls plants? Have they always been there (Inquiry-based question 1)?

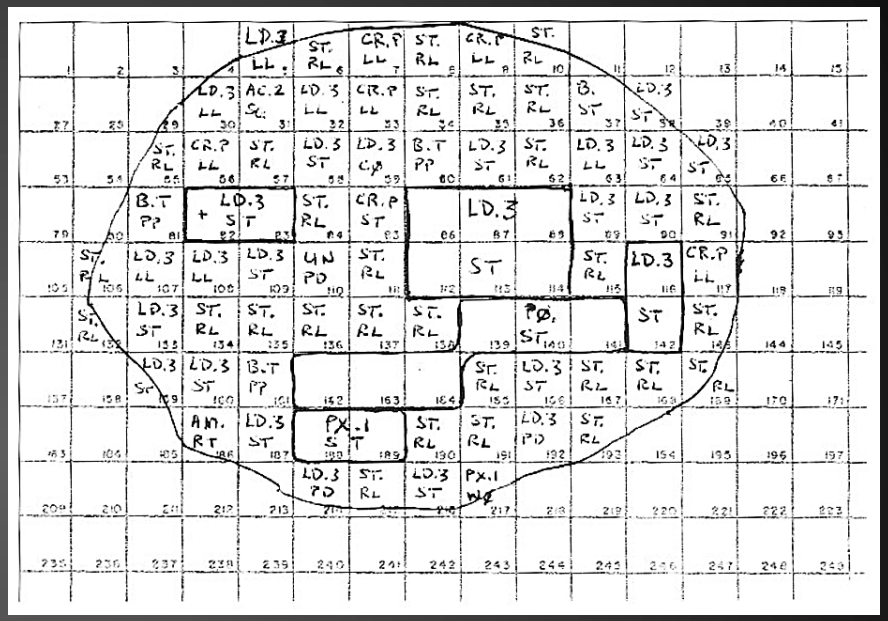
3) What changes can be documented between extant species and the fossilized taxa? Are they similar in size?

4) How would you compare species abundance measurements from coal balls with the abundance of extant plant species (Inquiry-based question 2)?

Quantitative Analysis



Schematic of coal ball overlain by counting grid (From Philipps & DiMichele 1999)



Grid sheet of peel with two letter code for taxa followed by organ types (root vs. stems biomass, lineage comparison)

Standard Exploratory Ecological Analyses:

(1) Dominance - diversity analysis

(2) Multivariate ordination

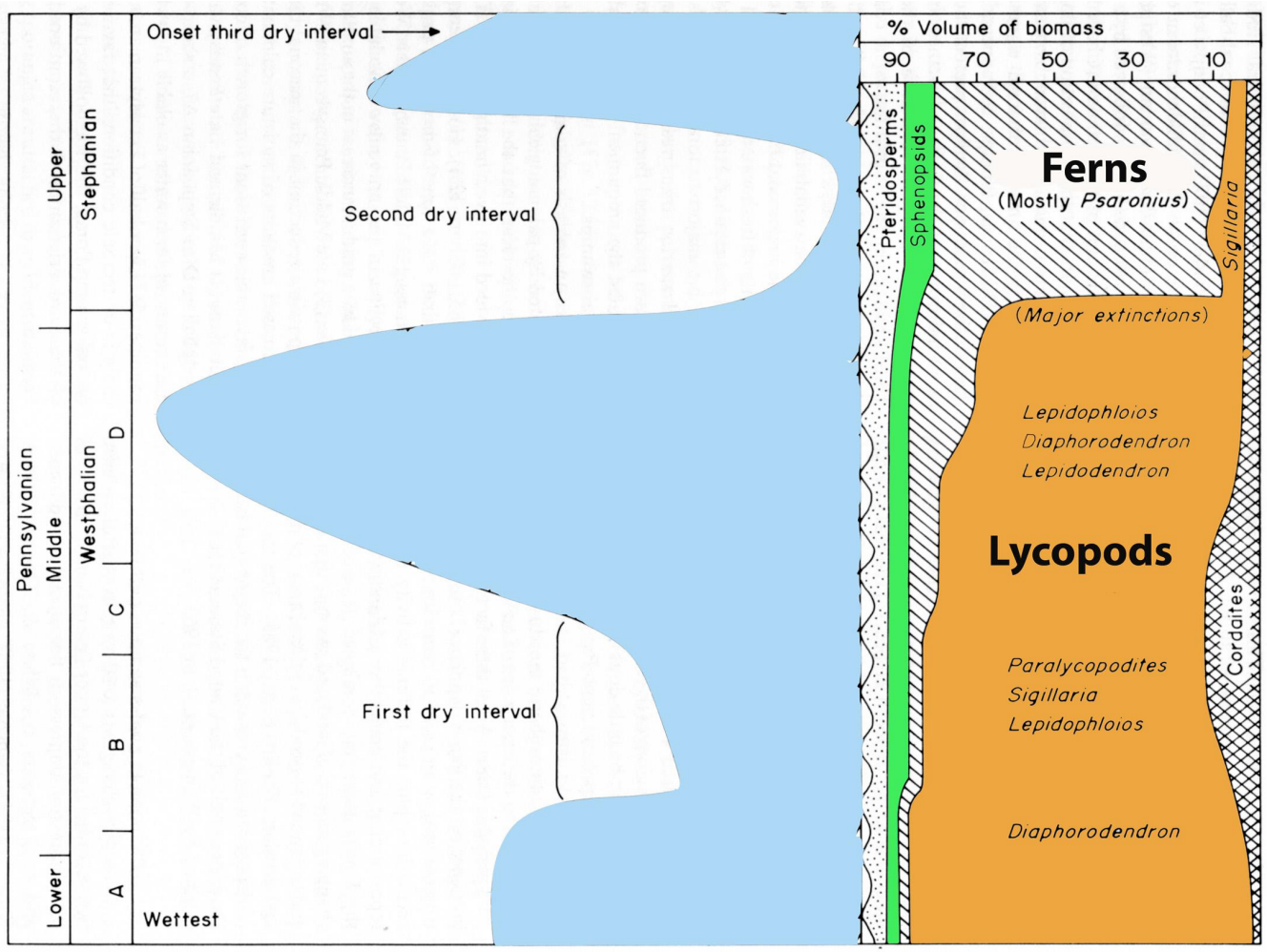
(3) Bivariate statistical analyses

Coal balls and climate change

Late

Middle

Early



Modified from Philipps, Peppers & DiMichelle (1985)

Additional documents:

(1) Coal Ball Plant Field Guide

(description of main characteristics of major groups of plants, modern and fossil diversity; incl. images of peels to showcase the taxa; based on over 200 scanned, identified coal ball peels)

(2) Coal Ball Lesson Plan

(teacher guide, material list, detailed instructions)

(3) Literature Cited

(annotated list of main papers; and for further reading)

(4) Coal ball kits

(available for sign-out by teachers at the Museum, incl. coal balls, acetate sheets, and other chemicals needed)