What we miss

Mesozoic and Cenozoic

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Triassic aged New Jersey Palisades Sill in fog
(photo from Palisades Interstate Park, NJ Section)
Objectives

1. Late Paleozoic
2. Assembly of Pangea
3. Permian-Triassic extinction and its causes
4. Mesozoic paleogeography and faunas
5. Cretaceous-Paleogene extinction and its causes
6. Cenozoic paleogeography and climates
7. Eocene forests
Pangaea

Early Permian (280 mya)
Permian vertebrate life

Synapsids (ancestors of mammals)

- First tetrapods were amphibians
- Starting in late Carboniferous they diversify into reptiles, synapsids (clade in which mammals later arise), and other extinct groups

*Dimetrodon, Ophiacodon*

*Lystrosaurus*

*Lycaenops*

*Dimetrodon, Edaphosaurus*
Permo-Triassic extinction
ca. 251 million years ago

Nearly 95% of the Earth’s species became extinct.

Eruption of Siberian traps peaked 251 mya, covering at least 1.6 million square km, an area the size of Europe, with 400 to 3000 m of flood basalt, lasting 600,000 years.

Oxygen isotope data suggest rapid global rise in temperature of 6C, which combined with Pangea’s continental configuration, reduces ocean circulation and dissolved oxygen to create anoxic conditions on the floor.

Carbon isotope excursions indicate that CO2 increased in atmosphere through production by the Siberian Traps, which raised global temperature enough to melt gas hydrate deposits, which further increased atmospheric CO2 and temperature... “runaway greenhouse effect”.

Tetrapods hard hit, with the dicyondont *Lystrosaurus* being one of the few found in fossil record for millions of years after extinction. Forest communities absent until Middle Triassic.
# The P-T casualties

(Percent of genera extinct)

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Extinction Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foraminifera</td>
<td>97%</td>
</tr>
<tr>
<td>Radiolaria (plankton)</td>
<td>99%</td>
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<tr>
<td>Anthozoa</td>
<td>96%</td>
</tr>
<tr>
<td>Tabulate and rugose corals extinct</td>
<td></td>
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<tr>
<td>Bryozoans</td>
<td>79%</td>
</tr>
<tr>
<td>Fenestrates, trepostomes, and cryptostomes extinct</td>
<td></td>
</tr>
<tr>
<td>Brachiopods</td>
<td>96%</td>
</tr>
<tr>
<td>Orthids and productids extinct</td>
<td></td>
</tr>
<tr>
<td>Bivalves</td>
<td>59%</td>
</tr>
<tr>
<td>Gastropods</td>
<td>98%</td>
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<tr>
<td>Ammonites</td>
<td>97%</td>
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<tr>
<td>Crinoids</td>
<td>98%</td>
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<tr>
<td>Inadunates and camerates died out</td>
<td></td>
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<tr>
<td>Blastoids</td>
<td>100%</td>
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<tr>
<td>Trilobites</td>
<td>100%</td>
</tr>
<tr>
<td>Eurypterids</td>
<td>100%</td>
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<tr>
<td>Acanthodians</td>
<td>100%</td>
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</table>
Mesozoic events
(percent of genera extinct)

- Break up of Pangea
- Fastest Tectonic Rates
- Highest Global Sea Levels
- Expansion of Western North America
- Evolution and Extinction of (Terrestrial) Dinosaurs
- Origin of Mammals
- Origin of Flowering Plants
- Several Extinctions

<table>
<thead>
<tr>
<th>Era</th>
<th>Period</th>
<th>Epoch</th>
<th>Age (millions of years ago)</th>
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<tbody>
<tr>
<td>Paleozoic</td>
<td>Permian</td>
<td></td>
<td>251</td>
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<tr>
<td></td>
<td>Pennsylvanian</td>
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<td>292</td>
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<td>Mississippian</td>
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<td>320</td>
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<td>Devonian</td>
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<td>Silurian</td>
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<td>Ordovician</td>
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<td>440</td>
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<td>Cambrian</td>
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<td>495</td>
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<td></td>
<td>Proterozoic</td>
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<td>545</td>
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<tr>
<td></td>
<td>Archean</td>
<td></td>
<td>2.5 billion</td>
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<td></td>
<td>Cenozoic</td>
<td>Quaternary</td>
<td>1.8</td>
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<tr>
<td></td>
<td></td>
<td>Holocene</td>
<td></td>
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<td></td>
<td></td>
<td>Pleistocene</td>
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<tr>
<td>Mesozoic</td>
<td>Cretaceous</td>
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<td>142</td>
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<tr>
<td></td>
<td>Jurassic</td>
<td></td>
<td>202</td>
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<tr>
<td></td>
<td>Triassic</td>
<td></td>
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</tbody>
</table>
Triassic paleogeography

