Mesozoic Era

The Mesozoic Era

- Mesozoic Era = 252 to 66 million years ago.
- Name Mesozoic means "middle life"
- Mesozoic Era consists of three periods:
  - Triassic - Oldest. Lasted about 51 million years
  - Jurassic - Lasted about 56 million years
  - Cretaceous - Youngest. Lasted about 79 million years

Triassic (252-201 my)

Separated into:

- Scythian
- Anisian
- Ladinian
- Carnian
- Norian
- Rhaetian

Scythian – Lower

Anisian, Ladinian – Middle

Carnian, Norian, Rhaetian – Upper

Jurassic (201-145 my)

Separated into:

- Hettangian
- Sinemurian
- Pliensbachian
- Toarcian

Lias (Lower)

- Aalenian
- Bajocian
- Bathonian
- Callovian

Dogger (Middle)

- Oxfordian
- Kimmeridgian
- Tithonian

Malm (Upper)

Cretaceous (145-66 my)

Separated into:

- Berriasian
- Valanginian
- Hauterivian
- Barremian
- Aptian
- Albian
- Cenomanian
- Turonian
- Coniacian
- Santonian
- Campanian
- Maartrichtian

Lower: Berriasian – Albian

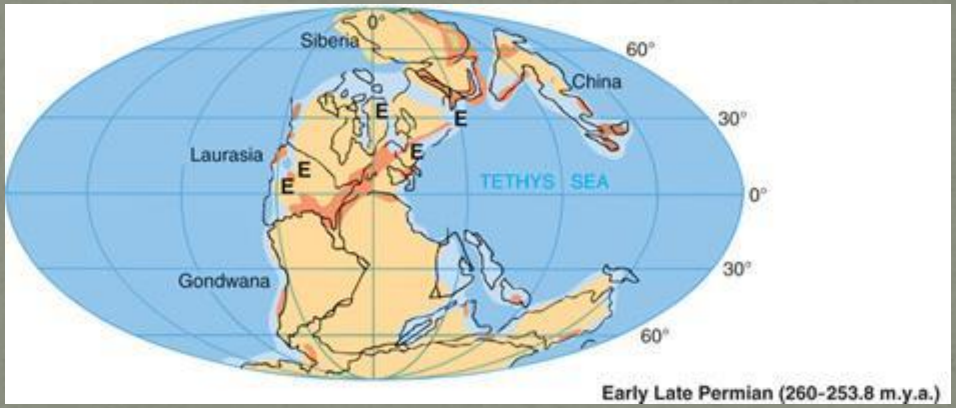
Upper: Cenomanian – Maartrichtian

The Mesozoic Era

- The Mesozoic Era followed the extinction of Paleozoic organisms.
- Mesozoic rocks contain the remains of organisms that are more advanced than those in the Paleozoic, but not as modern as those living today.
- Two new vertebrate classes appeared: birds and mammals.
- The Mesozoic Era lasted approximately 186 million years, and ended with an extinction event in which the dinosaurs met their demise.

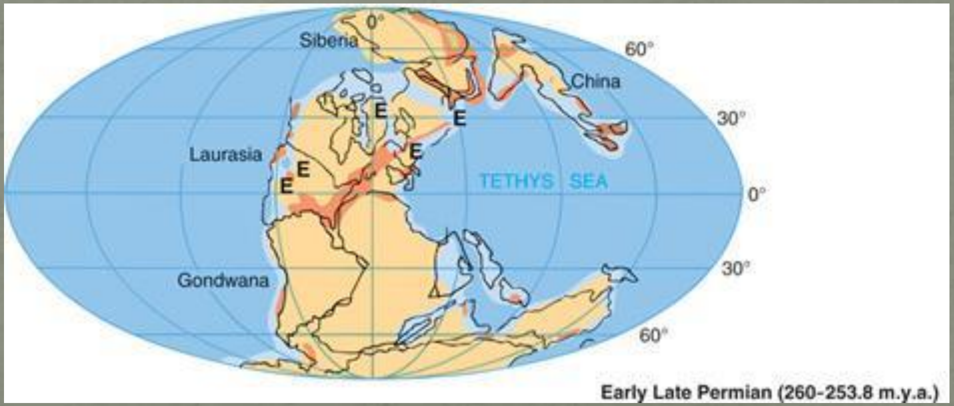
Pangaea

- At the beginning of the Mesozoic, the continents were assembled into a supercontinent, **Pangea**.



Pangaea

- In the equatorial area to the east, between Africa and Europe, and between India and Asia, was an embayment called the Tethys Sea.
- The climate became arid; evaporites (E) were deposited.



The Breakup of Pangaea

- Pangaea began to break up in the Mesozoic.
- The *northern* continents were called Laurasia and the *southern* continents were called Gondwana.
- As North America and Europe separated, they were called Laurentia and Baltica.

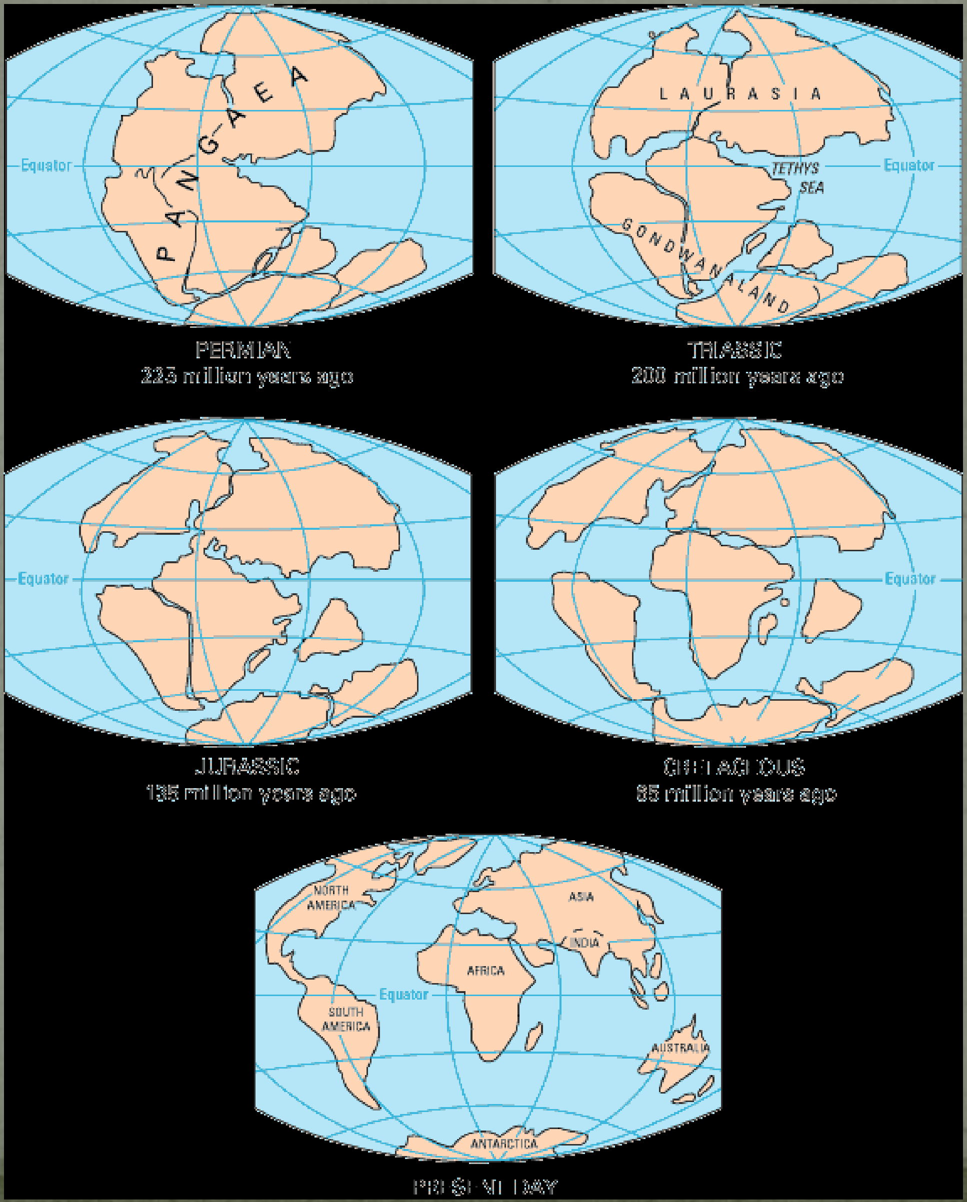
The Breakup of Pangea

Stage 1

Stage 2

Stage 3

Stage 4



The breakup occurred in four stages:

Stage 1:

- Rifting and volcanism along normal faults in the Triassic, resulting in the separation of North America (Laurasia) from Gondwanaland.
- Normal faulting in eastern North America, accompanied by the intrusion of dikes and lava flows.
- Atlantic Ocean opened and widened through the extrusion of oceanic basalts.

Stage 2:

- Rifting and separation of Africa, India, and Antarctica.
- Large volumes of basalt were extruded.

Stage 3:

- The Atlantic rift extended northward.
- Eurasia moved to the south, partially closing the Tethys Sea.
- South America began to split from Africa by the Late Jurassic, and completely separated by the Late Cretaceous.
- Australia remained connected with Antarctica.
- India was moving northward toward Asia.
- Greenland began to separate from Europe (Baltica), but remained attached to North America (Laurentia).

Stage 4:

- After the Mesozoic, the breakup of Pangea continued.
- North America (Laurentia) separated from Eurasia (Baltica) along the North Atlantic rift.
- Antarctica and Australia separated about 45 m.y. ago.
- Arabia broke up 20 m.y. ago from Africa.
- It continues today with the breakdown of East Africa Rift.

The total time for the fragmentation of Pangea was about 150 m.y.

Mesozoic Climate and its Effect on Life

Factors influencing climate:

1. Distribution and size of continents and oceans
2. Development and location of mountain ranges
3. Development and location of land bridges between continents
4. Changes in snow cover, cloud cover, or vegetation cover
5. Carbon dioxide content of the atmosphere

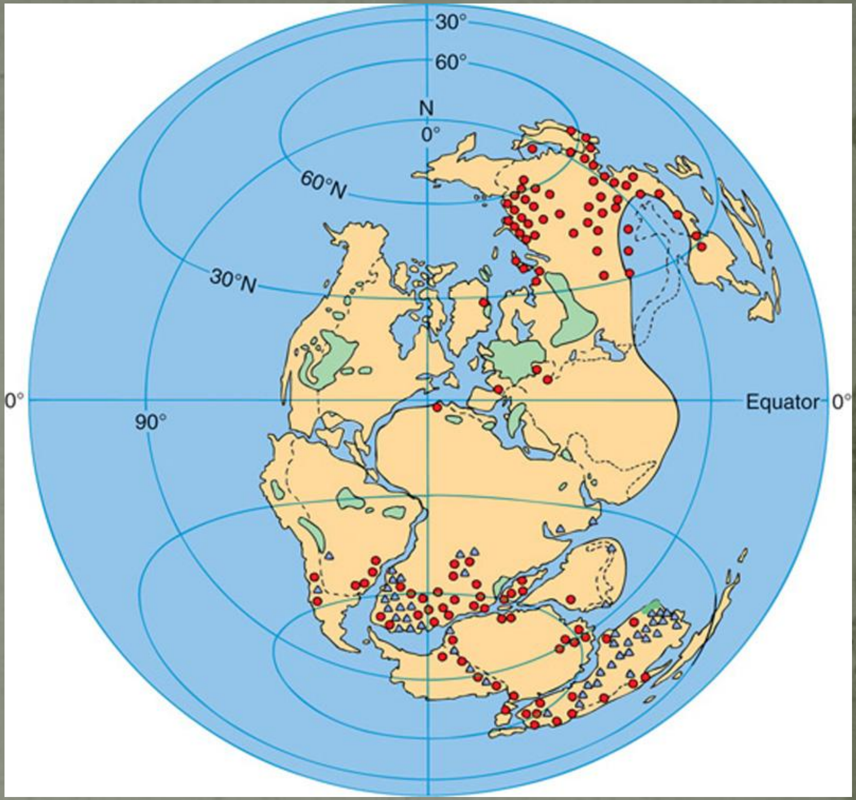
Factors influencing climate:

6. Location of the poles and equator (with respect to continents and oceans)
7. Amount of particulate matter and aerosols released into the atmosphere by volcanic eruptions
8. Astronomical factors concerning the Earth's orbit and tilt of the rotational axis

