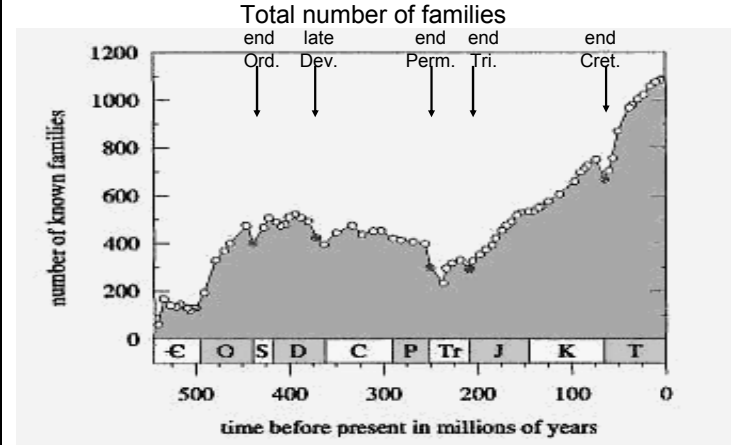


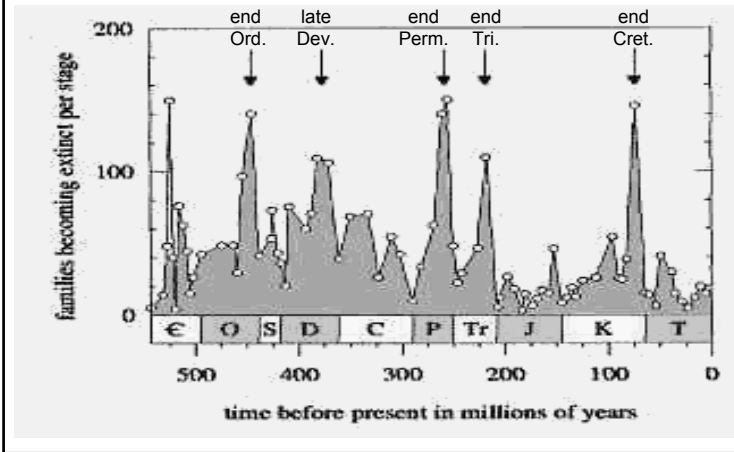
**Cretaceous Calamity:  
The Cretaceous-Tertiary Mass Extinction  
(and other mass extinctions)**



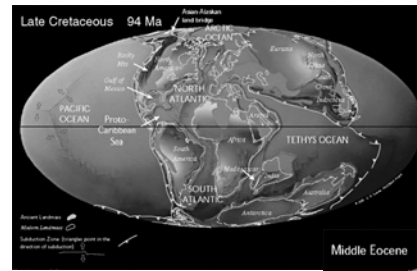
**Mass Extinctions of the Phanerozoic:  
The Big Five**



**Mass Extinctions of the Phanerozoic:  
The Big Five  
Families gone extinct**



**K-T Mass Extinction: Sea Level Fall**

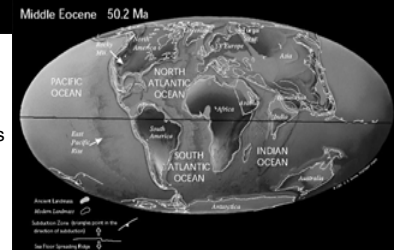


**Late Mesozoic**

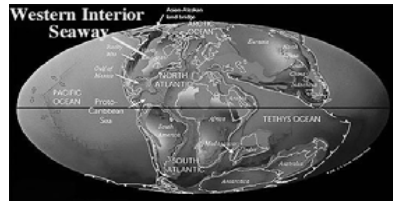
- sea level high
- land areas separated (despite fairly close proximity of continents to one another)
- lots of "shelf" area for shallow marine organisms

**Early Cenozoic**

- sea level lower
- continents further apart (but perhaps more land bridges)
- less "shelf" area for shallow marine organisms



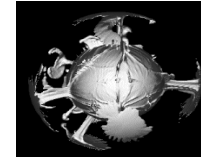
## Drainage of Interior Seas



Lowering of sea level resulted in:

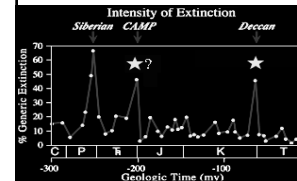
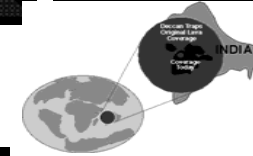
- loss of "shelf" area (largely through loss of interior seas such as Western Interior Seaway of North America).
- aridification of land areas (less habitat diversity)
- More connection between continents (via land bridges)

## Flood Basalt Volcanism



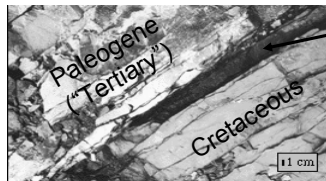
The result of great volcanic activity associated with rising heat plumes from mantle.

