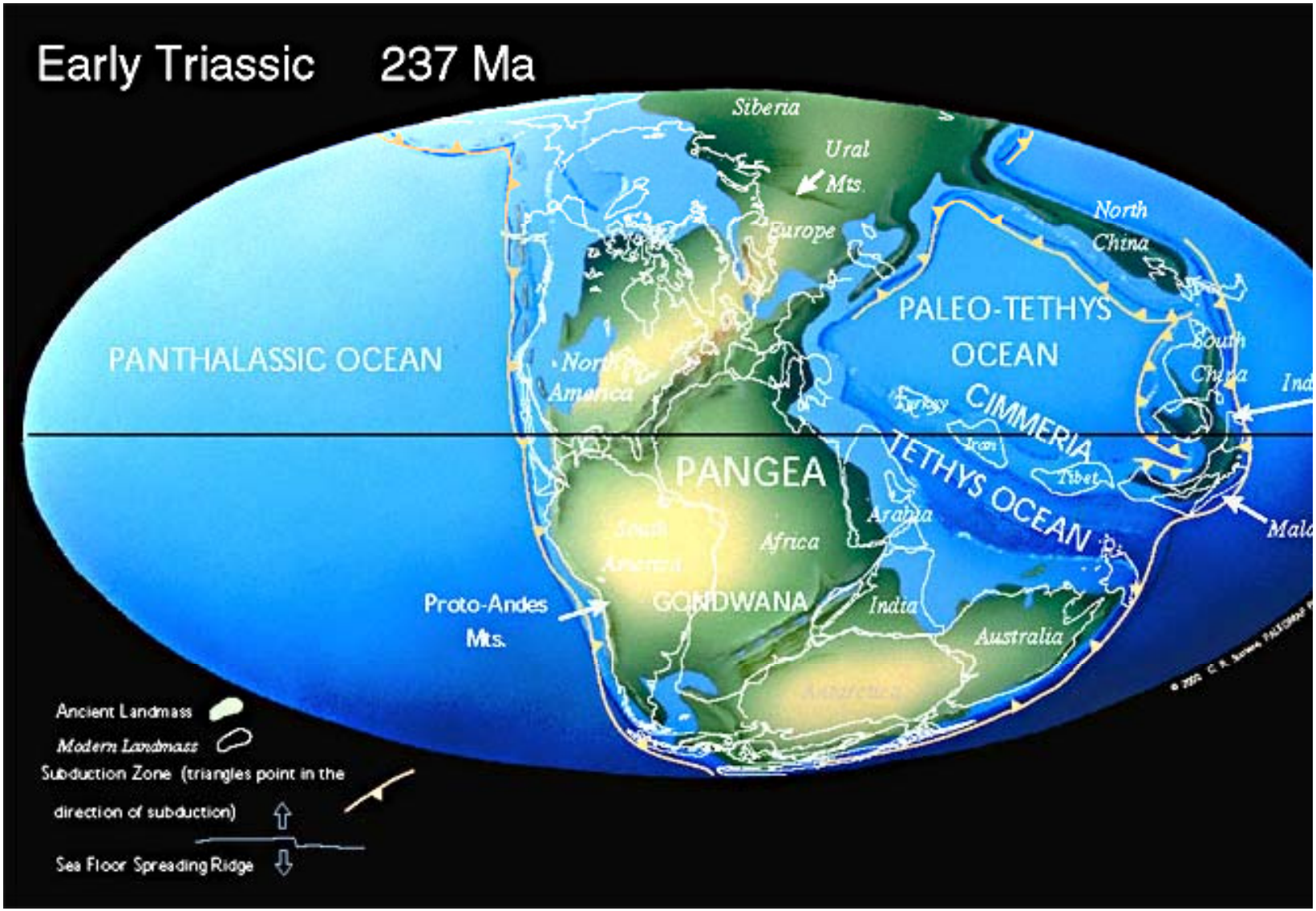
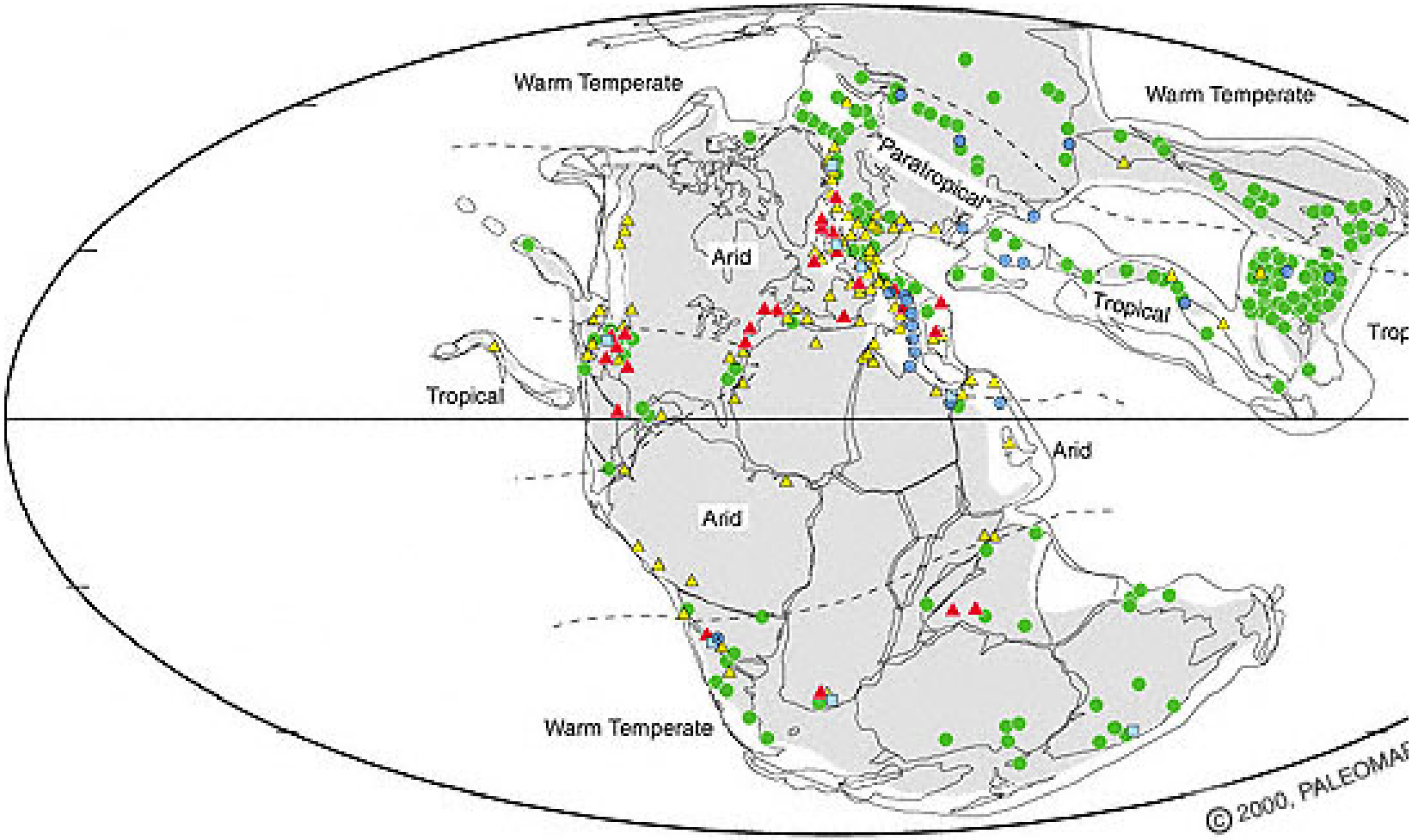
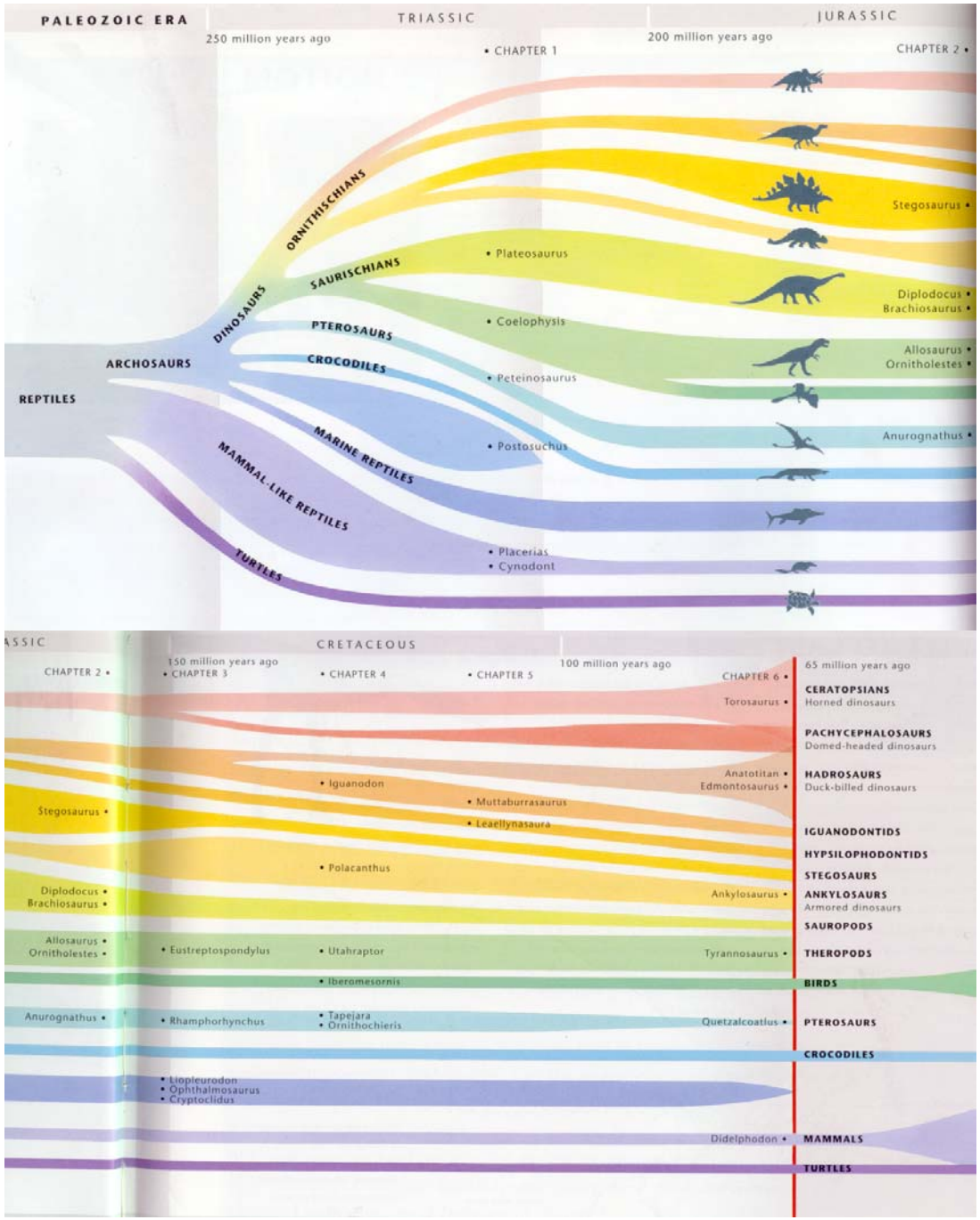
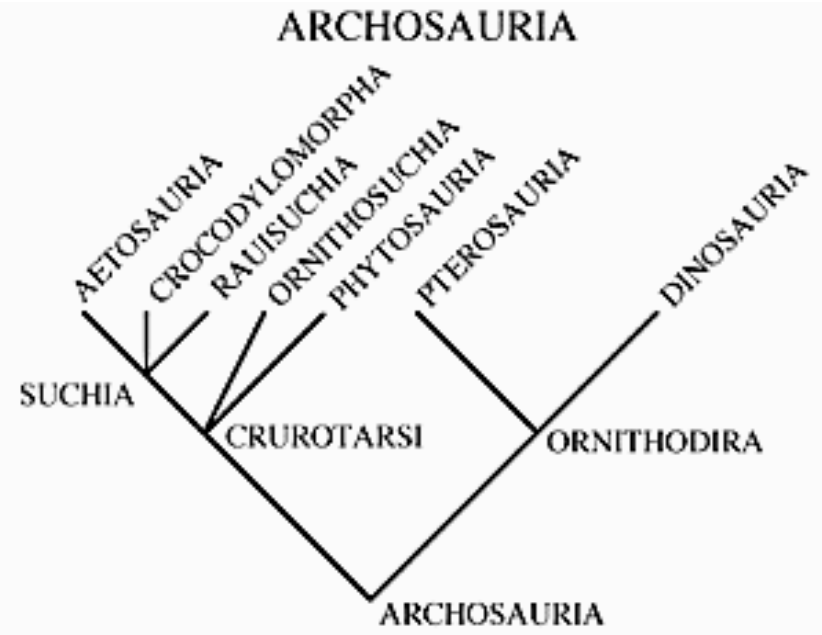
Period	**Classic Dinosaur Locality**
Late Triassic	Petrified Forest, St. John's, Arizona.
	Ghost Ranch, New Mexico.