Climate and Plate Tectonics

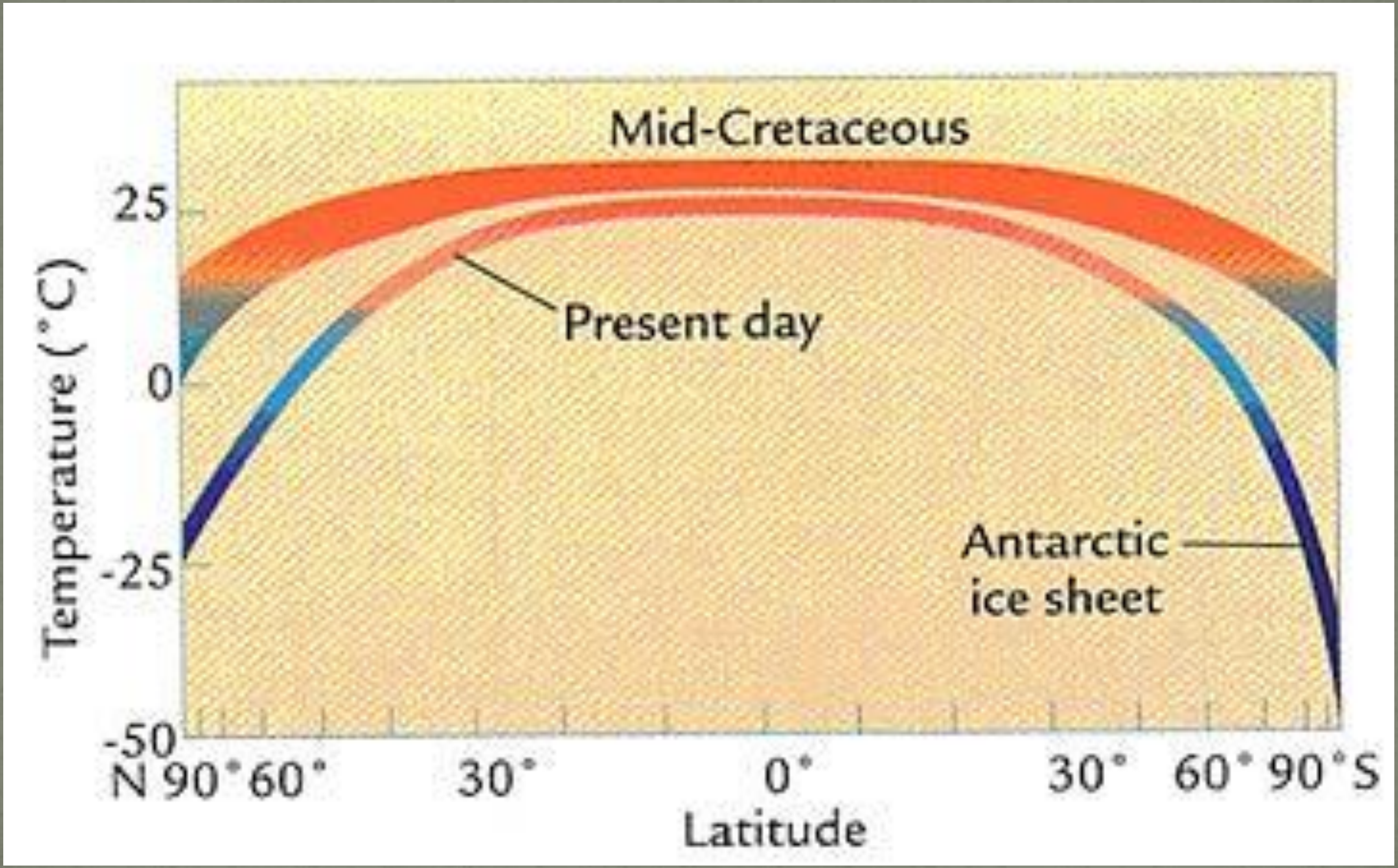
- Overall, climates in the Mesozoic Era were warm.
- This was in contrast to the cool dry climates which characterized many continental areas near the end of the Paleozoic Era.
- Evidence for warming includes the disappearance of glaciers which were common in many areas during the Permian.

Climatic warming was related to continental drift and the breakup of Pangea during the Mesozoic Era. As the continents moved away from the South Pole, conditions were no longer favorable for glaciers to exist.



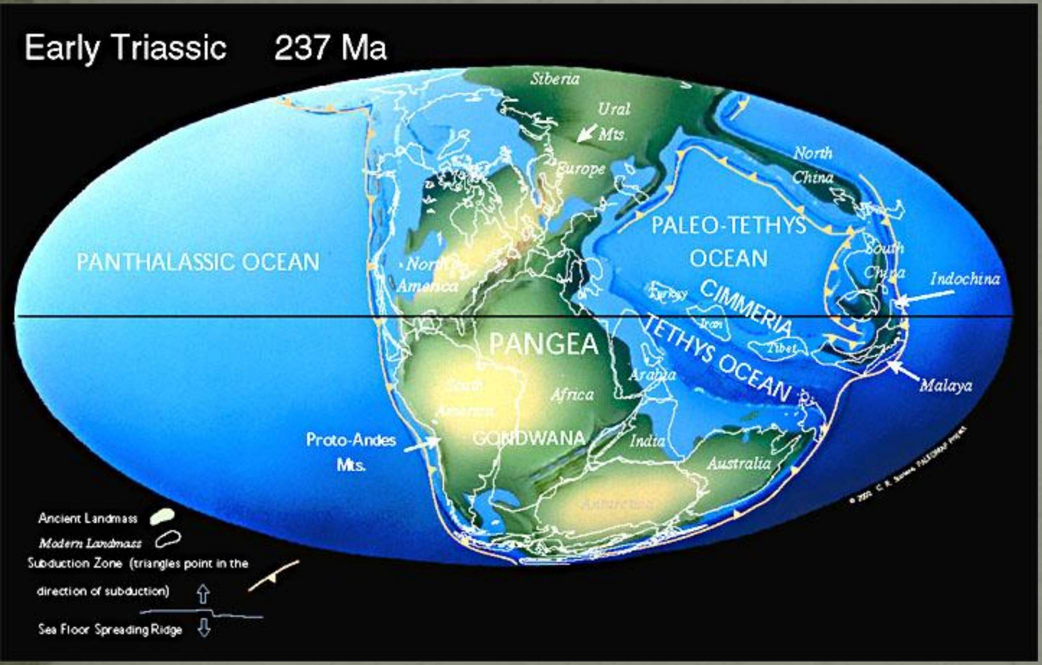
Blue triangles indicate glacial tillites.

- Fossil plants from the Jurassic and Cretaceous indicate that tropical climates existed in areas that today have temperate climates.
- Subtropical plants were living in areas that were 70° from the equator during the Cretaceous- a latitude similar to that of northern Alaska.
- This suggests that **temperatures were much warmer during the Cretaceous than they are today**.
- During the Jurassic and Cretaceous, the continents were at roughly the same latitudes that they occupy today.



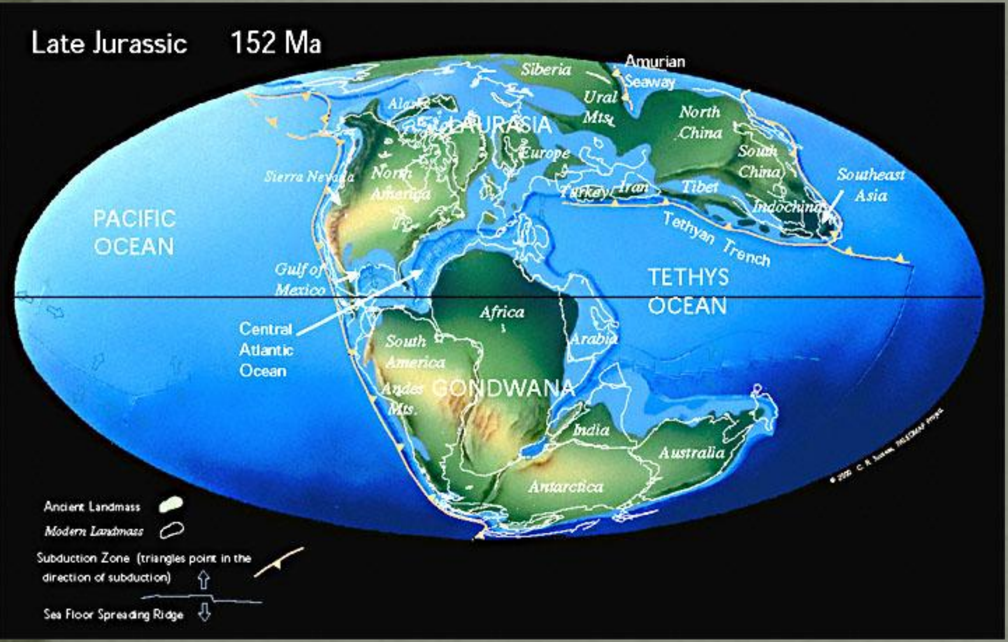
Mid-Cretaceous
Present day
Antarctic
ice sheet
Temperature (°C)
25
0
-25
-50
N 90° 60°
30°
0°
30°
60° 90° S
Latitude

Paleogeography of the Triassic



When the continents were clustered together to form Pangea, much of the land area was far from sea, and was arid.

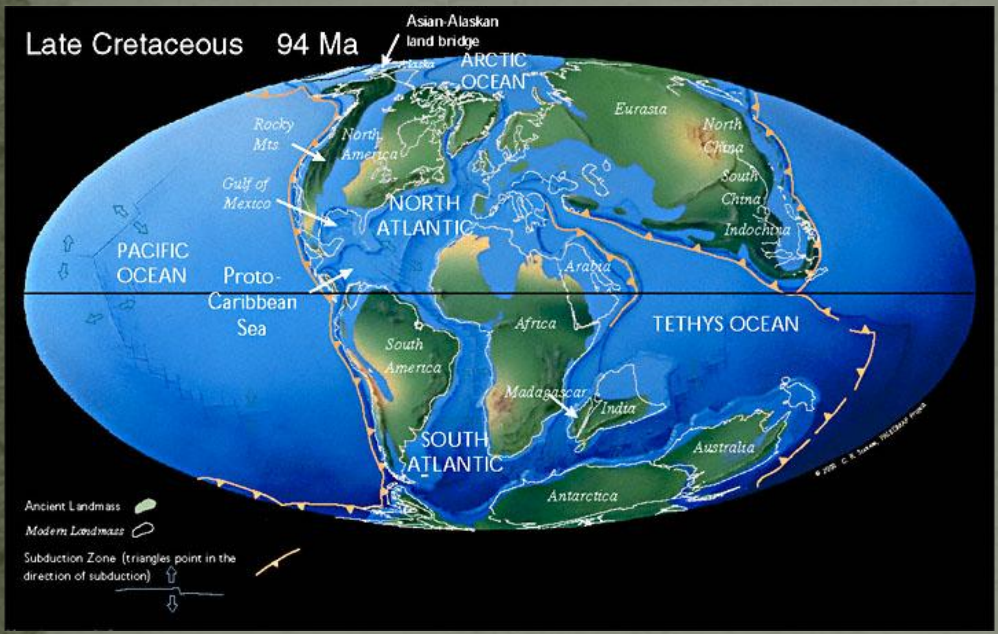
Paleogeography of the Jurassic



Evaporite deposits accumulated when dry areas became intermittently flooded by the sea, as the continents began to rift apart.

Example: Louann Salt, Gulf Coast region

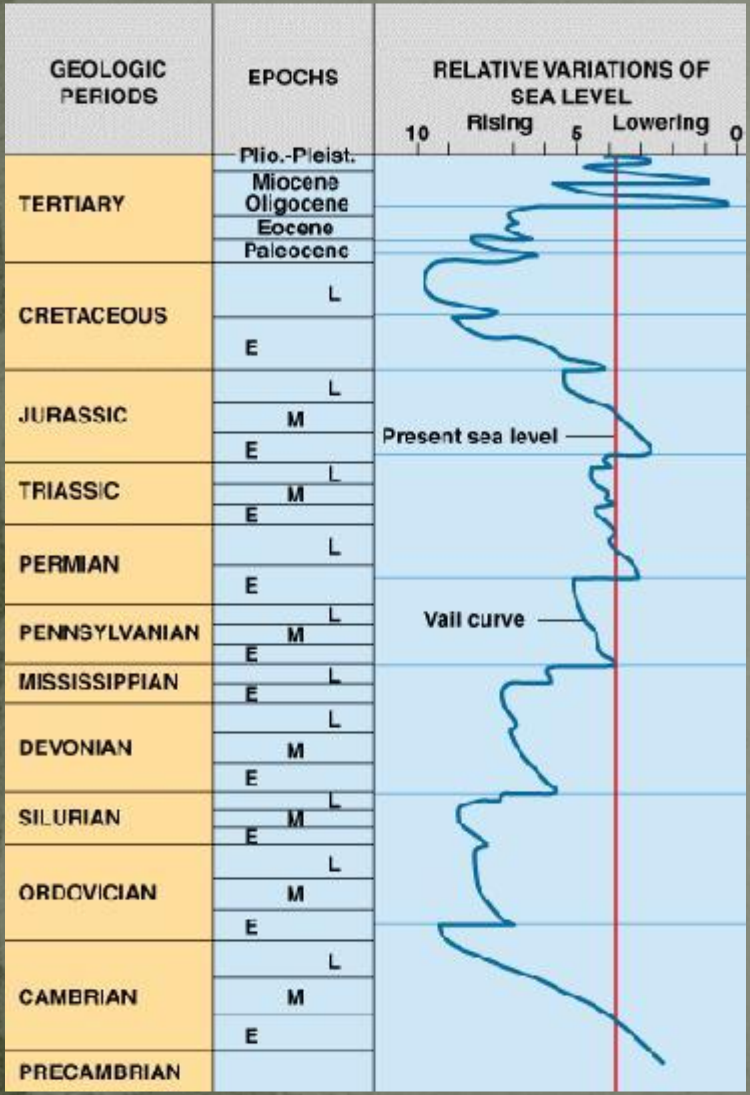
Paleogeography of the Cretaceous



As the continents separated, water was able to circulate in the equatorial and mid-latitudes.