Deccan Traps (India) record eruption of more than 500,000 million cubic km of basaltic lava over perhaps about 5 million years (but began before end of Cretaceous Period).



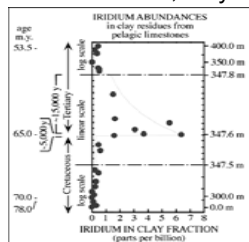
There appears to be correspondence between some (but not all) mass extinctions and flood basalt events.

## Initial Evidence of Bolide Impact: Iridium



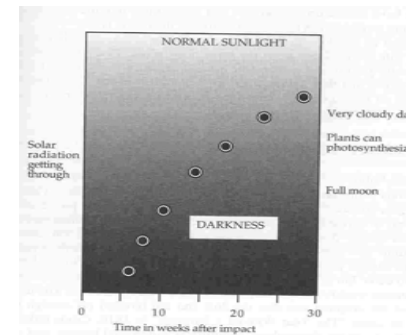
Iridium-rich boundary clay layer

Gubbio, Italy



Iridium "spike": High iridium concentrations from asteroid/comet or volcanism ?

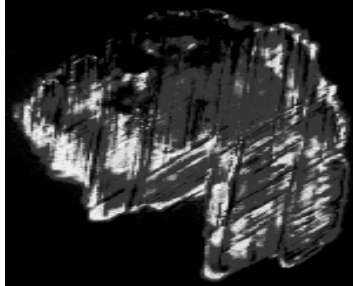
## Computer model of effects of K-T Impact Winter



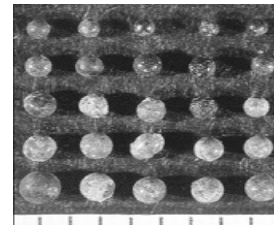
No sunlight = no photosynthesis= cascade of death through food chains Earth in darkness for at least 6 months after asteroid impact

### Shocked Quartz in K-T Boundary Clay

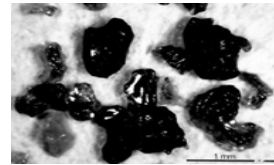
Shock Metamorphism  
Has only been observed at meteorite impact sites and nuclear test sites



### Tektites, glass beads found in boundary sediments

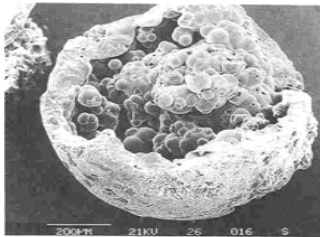


Due to melting of rock by energy of bolide (asteroid or comet) impact ?



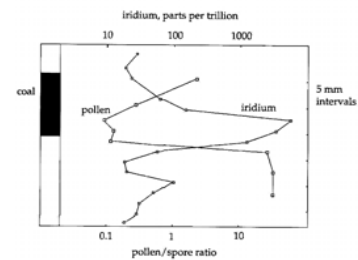
Glass found in boundary sediments of Gulf of Mexico

### Soot particles found in boundary clay Similar to Fly Ash From Coal-Burning Plants



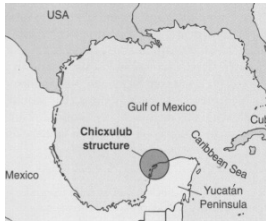
Suggest global wildfires associated with ignition of large amounts of dead plant matter on Earth's surface.

### Fern Spike / Pollen Trough



Pollen/spore ratio takes a dive at about same level as iridium spike  
Records early recolonization of land after impact winter ?