230 mya

Panthalassic Ocean

Future Mississippi Embayment

Rift Basins

Panthalassic Ocean

Future Mississippi Embayment

Rift Basins

c. Ron Blakey (http://jan.ucc.nau.edu/~rcb7/nam.html)
Continental rifting and breakup of Pangea
Newark Supergroup Rocks

Rifting produced basins that filled with sediments

These lacustrine environments preserve many terrestrial organisms, including synapsids and diapsids
Jurassic paleogeography

Active margin
Collision and orogeny

Passive margin
rifting
Cretaceous paleogeography

- Mancos Shale: marine sediments, Utah
- Hell Creek Formation: terrestrial sediments, Montana
Climate in the Mesozoic

- Higher sea, smaller continents
- High atmospheric CO2
- Very Hot and Moist
  Tropics extended nearly to the poles
  Sea surface temperature at equator as high as 36°C (97°F)
- Anoxic ocean waters

- High sea, smaller continents
- Hot and moist

- Large continents
- Hot and dry
Cretaceous marine organisms

Rudist bivalves
Reef-forming molluscs

Cephalopoda
Ammonites common

Bivalves molluscs
including oysters

Gryphaea
an oyster

Marine reptiles
Icthyosaurs, Plesiosaurs,
Mosasaurs

Coccolithophores
major component of
Cretaceous chalks
Cretaceous dinosaurs from Mississippi Embayment
Bollinger, Missouri

Ceratosaurs and hadrosaurs

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*Fig. 1—* *Nesaurus missouriensis* Gilmore Type. U. S. N. M. 16735. Caudal vertebrae viewed from left side. Site, point where section shown in fig. 3, was made. About one-seventh natural size.
Cretaceous-Paleogene (K/P) Extinction
end of the “age of dinosaurs” beginning of “age of mammals”

47% of all genera go extinct
Exact cause debated (heatedly)
Widespread extinction among shallow marine organisms
Ammonites, rudist bivalves, many formanifera and coccolithophores, marine reptiles
Some terrestrial extinctions

Last of the non-bird dinosaurs (but only a handful left), many plant species, some turtles, about half the mammals, but few amphibians or crocodilians

Decline in dinosaur diversity in Hell Creek Fm.
Intense Cretaceous vulcanism

DECCAN TRAPS
66-65 Ma
>2,000,000 km$^3$ of lava flows
Did an asteroid impact cause the non-avian dinosaurs to become extinct?

A large asteroid unquestionably hit North America at the end of the Cretaceous. It’s most devastating effect would have been darkness, which impacted photosynthesis and plant life.

But....

Major changes were already going on before end of Cretaceous
- loss of dinosaur diversity, gymnosperm diversity
- increase in mammal and bird diversity, angiosperm diversity
- major marine faunal changes and extinctions
- these trends continued after asteroid

Major events associated with those changes
- marine regression
- intense vulcanism (Deccan traps)
- climatic changes
Cenozoic
65 mya to present

- Fluctuating but generally cooling global temperatures
- Final breakup of Gondwana and changes in ocean circulation
- Radiation of land mammals
- Radiation of mammals into marine and aerial habitats
Early Cenozoic
Laramide Orogeny
Late Cretaceous to middle Eocene
Climate in the Cenozoic

Zachos et al., 2001

- W. Antarctic ice-sheet
- E. Antarctic ice-sheet
- Mid-Miocene Climatic Optimum
-ase
-Asian monsoons intensify
- Columbia River Volcanism
- Tibetan Plateau uplift
- Red Sea Rifting
- Drake Passage opens
- Tasmania-Antarctic Passage opens
- plate reorganization & reduction in seafloor spreading rates
- Mi-L glaciation
- Late Oligocene Warming
- OI-I glaciation
- Small ephemeral ice-sheets appear
- E. Eocene Climatic Optimum
- Late Paleocene Thermal Maximum
- N. Atlantic Rift & Volcanism
- India-Asia contact
- Mammals disperse
- Benthic extinction
- Meteor Impact
- K-T Mass Extinctions
- Large mammal extinctions
- Great American Interchange
- Hominids appear
- C4 grasses expand
- Horses diversify
- seals & sea lions appear
- Coral Extinction
- large carnivores & other mammals diversify
- archaic mammals & broad leaf forests decline; baleen whales appear
- Ungulates diversify, primates decline
- Archaic whales appear
Eocene Climatic Optimum

50 MYA
Subtropical forests extended to the northern Arctic

Figure 2  Paleogeography and global vegetation in the Early-Middle Eocene (around 50 Mya). Vegetation modified from Ref. 147 with additions from Ref. 68; paleogeography modified from Ref. 105.

Red Hot Truck Stop Locality
Meridian, Mississippi (Early Eocene)

Sharks, Primates, Carnivores, Rodents, Plants