The circulation of seawater distributed the **warmth** between the separating continents and around the globe.

Climate Affects Sea Level



With the disappearance of the glaciers, **sea level rose** through the Jurassic, and continued rising to a maximum during the Cretaceous.

Plate Tectonics Affects Sea Level

- Sea level rise was also related to the rifting and fragmentation of Pangea.
- The mid-Atlantic ridge system developed as the Atlantic Ocean widened.
- The basaltic rocks that were extruded along the mid-ocean ridge system were hot and thermally inflated.
- As a result, they **displaced a considerable volume of sea water** onto the continents.

Epicontinental Seas Flood the Continents

- In the Late Jurassic and Cretaceous, **epicontinental seas** flooded large areas of North America and Europe.
- These epicontinental seas also contributed to the warmer climate because the water carried heat.
- Epicontinental seas provided an extensive habitat for shallow marine organisms and probably led to the increase in diversity during the Mesozoic.

Terminal Cretaceous Cooling

The climate began to cool toward the end of the Cretaceous Period.

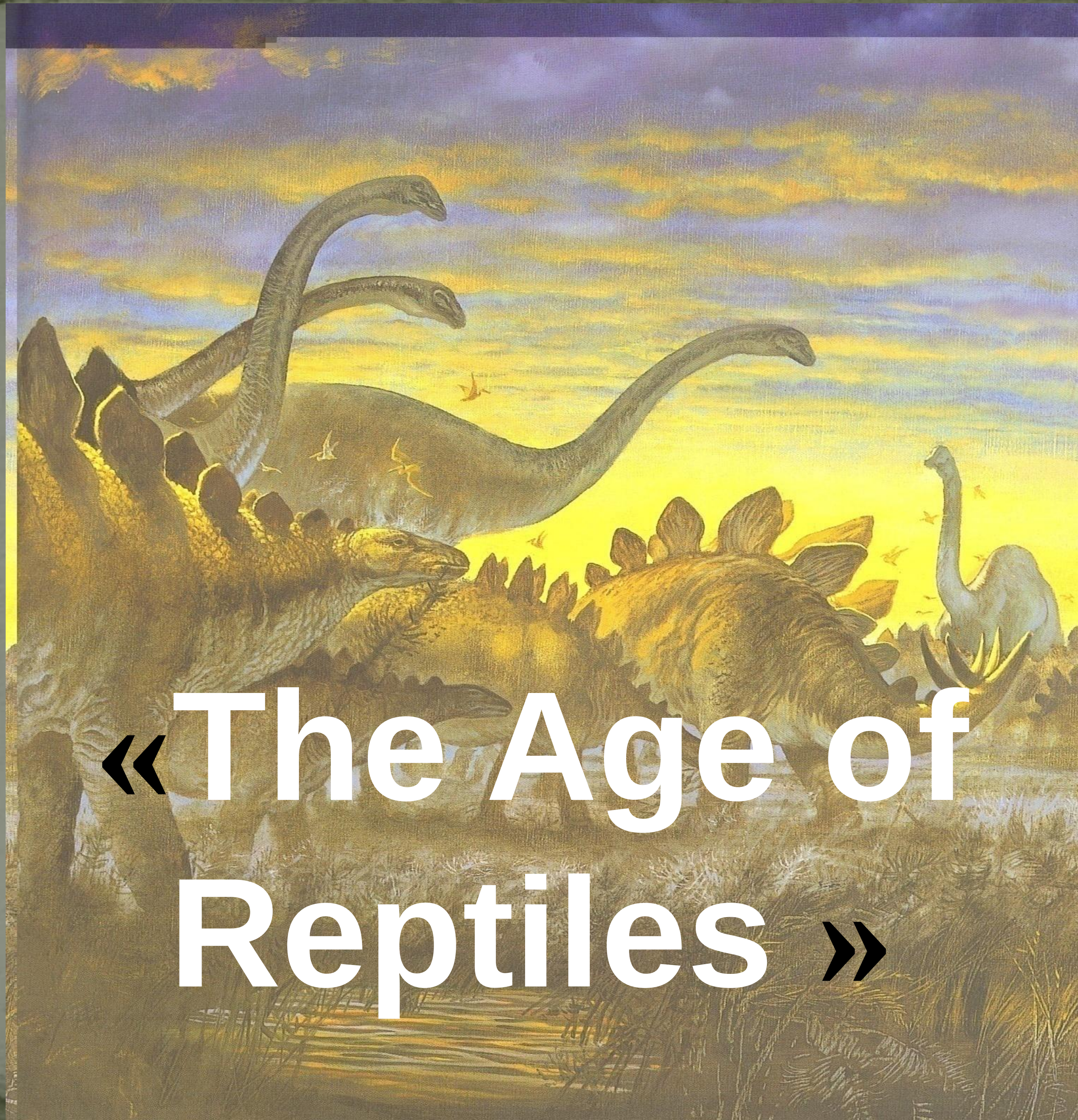
Evidence for Late Cretaceous Cooling

1. Regression of the epicontinental seas
2. Paleomagnetic data show that Antarctica drifted onto the South Pole, and parts of North America were near the North Pole
3. Changes in terrestrial plant populations:
   - Tropical cycads were sharply reduced
   - Ferns declined in North America and Eurasia
   - Conifers and angiosperms became more widespread
4. Oxygen isotope ratios of planktonic organisms, which can be used as paleothermometers, indicate a decline in ocean temperatures beginning about 80 million years ago.

The climatic cooling near the end of the Cretaceous may have contributed to the extinctions of plants and animals at the end of the Mesozoic Era.

Oil And Natural Gas

- Oil and natural gas are primarily formed from the remains of algae and bacteria and other microorganisms, primarily of marine origin.
- The largest oil and gas deposits in the world, in the Middle East and North Africa, come from Jurassic and Cretaceous sedimentary rocks deposited in shelf and reef areas of the Tethys Seaway.
- **Fossil fuels** are derived from the partially decomposed remains of ancient organisms in sedimentary rock.



«The Age of Reptiles »

The Age of Reptiles

- The Mesozoic Era is the "Age of Reptiles".
- During the Mesozoic, reptiles inhabited the land, the seas, and the air.
- Dinosaurs appeared in the Triassic Period, and were the dominant land vertebrates until the end of the Cretaceous.
- Marine reptiles - plesiosaurs, ichthyosaurs, and mosasaurs inhabited Mesozoic seas.
- Reptiles were able to fly by gliding in the Triassic, and to fly with flapping wings by the Jurassic.

The Appearance of Mammals, Birds and Flowering Plants

- Mammals first appeared in the Triassic, evolving from synapsids or so-called "mammal-like reptiles". Early mammals were small and rodent-like.
- The earliest true bird is *Archaeopteryx*, which appeared in the Jurassic Period.
- Flowering plants or angiosperms first appeared in the Early Cretaceous and became dominant during all of later geologic time.

The Diversity of Life in the Mesozoic

- At the beginning of the Mesozoic Era, diversity was low following the Permian extinctions.
- Recovery from the Permian extinctions was slow for many groups.
- In the oceans, the molluscs re-expanded to become much more diverse than in the Paleozoic.
- Modern reef-building corals, swimming reptiles, and new kinds of fishes appeared.

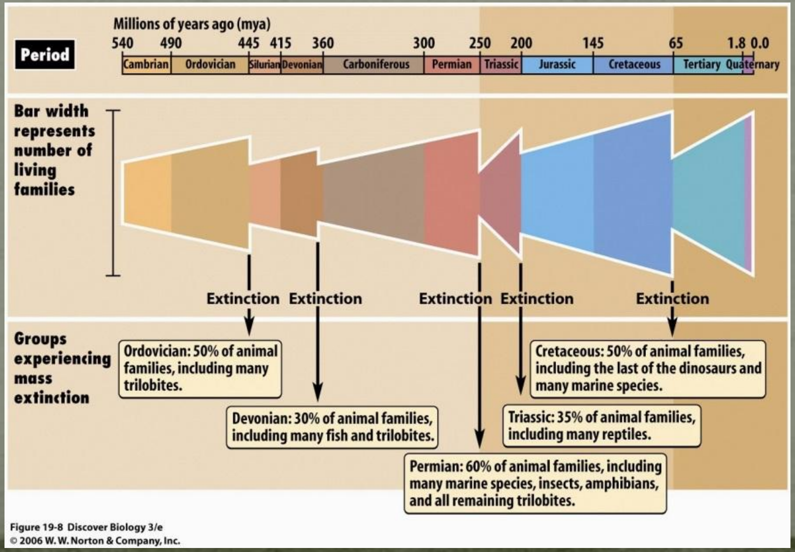
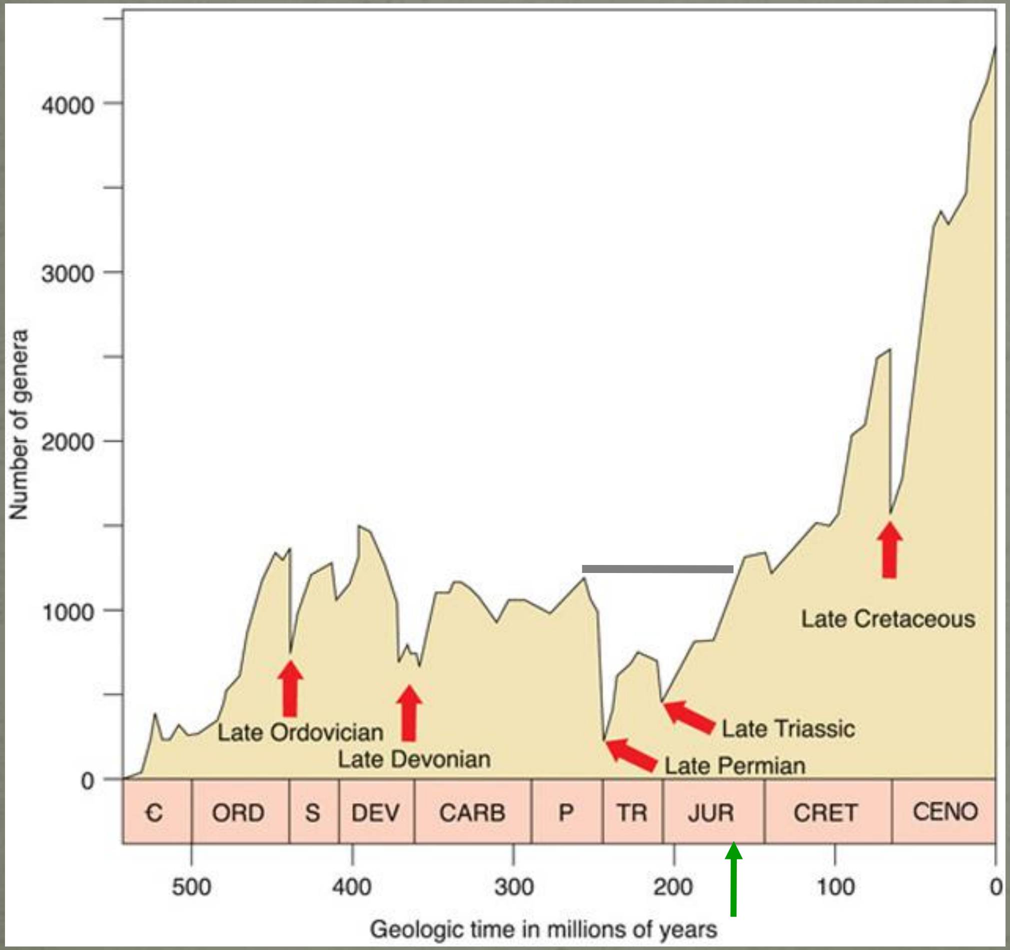


