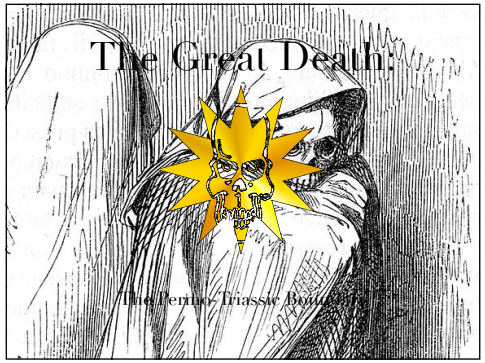
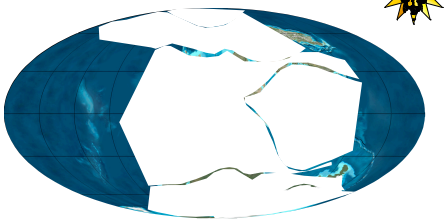


1

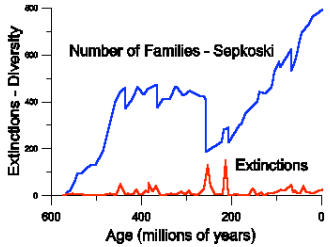
The Earth at the end of the Permian



Late Permian

2

History's Largest Extinction at the end of the Permian

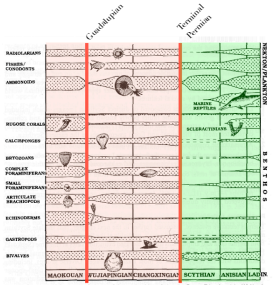


3

The terminal Permian extinctions are the greatest extinctions in the entire fossil record!!!!!

- 90% of marine species go extinct
- 54% of the marine families go extinct
- 64% of terrestrial vertebrates go extinct
- the extinctions are neither instantaneous nor catastrophic
- there are really two extinctions:
  - Guadalupian
  - Terminal Permian

4



P e r m i a n Triassic

5

The extinctions include:

- † all Paleozoic Tabulate corals and most Rugosa
- † all Fusilinids
- † all remaining trilobites, eurypterids, blastoids
- † all but one species of Echinoid (sea urchin)
- † all but one family of Crinoids
- † all but three genera of Ammonite Cephalopods
- † four of six orders of Bryozoans
- † 13 of 17 superfamilies of Brachiopods
- † all but one family of Anapsid Reptiles
- † all large Herbivores
- † 6 of 9 Amphibian families
- † 19 out of 20 families of Therapsid Synapsids

6

7

The First Extinction

- ~ most reef-building genera
- ~ 3/4 of fusilinids
- ~ 70% of marine species went extinct
- ~ coincides with a period of glaciation

8

The Second Extinction

- 80% of remaining species go extinct

Many reasons have been put forward over the years, but now better stratigraphy and geochemistry suggests that the second extinction was due to a combination of major marine anoxia and major terrestrial shifts in climate.

9

The Second Extinction

- Extinctions occurred within a million years.
- Tropical taxa were especially hit hard - especially reef communities.
- Carbon isotopes became enriched in carbon 12 at the expense of carbon 13 close to the end of the Permian.
- Sea level began a general drop in mid-Permian time and rapidly dropped about 100 meters during the final 2 million years of the Permian. At the end of the period shallow seas were confined to narrow continental margins.
- Rapid shift from cooler/moister flora to warmer/dryer flora at high latitudes, coinciding with shift from coal deposition to red bed deposition - indicating major climatic changes.

10

The Second Extinction

- Large spike in number of fungal spores in shallow marine rocks in the uppermost Permian; fungi appear to have flourished by deriving nutrition from large amounts of dead vegetation in coastal areas.
- Massive flood basalt eruptions (perhaps largest in entire Phanerozoic) across Siberia right at the time of the terminal extinction. Emissions would have caused major climatic shifts - not sure if global cooling or global warming!!
- 3 to 4 ma of deep sea anoxia - only upper waters of ocean were oxygenated.

11

The Second Extinction

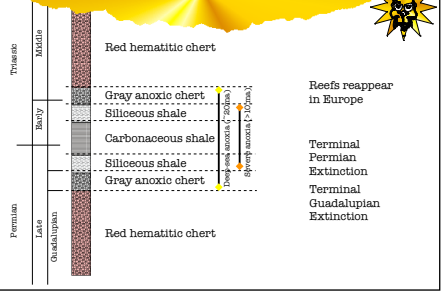
The last point - about deep sea anoxia - is particularly interesting.

The deep sea was well oxidized until the very end of the Guadalupian time. Guadalupian cherts indicate abundant radiolarians indicating that upwelling supplied abundant nutrients in shallow waters. Waters that downwelled (as the deep water upwelled) provided oxygen for the deep sea. Red cherts indicate the level of oxidation.

Gray cherts indicate the onset of anoxic conditions and higher in the sequence deep-sea sediments become rich in organic carbon, reflecting stagnation of the deep oceans. When stagnation occurred anoxic sediments began to accumulate in shallow water and for 3 to 4 million years ONLY the upper waters were oxygenated. By the early Triassic 'normal' conditions had returned.

12

The Second Extinction



13

The Second Extinction

So changes in ocean circulation must have been related (one way or another) to both late Permian extinctions.

The first event coincided with the onset of deep-sea anoxia and,

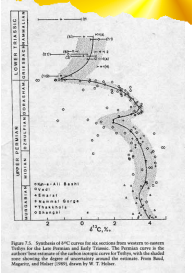
The second event occurred at the time of maximum oceanic anoxia.

Some workers suggest that brief episodes of mixing in the ocean carried large quanitites of carbon dioxide to surface waters and the atmosphere, poisoning many forms of life.

Carbon isotopic shift may represent large amounts of organic carbon being released by decaying organic matter in the shallow seas.

14

The Second Extinction

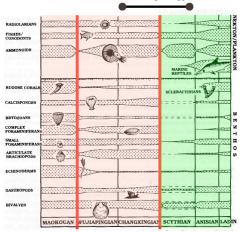


The light carbon is more than likely from methane. This must have come from decay of plant material and turnover of deep ocean gas hydrates.

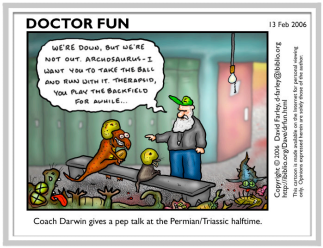
15

Deep Ocean Anoxia

Widespread Anoxia



16



Coach Darwin gives a pep talk at the Permian/Triassic halftime.