The Pennsylvanian

Climate gone wild
Objectives

1. Pennsylvanian paleogeography and rock units;
2. Terrestrial life in the Pennsylvanian;
3. Early land plants, lepidodendron forests, Pennsylvanian biomes;
4. Coal and its formation;
5. Transgression, regression, and cyclothsems;
6. Carbon and oxygen cycles and the effects of plant burial on atmospheric composition;
7. Cyclothsems and an Ice Age in the Pennsylvanian.
The Late Pennsylvanian
(300 mya)
Pennsylvanian Rocks of Indiana (Late Carboniferous)

- McLeansboro Group
- Carbondale Group
- Raccoon Creek Group
Pennsylvanian rock units

<table>
<thead>
<tr>
<th>TIME UNIT</th>
<th>THICKNESS (FT)</th>
<th>LITHOLOGY</th>
<th>ROCK UNIT</th>
<th>FORMATION</th>
<th>GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td>PENNSYLVANIAN</td>
<td>170 to 770</td>
<td>Merom Ss.</td>
<td>Mattoon</td>
<td>McLeansboro</td>
<td></td>
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<tr>
<td>MISSOURIAN</td>
<td>290 to 460</td>
<td>Livingston Ls.</td>
<td>Bond</td>
<td></td>
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<td></td>
<td></td>
<td>Carthage Ls.</td>
<td>Patoka</td>
<td></td>
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<td></td>
<td></td>
<td>Vigo Ls.</td>
<td>Shelburn</td>
<td></td>
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<td></td>
<td></td>
<td>West Franklin Ls.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>PENNSYLVANIAN DESMOINESIAN</td>
<td>290 to 460</td>
<td>Danville Coal</td>
<td>Dugger</td>
<td>Carbondale</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Hymera Coal</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Alum Cave Ls.</td>
<td>Petersburg</td>
<td></td>
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<td></td>
<td></td>
<td>Springfield Coal</td>
<td>Linton</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>Survant Coal</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Colchester Coal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PENNSYLVANIAN MORRO-WAN</td>
<td>160 to 980</td>
<td>Seelyville Coal</td>
<td>Stauton</td>
<td>Raccoon Creek</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Perth Ls.</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Minshall Coal</td>
<td>Brazil</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Lower Block Coal</td>
<td>Mansfield</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Lead Creek Ls.</td>
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</tbody>
</table>
Tetrapods from Indiana

Amphibian tracks left in the mud of a Pennsylvanian Age tidal flat in Martin County, Indiana. On display at Indiana Geological Survey. (photo by John Day)
Plants from Pennsylvanian of Indiana
Hurdles in the transition from water to land

Table 1. Four key physical differences between sea water and air that influence performance and behavior of aquatic versus terrestrial organisms (from Denny 1993)

<table>
<thead>
<tr>
<th></th>
<th>Sea water</th>
<th>Air</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (gm cm(^{-3}))</td>
<td>1.02</td>
<td>1.2 × 10(^{-3})</td>
</tr>
<tr>
<td>Viscosity (gm cm(^{-1}) sec(^{-1}))</td>
<td>1.1 × 10(^{-2})</td>
<td>1.8 × 10(^{-4})</td>
</tr>
<tr>
<td>Specific heat (J g(^{-1}) K) @20°C</td>
<td>4.10</td>
<td>1.01</td>
</tr>
<tr>
<td>Diffusion coefficient of O(_2) (m(^2) sec(^{-1})) @20°C, 1 atm</td>
<td>2.10 × 10(^{-9})</td>
<td>2.03 × 10(^{-5})</td>
</tr>
</tbody>
</table>
Division Chlorophyta
Green algae
Class Charophyceae
charophytes

Division Sphenophyta
horsetails
Order Equisetales
Equisetum

Division Lycophyta
Club mosses
Order Lycopodiales
Lycopodium (living club moss)

Division Bryophyta
Spagnum

Division Anthophyta
flowering plants

Division Coniferophyta
conifers

Division Pteridophyta
Ferns
Plants have different scientific names for different morphological structures

<table>
<thead>
<tr>
<th>Plant Part</th>
<th>Form Genus</th>
</tr>
</thead>
<tbody>
<tr>
<td>trunk and wood</td>
<td><em>Lepidodendron</em> (Feldman et al., 1996. <em>Fossils of Ohio</em>)</td>
</tr>
<tr>
<td>leaves</td>
<td><em>L. epidophyllum</em></td>
</tr>
<tr>
<td>cone</td>
<td><em>Lepidostrobus</em></td>
</tr>
<tr>
<td>sporophyll</td>
<td><em>Lepidostrobophyllum</em></td>
</tr>
<tr>
<td>sporangia</td>
<td><em>Lepidocystis</em></td>
</tr>
<tr>
<td>megasporae</td>
<td><em>Triletes</em></td>
</tr>
<tr>
<td>root</td>
<td><em>Stigmaria</em></td>
</tr>
</tbody>
</table>
Devonian *Archaeopoteris*