Figure 19-8 Discover Biology 3/e

The Diversity of Life in the Mesozoic

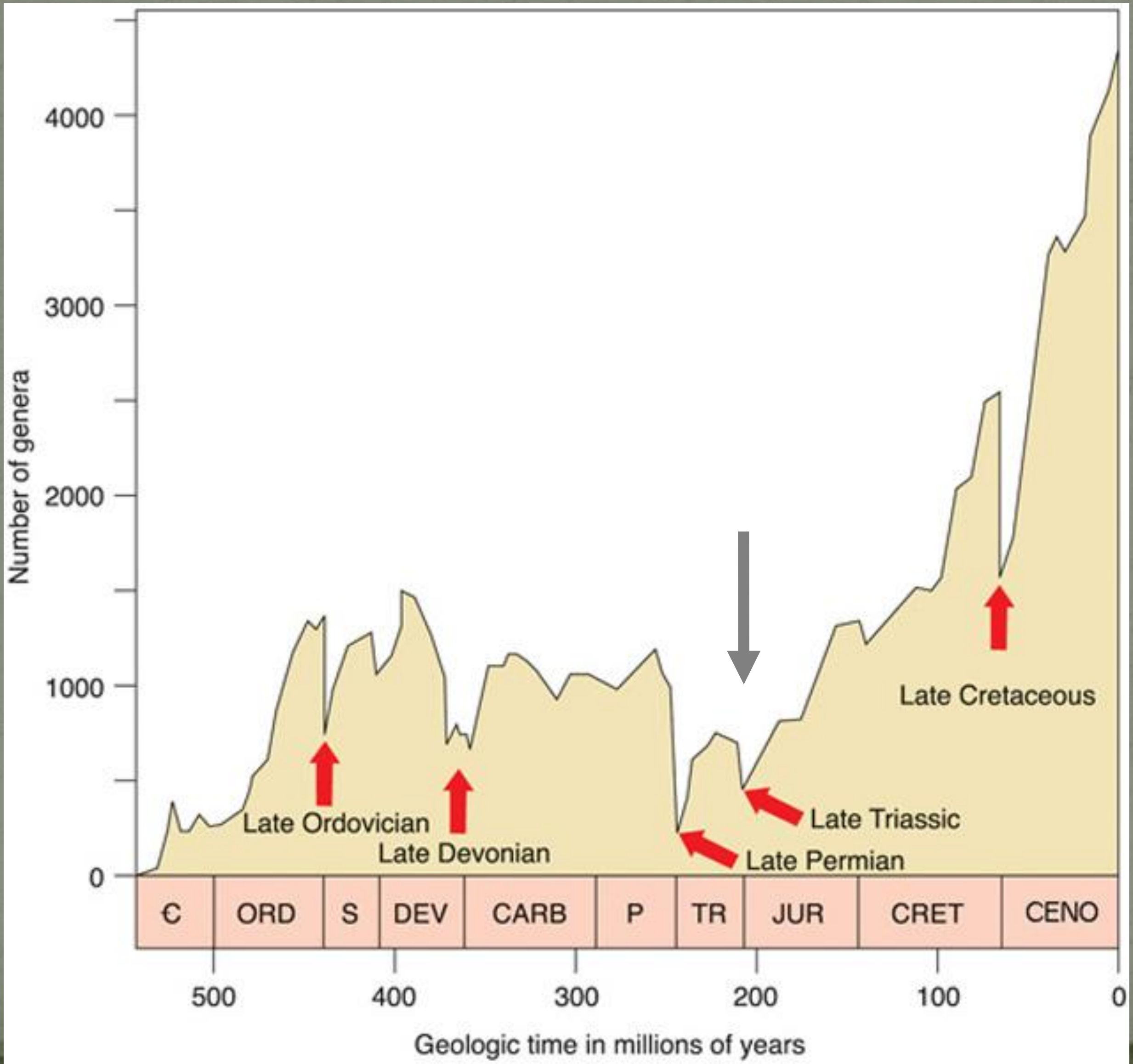


It took 90 - 100 m.y. for diversity to reach the levels it had before the Permian mass extinction event

Diversity in the Triassic

- It started with low diversity.
  It continued with an increase in Diversity and was completed with a mass extinction event.
- During the Triassic appeared the coccolithoforans (Rhaetian), Hexacorals, Squids, Cycads, Anourans, Nothosaurs, placodonts, archosaurs, Phytosaurs, Dinosaurs, Icthyosaurs, Plesiosaurs, Crocodiles, Pterosaurs, Cynodonts and Mammals

Late Triassic Mass Extinction



Late Triassic Mass Extinction

- Mass extinction occurred in the Late Triassic
- Affected life on the land and in the sea
- About 20% of all marine animal families extinct
- Conodonts and placodonts (marine reptiles) extinct
- Bivalves, ammonoids, plesiosaurs, and ichthyosaurs affected but recovered and rediversified in the Jurassic.
- Among the terrestrial organisms affected by the extinction were synapsids (“mammal-like reptiles") and large amphibians.

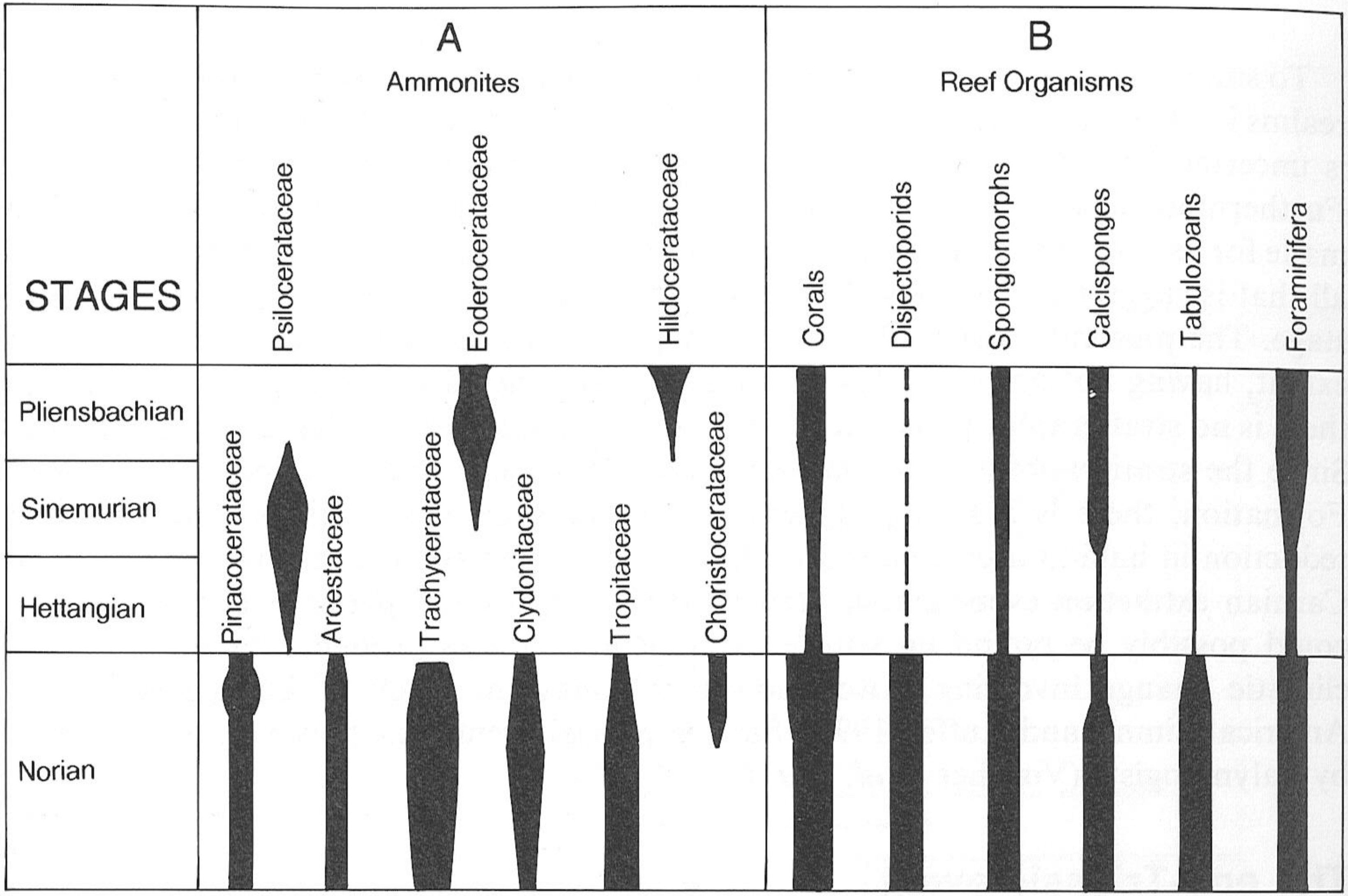
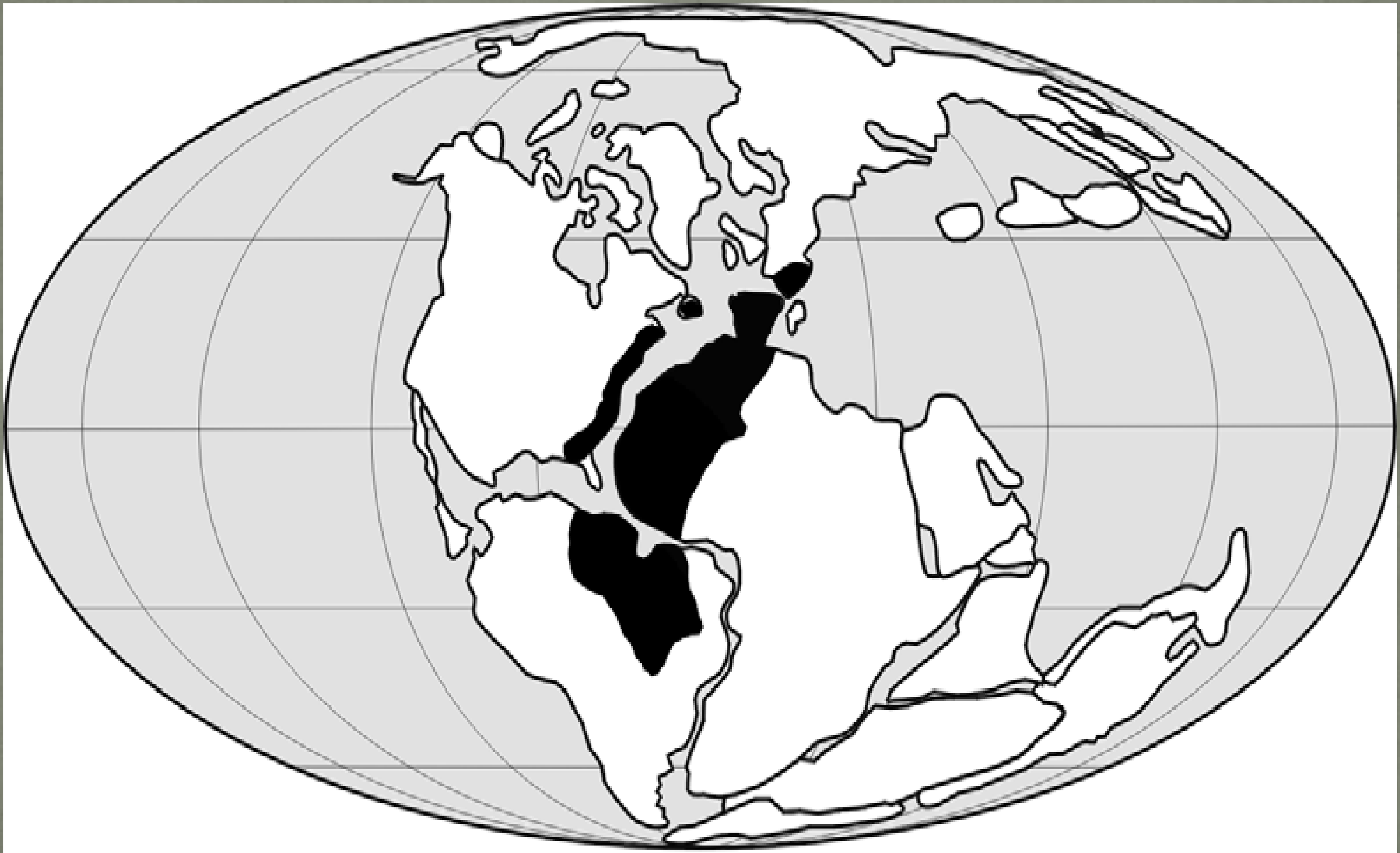


Fig 6.3 End-Triassic (Norian–Hettangian boundary) extinction in important marine groups: A, ammonites; B, reef organisms. After Hallam (1990a).