## Impact Site: Chicxulub



180 km in dia

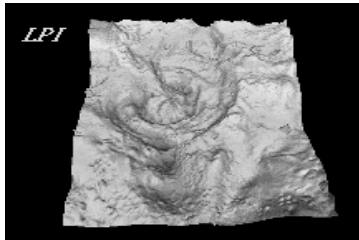
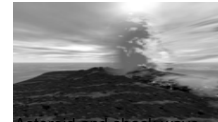
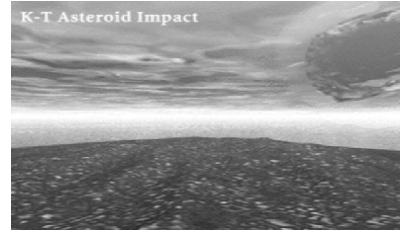


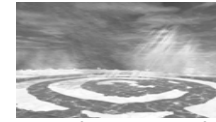
Image from geophysical survey over Yucatan Peninsula

Crater actually discovered in 1978 by a geophysicist working for Petróleos Mexicanos  
 Pemex did not release the data for fear of revealing valuable information to competitors.  
 "Rediscovered" by Alan Hildebrand in 1991

## K-T Asteroid Impact



Asteroid and shock wave blast long trench

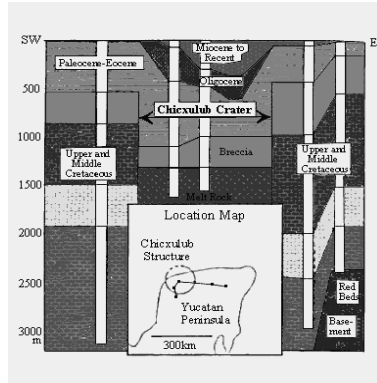


Rings of complex crater form, by rebound



- Impact winter
- debris injected into atmosphere
  - lots of dead, rotting organic matter
  - global wildfires
  - blocking of sunlight
  - consumption of ozone ?

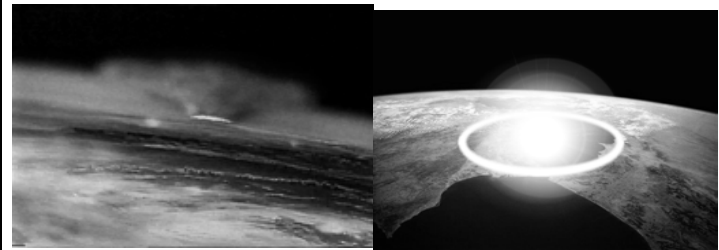
## Bedrock lithology in vicinity of crater



Yellow = anhydrite  
 Green = carbonates

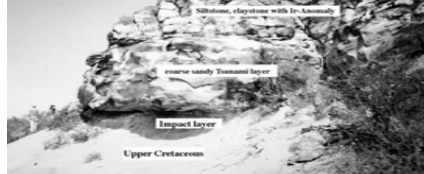
Effects of vapourization during impact ? Severe acid rain ?

## So what happened to impactor ?



Most of impactor probably vapourized during blast  
 ...but possible fragment 100 trillionth of a gram found in drillcore in NW Pacific

**NE Mexico: Tsunamites ?**



Believed to have been deposited by tsunami generated by impact

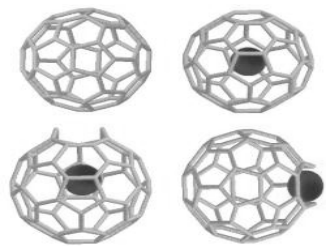
**Belize: Ejecta Blanket**



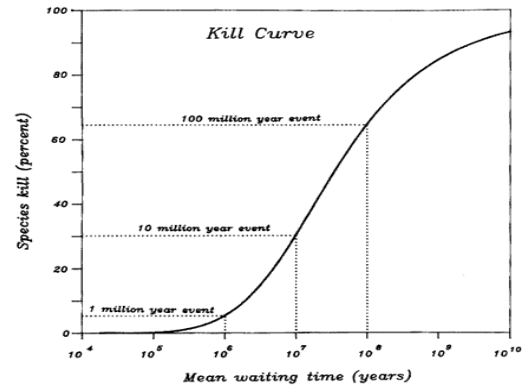
Poorly sorted debris believed to be ejecta deposited close to crater.