A progymnosperm tree from eastern North America


(Beck, 1960. The identity of *Archaeopteris* and *Callixylon*. Brittonia, 12: 351-368)

Catskill Delta

Late Devonian (360 mya)
Time of New Albany Shale
Callixylon logs (*Archaeopteris*)
Late Devonian, New Albany Shale
Pennsylvanian ferns

*Pecopteris*
- Greene County
- Knox County
- Pike County

(Canright, 1959. Fossil Plants of Indiana. Indiana Geol Survey Report 14)
Pennsylvanian Horsetail trees (Sphenophyta)

*Calamites* (trunk and whole plant)

*Annularia* (leaves)

*Palaeostachya* (stems)

*Calamites* Greene County

(Canright, 1959. Fossil Plants of Indiana. Indiana Geol Survey Report 14)
Lepidodendron trees (Lycophyta)

- **Lepidodendron**: Orange County
- **Lepidostrobus**: Greene County
- **Stigmaria**: Lawrence County

(Canright, 1959. Fossil Plants of Indiana. Indiana Geol Survey Report 14)
Pennsylvanian *Lepidodendron* Forests

*Early stage forest*  

*Reproductively mature forest*

*Cypress swamp in Arkansas*  
(Zack Weinberg, 2006)

Pennsylvanian coastal biome

Fig. 6. Ecosystem reconstruction of poorly drained coastal plain (pPDF) facies association. 1, Cordaitalean coastal forests; 2, lepidodendrid peat-forming forests; 3, pteridosperm–calamitean–fern riparian forests; 4, rotten sigillarian stump; 5, Protodiscus; 6, Dendropupa/Pupa; 7, Archidus; 8, Xylopterus; 9, Aminilyspes; 10, Megasecoptera; 11, cf. Mazonia; 12, Coryphomartus; 13, Arthropleur; 14, Graeophonus; 15, indet. eurypterid; 16, Baphetes; 17, microsaur; 18, Hylonomus.
Indiana Coal

Pennsylvanian
Peat is accumulation of partly decayed vegetation, usually forming in some type of wetlands.

Transgression

Regression

Transgressive local section

Regressive local section
Transgression and peat formation

Typical Illinois basin cyclothem

A cyclothem is a mappable unit of rock made of beds of many rock types (usually limestones, sandstones, shales and often coals) that are too thin and complicated to subdivide. Usually deposited during transgression-regression cycles.

- Coals usually form in transgressive sequences right at the paleo shoreline
- Coals usually have fluvial sands and non-marine shales below them
- Coals usually have marine shales and limestones above them

Rate of organic carbon burial through Phanerozoic
Carbon and Oxygen cycles

Effects of plant burial on atmospheric CO$_2$

- Normally rate of burial of organically bound carbon is roughly equal to the rate at which it is released by weathering.
- Burial removes carbon from cycle, either in carbonates, coal, or other carbon-rich rocks.
- Weathering of carbonates also decreases atmospheric CO$_2$. Carbon dioxide in atmosphere prevents heat from radiating back into space.
Atmospheric carbon dioxide through the Phanerozoic

(Royer, Berner, Montañez, Tabor and Beerling, 2004. CO2 as a primary driver of Phanerozoic climate. GSA Today, 14: 4-10)
River channels in Pennsylvanian of Indiana

Ice caps drop sea level, which exposes land

(Friedman, 1960. Channel-fill sandstones in the Middle Pennsylvanian rocks of Indiana)
Pennsylvanian channel sandstones near New Goshen, Indiana

(Friedman, 1960. Channel-fill sandstones in the Middle Pennsylvanian rocks of Indiana)
Carboniferous events that triggered an ice age and cyclothem formation

- Increasing diversity of plants from Devonian into Mississippian.

- Warm, tropical temperatures in early Carboniferous (Mississippian) resulted in large carbonate platforms in the shallow seas and huge forested swamps on land, increased the O₂ in the atmosphere and decreased the CO₂

- Plants reduced CO₂ in the earth’s atmosphere, but were being buried in anoxic swamp conditions. These became the Carboniferous coal deposits that are widespread around the world.

- Reduced CO₂ resulted in cooling (no ‘greenhouse effect’), which brought on major ice age, the coldest in earth’s history.

- Position of massive Gondwana continent at south pole allowed large terrestrial ice caps to form

- The effect was climate change and lowered sea levels.

- Global temperature cool enough that Milankovitch astronomical cycles resulted in geologically cyclic glacial inter-glacial cycles like at present.

- Cyclic rise and fall of sea level, resulting in cyclothemes and coals.