Mechanisms of Extinction

- Climate change
- Volcanism (Central Atlantic Magmatic District)
- Meteorite impact (no clear indication)
- Changes in sea level
- Anoxic conditions
- Methane releases
- All these together?

The Central Atlantic magmatic province



Late Triassic Mass Extinction

- Environmental intensity from changes in sea level or climate change may have been exacerbated by one or more meteorite impacts and all these have been matched by the climatic effects of volcanism.
- So the resulting scenario involves several mechanisms that although each one may have had no serious effects, but all together could cause a major disruption to life on earth.
- The lack of evidence for a sudden event seems more compatible with the multiple mechanisms Extinction Scenario.

Diversity in the Jurassic and Cretaceous

- The diversity grew again in the Jurassic and grew rapidly during the Cretaceous to the highest levels ever.

- Approximately 2,500 genera of marine animals have been found in the Cretaceous region far more than the level of maximum variation that existed in the Paleozoic (1,000 to 1,500 genera).

Diversity in the Jurassic and Cretaceous

- Much of this expansion in diversity was related to the appearance of new types of marine predators, including advanced teleost fishes, crabs, and carnivorous gastropods.
- The decline of organisms which lived attached to the seafloor (such as brachiopods and stalked crinoids) may be related to the increase in predators in the Cretaceous seas.

Diversity in the Jurassic and Cretaceous

- During the Jurassic appeared: ruddists, gastropods, urodelian amphibians, legless amphibians, planktonic foraminifera, and birds towards the end.
- In the Cretaceous, diatoms, carnivorous gastropods (neogastropods), teleostes, sea turtles and mosasaurs appeared.
- Cretaceous ends with a drop in sea level and closes with a major mass extinction event

Cretaceous Life

- Life in the Cretaceous consisted of a mixture of both modern and ancient forms.
- Modern types of bivalves, gastropods, and fishes were present along with now-extinct organisms such as ammonoids, belemnoids, and marine reptiles.
- On the land, the dominant plants changed from gymnosperms to angiosperms (flowering plants).

Mesozoic Life in the Seas

Life in the Water Column – The Pelagic Realm

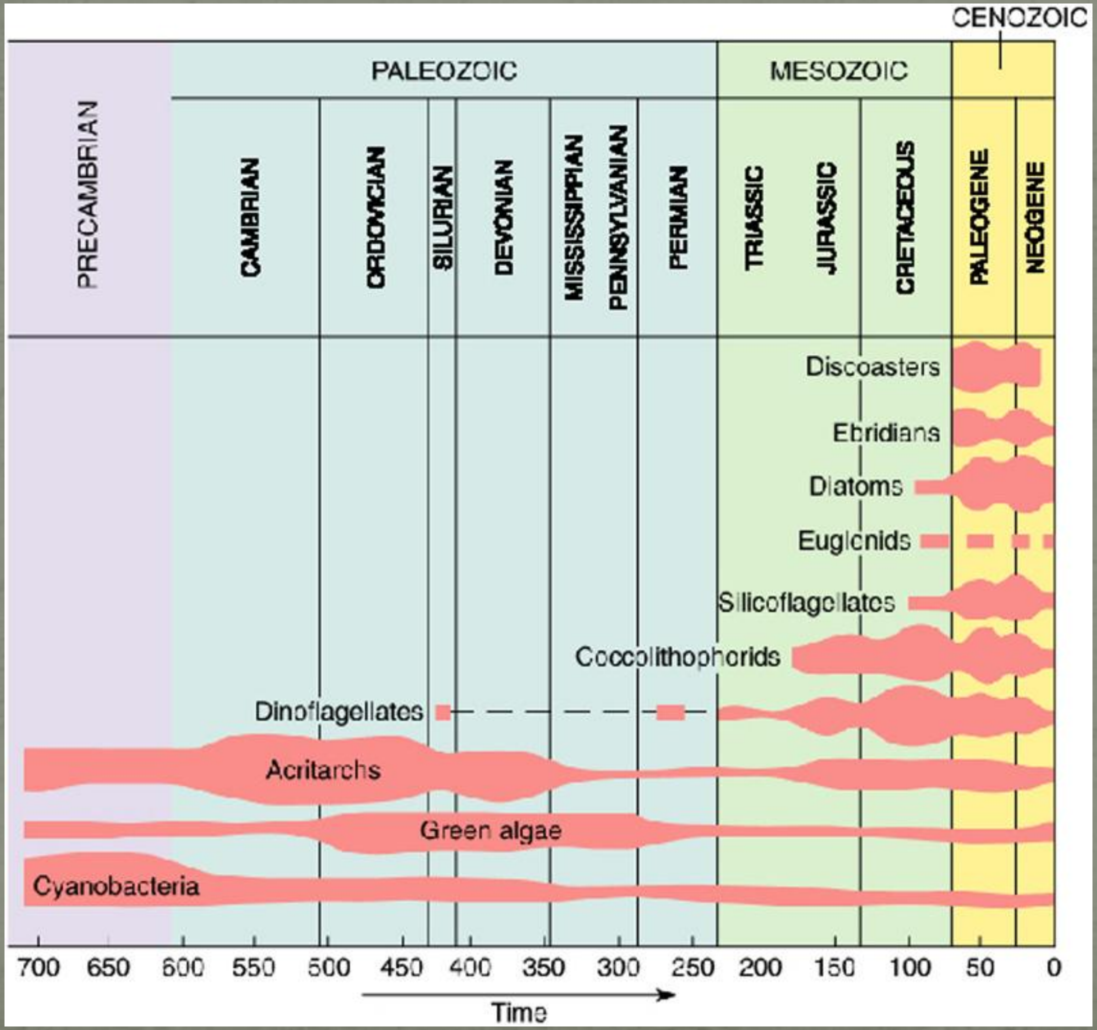
Plankton

- Both plant-like plankton (phytoplankton) and animal-like plankton (zooplankton) were present in the Mesozoic seas.
- Several groups of unicellular organisms adopted a planktonic mode of life at about the same time in the Mesozoic (foraminifera, diatoms, and coccolithophorids).
- This suggests that there must have been a major change in ocean chemistry or food chains in the Cretaceous which led to this development.

Plankton Through Time

- Prior to the Mesozoic, the dominant phytoplankton were organic-walled
  - Cyanobacteria, green algae, acritarchs, dinoflagellates
- Phytoplankton with mineralized skeletons became dominant during the Mesozoic
  - Coccolithophorids, silicoflagellates and diatoms

Geologic ranges and distribution of phytoplankton



Phytoplankton in the Mesozoic Seas

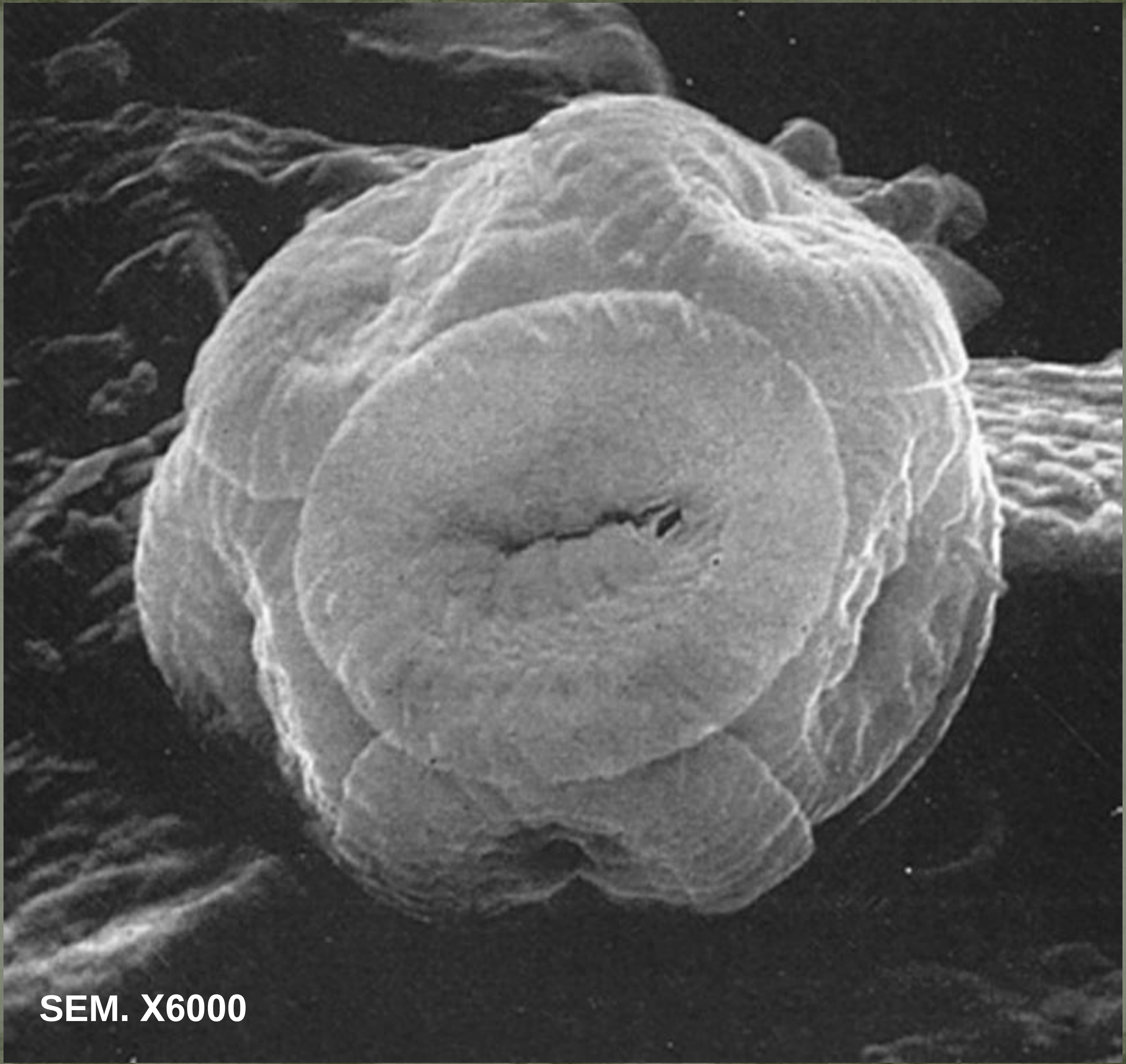
- Diatoms
- Euglenids
- Silicoflagellates
- Coccolithophorids – most abundant
- Dinoflagellates – most abundant
- Acritarchs
- Green algae
- Cyanobacteria

Dinoflagellates

- Organic walled
- Move using flagellae
- Common in Mesozoic and Cenozoic rocks
- Useful in correlation and dating
- Diversified in the mid-Jurassic
- They cause paralytic shellfish poisoning, red tides, and they bioluminesce (glow in the dark).

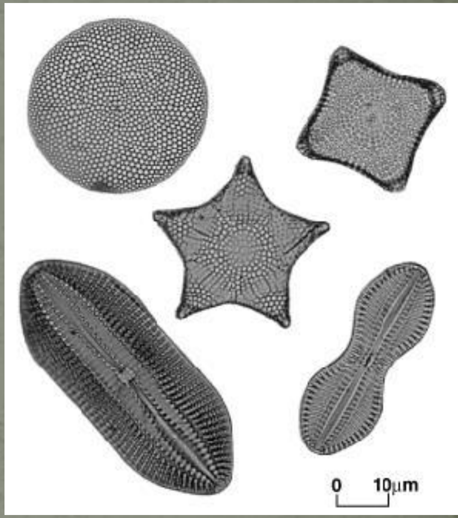
Coccolithophorids

- Appeared in Late Triassic
- Calcium carbonate disks arranged into spherical structures called coccospheres
- So abundant in the Cretaceous that they formed extensive chalk deposits (White Cliffs of Dover)
- Extremely small (0.001 - .015 mm). An electron microscope must be used to view them
- Golden-brown algae (Phylum Chrysophyta)
- Useful in stratigraphic correlation of Cretaceous to Holocene sedimentary rocks


SEM. X6000

Diatoms and Silicoflagellates

- Secrete delicate hard parts made of silica
- Appeared in the Cretaceous
- Declined at the end of the Cretaceous
- Rediversified in the Cenozoic
- Phylum Chrysophyta - golden brown algae, like the coccolithophorids



Diatoms

Zooplankton

- Among the single-celled animal-like plankton (or zooplankton) in the Mesozoic seas were the radiolarians and the foraminifera (often called "forams").
- Both of these groups appeared in the Paleozoic and both belong to Phylum Sarcodina.
- In addition to the planktonic forms, some radiolarians and foraminiferas were benthic or bottom dwellers.