Other (more recent) evidence for impact:

- Fullerines (molecular cage of carbon atoms)
- also called "bucky balls"
- contain  $^3\text{He}$  (vs. the more common  $^4\text{He}$ ),
- suggested to be of cosmic origin
- elevated  $^3\text{He}$  at K-T boundary



**David Raup's Kill Curve**



Basic premise: Major events occur less frequently than minor events (and have greater "killing power")

Does "survival of the fittest" work during a mass extinction ?

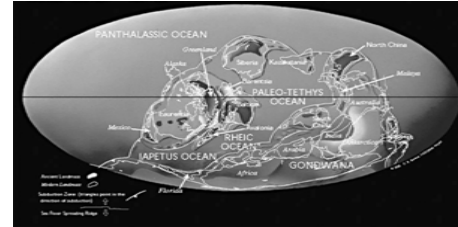
In mass extinctions, the specialists lose !



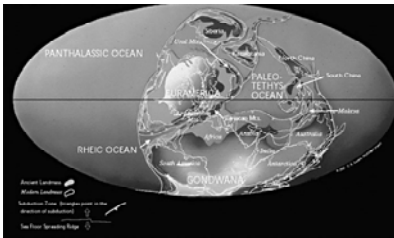
Early mammals "inferior" in their time (when conditions were stable), but, because of their generalized life habits, had a higher chance of surviving ecological disaster than dinosaurs.

## The Other Big Four

End Ordovician Mass Extinction  
Cooling due to gathering of continents  
at south pole (possible glaciation ?)

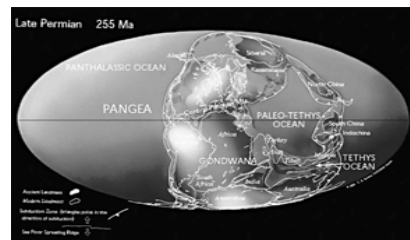


Late Devonian Mass Extinction  
First forests  
Onset of glaciation (could this be linked to first forests ?)



The Mother of All Mass Extinctions:  
End-Permian

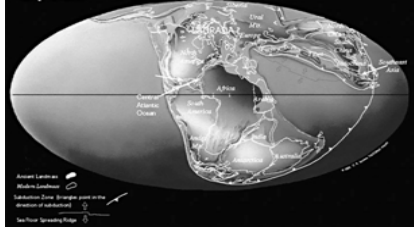
Coincided with final assembly of Pangaea  
and Eruption of Siberian Traps



## End-Triassic Mass Extinction

Little known about this one but possibly due to oxygen depletion in oceans.

Coincided with extrusion of flood basalts accompanied initial spreading of Atlantic



## Mass Extinctions: Summary of “The Big Five” (numbered according to severity)

5. Cretaceous-Tertiary extinction (65 Ma) → victims: 47 % marine genera
  - bolide impact
  - flood volcanism (Deccan Traps in India)
  - cooling, rapid sea level fall ?
4. Triassic-Jurassic extinction (199 - 214 Ma) → victims: 52 % of marine genera.
  - flood basalt volcanism (central Atlantic)
1. Permian-Triassic extinction (251 Ma) → victims: 84 % marine genera  
95 % all marine species !!!
  - bolide impact ?
  - flood basalt volcanism in Siberia ?
  - assembly of Pangaea (continents interconnected)
  - global cooling, major sea level fall

## Mass Extinctions: Summary of “The Big Five” (numbered according to severity)

3. Late Devonian extinction (364 Ma) → victims: 57 % of marine genera.
  - global cooling (note: coincident with expansion of land plants) ?
2. Ordovician-Silurian extinction (439 Ma) → victims: 60 % percent of marine genera.
  - global cooling, then rapid warming
  - rapid sea level fall followed by rapid sea level rise

Different mass extinctions, different causes ?

## Towards the Sixth Big Mass Extinction

“Today, we may be losing up to 30,000 species a year -- a rate much faster than at any time since the last great extinction 65 million years ago that wiped out most of the dinosaurs. If we continue on this course, we will destroy even ourselves.”

- M. Novacek, American Museum of Natural History

“Almost a quarter of the world’s mammals face extinction within 30 years.”

- United Nations report on the state of the global environment.

“Less than 10 per cent of the remaining habitat of the great apes of Africa will be left relatively undisturbed by 2030 if road building, mining camps and other infrastructure developments continue at current levels.”

-United Nations Environment Programme (UNEP)

The Biosphere’s Future Lies in  
Our Understanding of the Earth System,  
Past and Present !

*END OF LECTURE*