The Cretaceous-Paleogene Extinction

and the radiation of placental mammals

Reading: Benton, Chapters 9 & 10
Late Cretaceous time scale
The Cretaceous-Paleogene (K-P) extinction

Extinction of the last non-avian dinosaurs

Major turnover in calcareous nanoplanckton, especially coccolithophores

Major extinctions in ostracodes, scleractinian corals, ammonites, gnathostomes, as well as major changes to plant communities

Marine diversity
Bolide impact theory

Proposed by Luis Alvarez, Walter Alvarez, Frank Asara, and Helen Michels in 1980

Theory based on high concentration of iridium in several boundary sections

Later evidence included presence of shocked quartz, chromium concentrations, and the discovery of Chicxulub crater in Yucatan Peninsula

Proposed that asteroid was 10 km in diameter, releasing energy equal to 2 million times the most powerful nuclear bomb

Effects: dust cloud lasting several years (blocking photosynthesis), blocked insolation, caused firestorms, and greenhouse effect
Multiple causes

Many or most paleontologists argue that impact alone can explain only part of the extinction.

Impact had an effect and caused final extinction of some organisms, but:

1. many groups had a longer pattern of extinction

2. many groups that should have been affected if bolide was a devastating as purported were not

Causes: regression of shallow seas, vulcanism and atmospheric changes, correlated ecological changes in plant, animal, and marine communities
The Hell Creek Fm., Eastern Montana

One of the few terrestrial sections in the world that cross the K-P boundary

Figure 1. Index map of the Upper Cretaceous Hell Creek Formation along Ft. Peck Lake in northeastern Montana, USA. Contiguous outcrops are traceable over an area of about 1000 square km adjacent to Fort Peck Lake shown in blue. Dark orange represents the lower Hell Creek Formation and light orange represents the middle and upper Hell Creek Formation. The enlarged view of the study area is indicated by the rectangle in the northeast quarter of the map of Montana.

doi:10.1371/journal.pone.0016574.g001

(Horner et al., 2010. PLoS One, 6(2): e16574)
Total dinosaur diversity from Hell Creek Formation

- *Triceratops* (24%)
- *Tyrannosaurus* (40%)
- *Edmontosaurus* (20%)
- *Thescelosaurus* (8%)
- *Ornithomimus* (5%)
- *Pachycephalosaurus* (1%)
- *Ankylosaurus* (1%)

Dinosaur diversity in Hell Creek Fm.
Declines from seven genera to three

End Maastrichtian: 3 genera
Late Maastrichtian: 32 genera
Early Maastrichtian: 32 genera
Late Campanian: 48 genera

(Horner et al., 2010. PLoS One, 6(2): e16574)
Diversity in the last 2 million years before KP

Other taxa show little or no decline
## Comparative extinction of terrestrial vertebrates

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Number Extinct</th>
<th>Number Survivors</th>
<th>Percent extinction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-avian dinosaurs</td>
<td>3</td>
<td>0</td>
<td>100%</td>
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<tr>
<td>Mammals</td>
<td>18</td>
<td>13</td>
<td>60%</td>
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<tr>
<td>Crocodilians</td>
<td>1</td>
<td>4</td>
<td>20%</td>
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<tr>
<td>Turtles</td>
<td>2</td>
<td>15</td>
<td>12%</td>
</tr>
<tr>
<td>Amphibians</td>
<td>0</td>
<td>8</td>
<td>0%</td>
</tr>
</tbody>
</table>

Archibald, 2011. *Extinction and Radiation*
The Cenozoic

The most recent 65 million years

Formerly divided into the Tertiary and Quaternary, now divided into Paleogene, Neogene, and Quaternary
Eutherian Orders

**Infraorder Eutheria**—Placental Mammals

- **Magnorder Afrotheria**—Afrotherians
  - **Order Afrotheriida**—Tenrecs and Golden Moles
  - **Order Macroscelidea**—Elephant Shrews
  - **Order Tubulidentata**—Aardvark
  - **Order Hyaenidae**—Hyraxes
  - **Order Proboscidea**—Elephants
  - **Order Sirenia**—Dugongs, Manatees, and Sea Cows

- **Magnorder Xenarthra**—Xenarthrans
  - **Order Cingulata**—Cingulate Edentates
  - **Order Pilosa**—Sloths and Anteaters

- **Magnorder Boreoeutheria**—Boreoeutherians
  - **Order Scandentia**—Scandentians
  - **Order Dermoptera**—Flying Lemurs
  - **Order Primates**—Primates
  - **Order Lagomorpha**—Pikas, Hares, and Rabbits
  - **Order Erinaceomorpha**—Hedgehogs and Relatives
  - **Order Soricomorpha**—Shrew and Mole-like Insectivores

**Lipotyphla Archonta**

- **Archonta**
  - **Order Chiroptera**—Bats
  - **Order Pholidota**—Pangolins
  - **Order Carnivora**—Carnivores
  - **Order Perissodactyla**—Horses, Rhinos, Tapirs
  - **Order Artiodactyla**—Artiodactyls
  - **Order Cetacea**—Whales
  - **Order Rodentia**—Rodents

Centennial Museum, University of Texas El Paso
Radiation of Eutheria - placental mammals
Tribosphenic dentition - ancestral condition for Theria

Interlocking teeth that combine shearing, grinding, and puncturing

Associated with insectivorous diet

In Eutheria, ancestral dental formula is: I3, C1, P4, M3

All teeth but molars have deciduous counterparts (milk teeth, or baby teeth). Molars are not replaced.

Other dentition types rapidly derived from these, including omnivorous and herbivorous types formed by addition of hypocone and loss of paraconid
Occlusion in Tribosphenic Teeth

*Chalinolobus gouldii*, Gould’s Wattled Bat
Diversity of dentitions and diets

- **Fox**: Carnivorous to omnivorous
- **Shrew**: Insectivorous
- **Deer**: Herbivorous
- **Wood rat**: Granivorous
Evolution of whales (Cetacea)

First whales: Early Eocene of Pakistan and India, *Pakicetus*
Derived from Artiodactyla (contains living camels, pigs, deer)
Closest living relative: Hippo (clade Whippomorpha)

Uhen, 2010, Origin of Whales
Phylogeny of whales

Pakicetus: 49 mya

Ambulocetus

Phylogeny of whales

Basilosaurus: 39 mya

Rhodocetus

Dorudon

Uhen, 2010
Cenozoic geography and whales

Pangea, 251 mya

Remnants of the Tethys Sea

Tethys Sea

Uhen, 2010. Origin of Whales
Scientific papers for further reading