Radiolarians

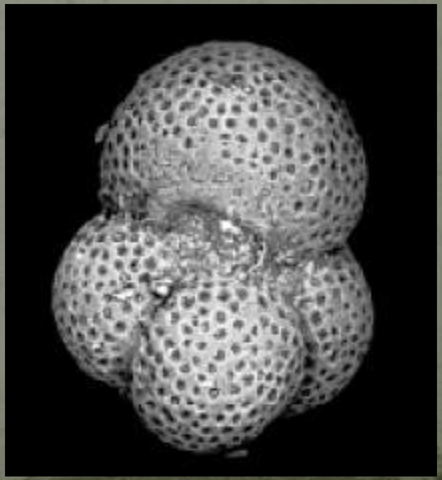
- The radiolarians secrete lace-like skeletons with hard parts made of opaline silica.
- The accumulation of silica skeletons of radiolarians and diatoms in the modern ocean forms siliceous oozes, and in the past, contributed to the formation of chert.

Foraminifera

- Calcium carbonate hard parts
- Paleozoic foraminifera were bottom dwellers (benthic).
- First planktonic foraminifera appeared in the Jurassic
- Planktonic forams experienced an adaptive radiation during the Cretaceous.
- Very useful biostratigraphic indices and for the interpretation of paleogeographic conditions.

Uses of Foraminifera

- Petroleum exploration - Because of their small size and hard shells, large numbers of forams can be recovered while drilling for oil. They are used to correlate and trace stratigraphic units between wells.
- Sensitive indicators of water temperature and salinity
- Useful for interpreting ancient environmental conditions



Mesozoic Invertebrates

- Following the Permian extinctions, the evolution of marine invertebrates in the Mesozoic was relatively slow, as indicated by the limited diversity of Early Triassic faunas.
- Mesozoic invertebrates included both benthic (bottom dwelling) and nektonic (swimming) forms in the sea, as well as freshwater and terrestrial forms.

Mesozoic Invertebrates

Mesozoic benthic marine invertebrates include:

- corals
- bivalves
- gastropods
- sea urchins
- starfish
- crinoids
- sponges
- bryozoans
- brachiopods,
- barnacles

Mesozoic Invertebrates

- Benthic marine organisms include:
  - Sessile forms that live attached to the bottom (corals, sponges, and bryozoans)
  - Vagrant forms that are free to move about (snails and starfish)
- Nektonic organisms that swam in the water column and lived on the seafloor include crayfish, lobsters, crabs, shrimp, and ostracodes.

Mesozoic Invertebrates

- Overall during the Mesozoic there was a decline in sessile benthos.
- The ability to swim or burrow may have been the best defense against increasingly diverse predators.

Corals

- Scleractinian corals or hexacorals appeared in the Triassic.
- Reef-building corals are restricted to clear, warm, shallow waters of normal marine salinity, in part because they have a symbiotic relationship with algae that live within the coral polyp.
- The symbiotic algae are photosynthetic and dependant on sunlight, which necessitates the clear, shallow water.

Corals

- Some Triassic coral reefs were in deep water, suggesting that the symbiotic relationship with algae had not yet developed at that time.
- The symbiotic relationship between corals and algae may not have appeared until the Late Triassic or Early Jurassic.

Molluscs

- The molluscs include:
  - Bivalves
  - Gastropods (snails)
  - Cephalopods (ammonoids, belemnoids, squids, etc.)
- Molluscs diversified following the Permian extinctions, and became more diverse than in the Paleozoic.
- During the Mesozoic, the molluscs surpassed the brachiopods (which had dominated the Paleozoic seafloor).

Bivalves

- Oysters were among the most successful bivalves, including such genera as *Exogyra* and *Gryphaea*.

Exogyra, Κρητιδικό

***Gryphaea*, Ιουρασικό, Κρητιδικό**

Rudist Bivalves

- Rudists were bivalves that built during the Jurassic and Cret
- One of their two valves (or shells) was enlarged and conical in shape, up to 1 m tall.
- The other valve was small and served as a lid on top of the other large, conical valve.
- Rudists became extinct at or near the end of the Cretaceous.


Radiolites
CM


Macgillavryia nicholasi

Gastropods

- Predatory gastropods appeared in the Cretaceous.
- They were able to drill circular holes in shells in order to extract the soft parts of the organism for food.
- This was a new mode of predation not seen before.
- A common living example of a carnivorous gastropod is the moon snail.

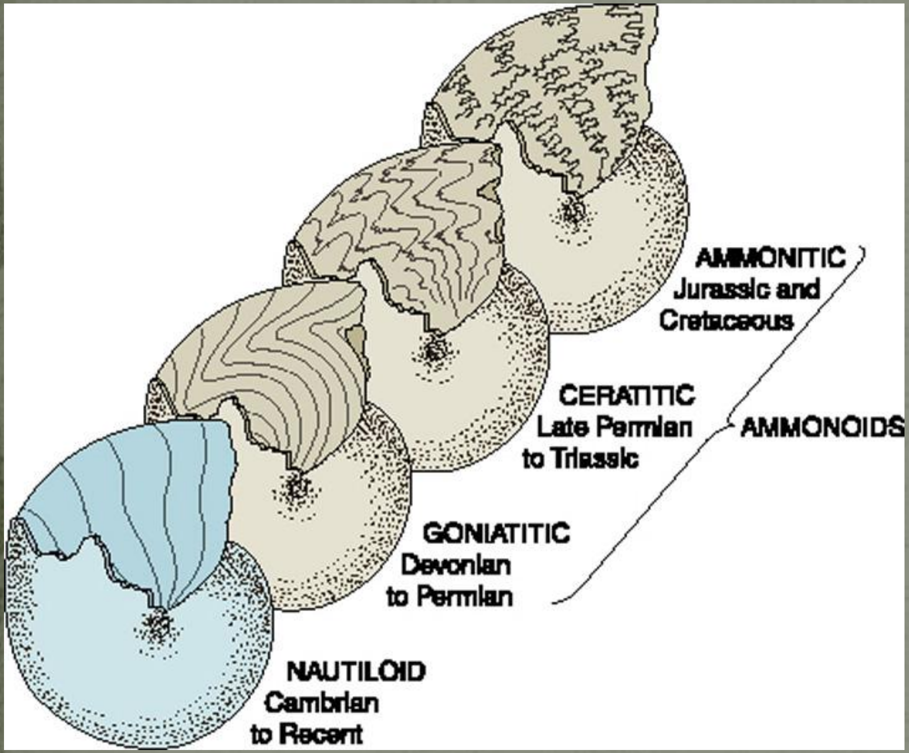
Cephalopods

- The Mesozoic cephalopods include:
  - Ammonoids
  - Nautiloids
  - Belemnoids
  - Squids
- Most were nektonic (swimmers).

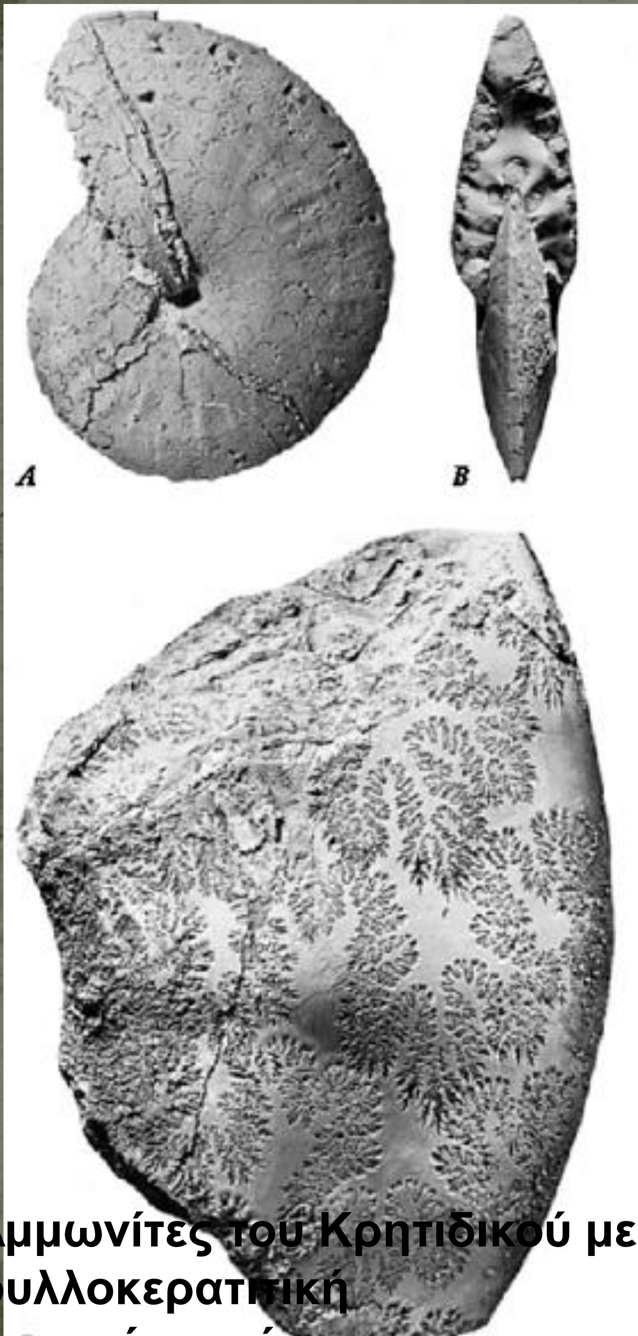
Ammonoids

- Ammonoids were among the dominant swimming invertebrates in Mesozoic seas.
- Ammonoids were so abundant and varied that the Mesozoic could be called the "Age of Ammonoids".
- The geologic range of ammonoid cephalopods is Devonian to Cretaceous.

Suture Patterns



- Three suture patterns of the ammonoids are goniatite, ceratite, and ammononite.
- Nautiloid cephalopods have smoothly curved septa.



Αμμωνίτες του Κρητιδικού με φυλλοκερατιτική γραμμή ραφής

Αμωνίτης του Τριαδικού με κερατιάτικη γραμμή ραφής

Squids

- Squids were numerous during the Jurassic and Cretaceous.
- Soft parts are preserved in a few rare specimens.
- Squids may have evolved from Triassic belemnites.

Arthropods

- Modern types of marine crustaceans and other types of arthropods appeared during the Mesozoic, including crabs, shrimp, crayfish, lobsters, and ostracodes.

Echinoderms

- All echinoderms have 5-part symmetry.
- Echinoids include the sand dollars, sea biscuits, and sea urchins.
- Echinoids became more diverse in the Mesozoic than they had been during the Paleozoic.
- Other echinoderms included starfish and ophiuroids (or brittle stars). Crinoids were not as common as they had been during the Paleozoic.

Invertebrates in Terrestrial Aquatic Settings

- Pulmonate or air-breathing snails (rare)
- Freshwater snails
- Freshwater clams
- Freshwater crustaceans
  - Ostracodes
  - Conchostracans ("clam-shrimp")
  - Notostracans ("tadpole-shrimp")
- Worms (trace fossils)
- Spiders, millipedes, centipedes, insects

Mesozoic Vertebrates

Fishes

- Two major types of fishes existed during the Mesozoic:
  - Chondrichthyes - cartilaginous fishes or sharks
  - Osteichthyes - ray-finned bony fishes
- Both of these groups existed during the Paleozoic, and experienced a decline during the Permian extinction, and both groups rediversified during the Mesozoic.
- Jawless fishes (Agnatha) were also present.

Evolutionary Changes in the Fishes

- Many evolutionary changes occurred among the fishes during the Mesozoic. By the end of the Mesozoic, few fishes remained with primitive characteristics.
- The swim bladder appeared during the Mesozoic Era. It is a sac of gases used for buoyancy regulation.
- The swim bladder evolved from the lungs that were present in Paleozoic fishes.

Teleost fishes

- Teleost fishes appeared during the Cretaceous.
- Dominant groups of marine and freshwater fishes in the world today.
- Teleost fishes have the following characteristics:
  - Round scales
  - Symmetrical tails
  - Specialized fins
  - Short jaws adapted for specific kinds of food.

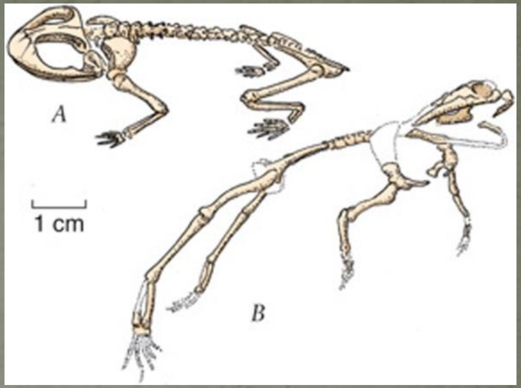
Cretaceous Fish

***Xiphactinus audax**, a ray-finned fish, the largest bony fish of the Cretaceous. Typically 18-20 feet long. Niobrara Chalk, Lane County, Kansas. Temporary exhibit on display at the Fernbank Museum of Natural History.*

Amphibians

- A group of labyrinthodont amphibians (known as temnospondyls) from the late Paleozoic survived the Permian extinctions, but declined after the Triassic.
- Their descendants are the modern amphibians (called Lissamphibia).

Amphibians



The Lissamphibia include:

- Frogs and toads (Anuria)
  Oldest known frog is from Early Triassic of Madagascar.
- Salamanders and newts (Urodela)
  The oldest known are from Late Jurassic of Kazakhstan.
- Limbless amphibians (Caecilians)
  Although they resemble earthworms, they have as many as 200 vertebrae. The oldest is from Early Jurassic of Arizona.

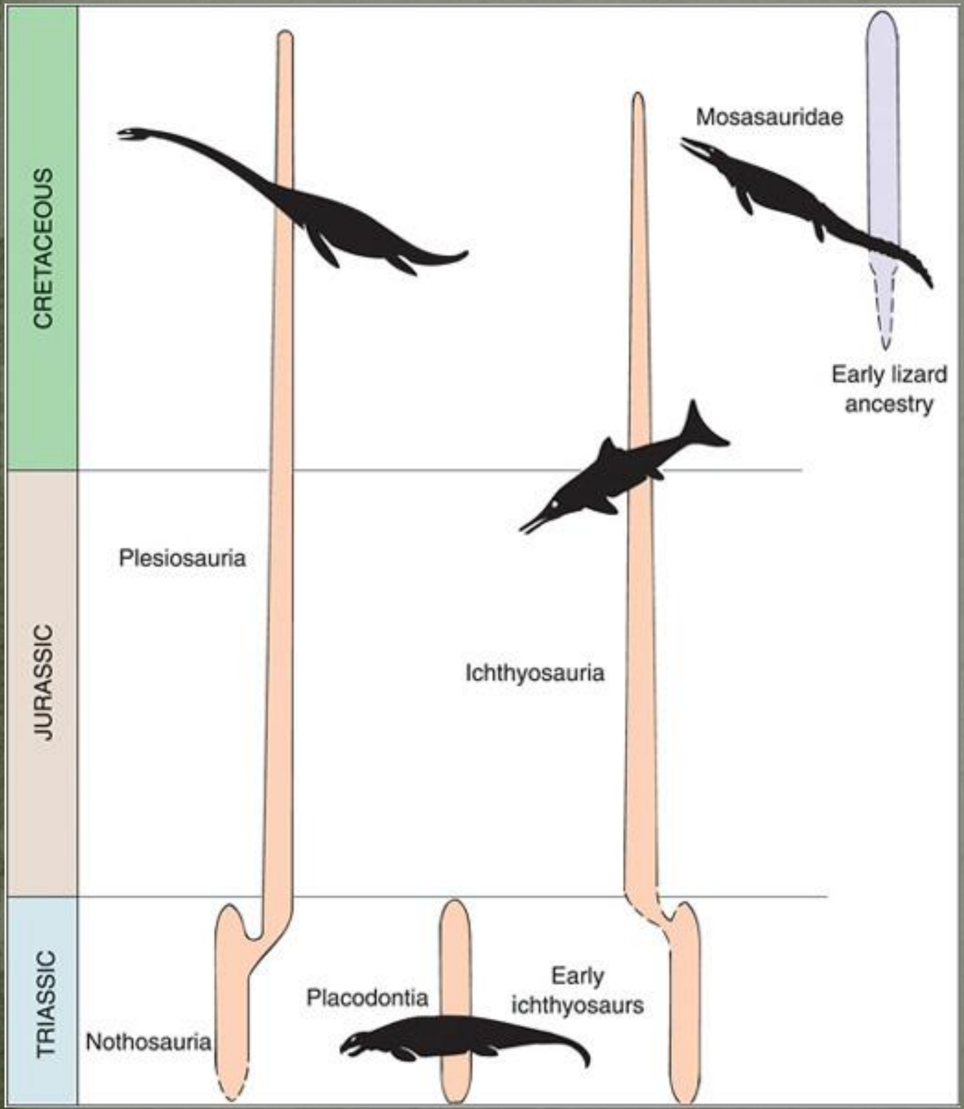
Reptiles

- Reptiles were diverse during the Mesozoic.
- Many new groups of reptiles appeared in the Mesozoic including the ancestors of the turtles, and many types of marine reptiles.
- The most interesting of Mesozoic reptiles were the archosaurs, a group of large diapsids which includes crocodiles, extinct flying reptiles, dinosaurs, and thecodonts.

Reptiles Colonize the Sea

- Several groups of reptiles were successful in adapting to the marine environment.
- The colonization of the sea by reptiles may seem somewhat "backwards", because reptiles originally developed adaptations so that they could live on dry land without returning to the aquatic environment for reproduction.
- In this case, the reptiles, as predators, seem to be colonizing the sea to take advantage of an abundant food source.
- Marine reptiles fed on ammonoids, sharks, and bony fishes that populated the seas.

Mesozoic Marine Reptiles



1. Nothosaurs
2. Placodonts
3. Plesiosaurs
4. Ichthyosaurs ("fish-lizards")
5. Mosasaurs
6. Crocodiles
7. Sea turtles

Dinosaurs

- The name "dinosaur" comes from the Greek *deinos* = "terrifying" and *sauros* = "lizard".
- Dinosaurs appeared in the Late Triassic, about 225 m.y. ago.
- The earliest dinosaurs were small. Many were less than 1 m long.
- By the end of the Triassic, dinosaurs were up to 6 m long.
- They became much larger later in the Jurassic and Cretaceous.

Pterosaurs

- Pterosaurs dominated the skies for more than 100 million years. They existed from the Late Triassic to the Late Cretaceous.
- Jurassic and Cretaceous pterosaurs had large heads and eyes, and long jaws with thin slanted teeth.
- The bones of the fourth finger were elongated to support the wing membrane.

Birds

- Feathers evolved from reptilian scales. The earliest feathers may have been used for insulation, camouflage, or display, rather than flight.
- It has been proposed that birds are closely related to dinosaurs, and that the two should be reclassified into Class Dinosauria. This would eliminate Class Aves (where birds are currently classified). This has not yet been generally accepted.

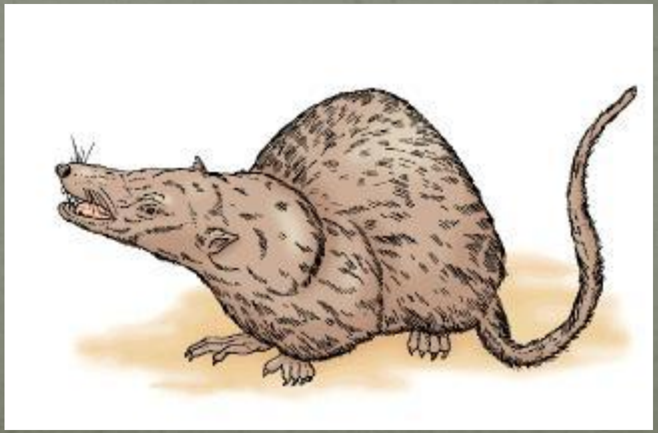
Origin of Birds

- Bird-like features are found in some dinosaurs, including feathers or protofeathers, in *Sinosauropteryx prima*, more than 120 million years old, and *Caudipteryx zoui*, a dinosaur with a feathered tail.
- The line between dinosaurs and birds has blurred with the new discoveries, so it is difficult to say when the first bird appeared.
- Birds probably appeared near the end of the Jurassic.
- Many different types of birds lived during the Cretaceous Period.

The Rise of Mammals

- Therapsids became extinct in the Early Jurassic, after giving rise to the mammals.
- Mammals evolved in the Late Triassic.
- Early mammals were rodent-like, and remained small throughout the Mesozoic.

Morganucodon, an early mammal from the Late Triassic



The early Mesozoic was dominated by plants which did not bear flowers. These included:

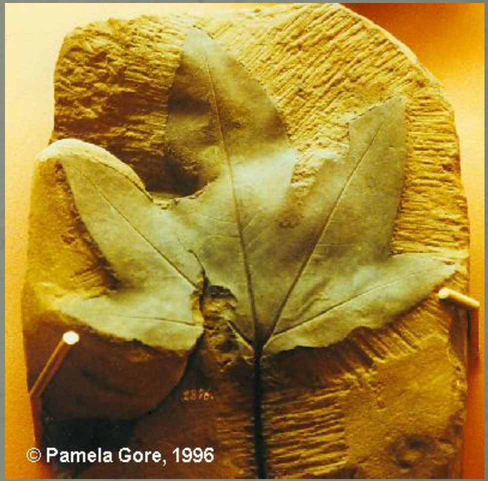
1. **Ferns** - spore-bearing plants, dominant during the Triassic.
2. **Seed ferns** - less abundant than during the Paleozoic, but survived into the middle Mesozoic. Extinct.
3. **Lycopods** (scale trees) and **sphenopsids** survived into the Mesozoic. Most were small. The decline of lycopods, sphenopsids and cordaites trees began before end of Permian.

4. **Gymnosperms** - dominant trees in the Triassic and Jurassic. Pollinated by wind. Their seeds are exposed, rather than being enclosed within fruits. “Gymnosperm" means "naked seed".

Types of gymnosperms include:

a. Cycads
b. Ginkgoes
c. Conifers

Angiosperms – The Flowering Plants



Angiosperms

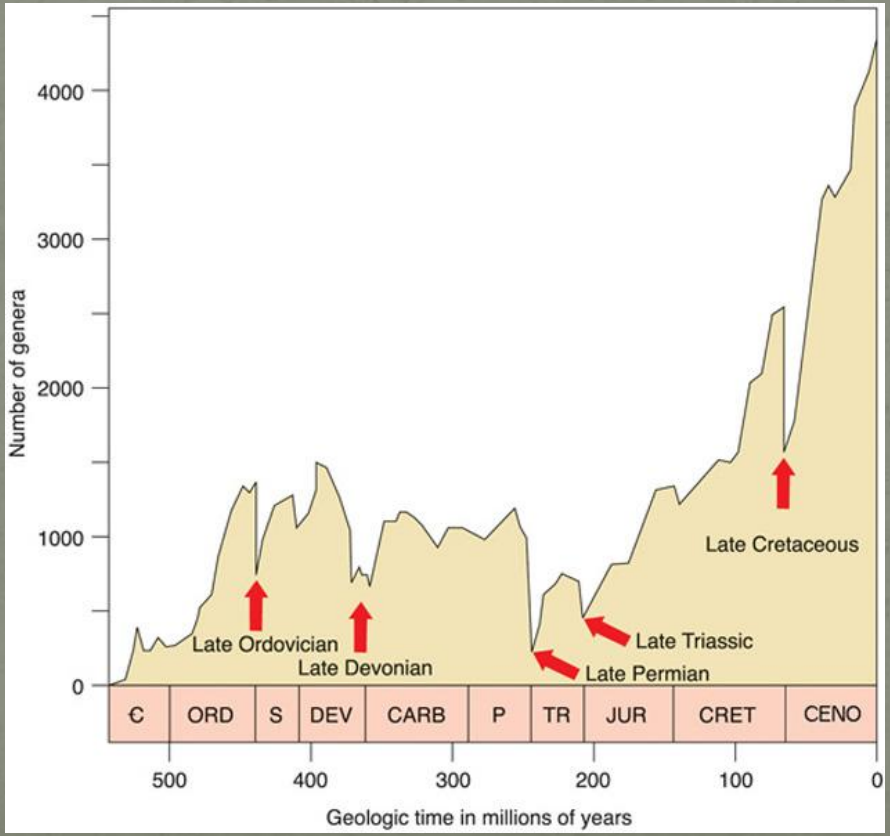
- The angiosperms or flowering plants made their first appearance during the Cretaceous.
- Angiosperms diversified while the gymnosperms declined during the Late Cretaceous.

- Angiosperms provide many examples of coevolution with Mesozoic insects, dinosaurs, mammals, and birds.
- Coevolution occurs when two or more different organisms become dependent on one another.
- An example involves the coevolution of insects and flowering plants.
- Insects depended on the plants for food, and the plants depended on the insects for pollination.
- Plant differences evolved due to competition for pollinators.
- Different insects were attracted by different varieties of flowers.

Late Cretaceous Extinction

- The Mesozoic Era ended with a major extinction.
- Affected both vertebrates and invertebrates, on land and in the sea.

A mass extinction occurred at the end of the Cretaceous Period that caused the disappearance of about 1000 genera of marine animals, and about 25% of all known families of animals.



- Many groups died out gradually, and others disappeared suddenly.
- The extinctions did not all happen simultaneously.
- On land, only small (less than 20 kgs) animals survived.
- Of the reptiles, only turtles, snakes, lizards, crocodiles, and the tuatara (a reptile from New Zealand) survived the extinction.
- More than 75% of the marine plankton species disappeared at the end of the Cretaceous.

Animals both on land and in the sea were affected. The extinction at the end of the Cretaceous totally wiped out these groups:

- **Dinosaurs**
- **Pterosaurs** (flying reptiles)
- **Ammonoids** (cephalopod molluscs)
- **Large marine reptiles** (**ichthyosaurs**, **plesiosaurs** & **mosasaurs**)
- **Rudists** (bivalve molluscs)
- and many other invertebrate taxa

There were drastic reductions of these groups, wiping out entire families. Some of these groups had very few survivors:

- **Coccolithophores** (calcareous phytoplankton)
- **Planktonic foraminifera**
- **Radiolarians**
- **Belemnoids** (cephalopod molluscs)
- **Echinoids**
- **Bryozoans**

What caused the extinctions?

There are many **hypotheses** to attempt to explain the cause of these extinctions. They can be divided into two groups:

1. Catastrophic external or extraterrestrial triggers for the event
2. Events occurring on the Earth, without outside influences

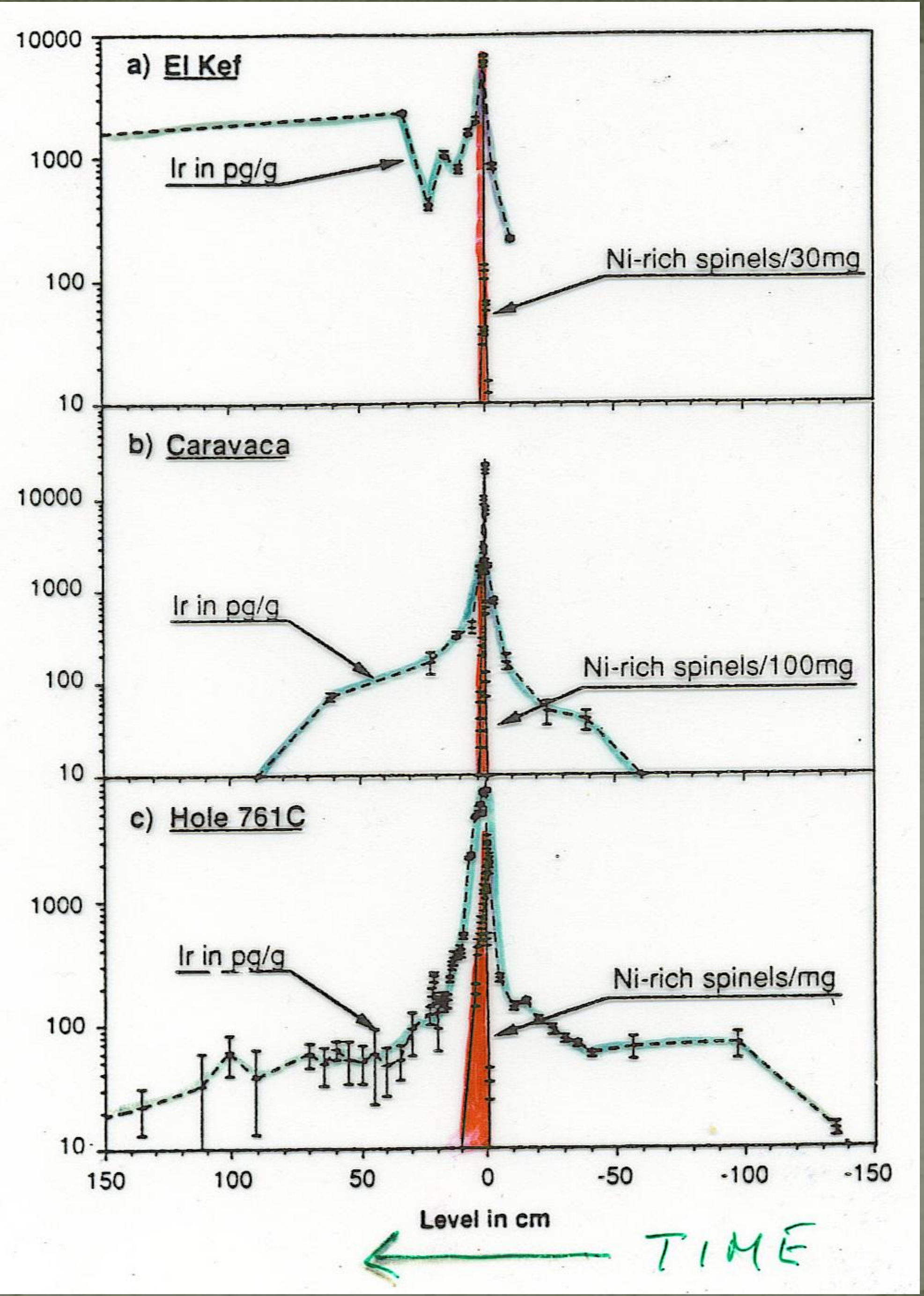
Hypotheses of catastrophic external or extraterrestrial triggers for the event

- Asteroid impact?
- Comet impact?
- Cosmic radiation from a nearby supernova?

Evidence for extraterrestrial causes?

- A thin layer of clay with a concentration of **iridium** is found at the boundary at the end of the Cretaceous Period (the boundary clay).
- Since iridium is more abundant in meteorites than in normal Earth's surface rocks, it was proposed that a large impact of an extra terrestrial object with the Earth at the end of the Cretaceous might have spread iridium around the globe.
- Other things may also have been responsible for the presence of the iridium, and all possibilities must be considered.

Fig 9.6 K–T boundary section at Stevns Klint. Denmark showing 1, latest Maastrichtian chalk (capped by a hardground); 2, the Fish Clay at the boundary, and 3, Danian bryozoan calcarenites. Thomas Wignall for scale.


a) El Kef
Ir in pg/g
Ni-rich spinels/30mg
b) Caravaca
Ir in pg/g
Ni-rich spinels/100mg
c) Hole 761C
Ir in pg/g
Ni-rich spinels/mg
10000
1000
100
10
150
100
50
0
-50
-100
-150
Level in cm
TIME

Other evidence for extraterrestrial causes?

- Shocked quartz (from an impact?)
- Tiny glass spherules or tektites (cooled droplets of molten rock from an impact?)
- Carbon soot (ash) (remnants of forests burned in a firestorm caused by an impact?)


HARDY

If a bolide (large extraterrestrial object) collided with the Earth, where is the impact crater?

The most likely location of an impact structure of the proper age is the **Chicxulub structure**, a buried circular crater-like structure on the Yucatan Peninsula of Mexico.

Hypotheses for the extinction involving events occurring on the Earth, without outside influences

1. Volcanic eruptions causing ash and aerosols in atmosphere leading to a drop in temperature. *Volcanism was widespread toward the end of the Cretaceous, and volcanic ash can be a source of iridium.*

   Other elements in the boundary clay like antimony and arsenic are common in volcanic ash but not in meteorites.
2. Volcanic eruptions releasing sulfur dioxide, leading to sulfuric acid in the atmosphere and acid rain, changing the alkalinity of the oceans, and placing lethal stress on plankton at the base of the food chain, and indirectly affecting the organisms that depended on them for food.

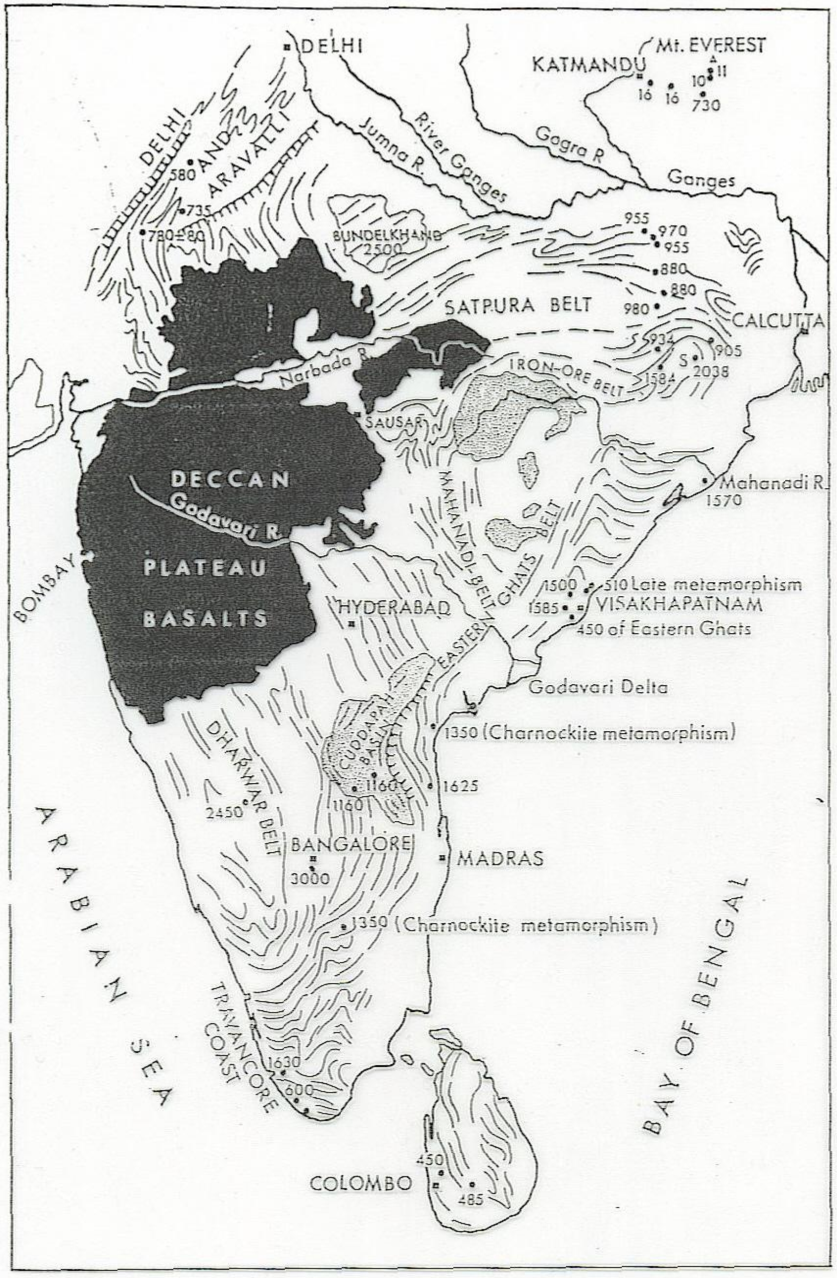


Fig. 880 Provisional tectonic map of the Precambrian orogenic belts of Peninsular India (*Arthur Holmes*, 1955, *with additional data from U. Aswathanarayana and S. N. Sarkar*, 1963)

3. Decrease in rate of seafloor spreading, leading to a sea level drop, which eliminated the epicontinental seas.
   There is evidence for a global lowering of sea level at the end of the Mesozoic. Disappearance of the epicontinental seas would have meant a habitat loss for many shallow water species.
4. Climatic change as a result of the lowering of sea level and disappearance of the epicontinental seas. Would have caused a harsher climate and more extreme seasonality.

5. Change in atmospheric CO_2 levels and O_2 levels, as a result of the appearance of new types of plants, or the proliferation of photosynthetic plankton that formed the Cretaceous chalk deposits?
7. Appearance of angiosperms changed food chain on land? (Many of the dinosaurs ate gymnosperms.)
8. Disease? Viruses?
9. Magnetic reversal?
10. Other?

Whatever the cause, changing environmental conditions at the end of the Mesozoic Era led to the disappearance of many kinds of organisms in what may have been a domino effect, as organisms at the base of the food chain were killed, sending waves of extinctions through species higher on the food chain that depended on them.

Once again we see that in mass extinctions, the factors that affect degradation of ecosystems are several and all contribute towards increasing the power of an event and thus causing a mass extinction event.