Early Jurassic	
Late Jurassic	Morrison Formation. Colorado/Wyoming.
Early Cretaceous.	Wealden beds. Southern England.
Late Cretaceous.	Flaming Cliffs, Mongolia.
	Hell Creek Formation, Montana.

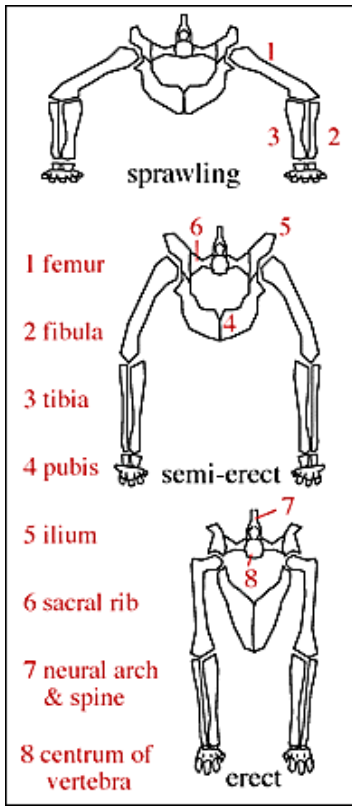

Early Triassic 237 Ma
Siberia
Ural Mts.
Europe
North China
PALEO-TETHYS OCEAN
South China
PANTHALASSIC OCEAN
North America
CIMMERIA
Turkey
Iran
Tibet
TETHYS OCEAN
PANGEA
Arabia
Africa
South America
Proto-Andes Mts.
GONDWANA
India
Australia
Ancient Landmass
Modern Landmass
Subduction Zone (triangles point in the direction of subduction)
Sea Floor Spreading Ridge



Upper Triassic


PALEOZOIC ERA
TRIASSIC
JURASSIC
250 million years ago
200 million years ago
• CHAPTER 1
CHAPTER 2 •
REPTILES
ARCHOSAURS
DINOSAURS
ORNITHISCHIANS
SAURISCHIANS
PTEROSAURS
CROCODILES
MARINE REPTILES
MAMMAL-LIKE REPTILES
TURTLES
• Plateosaurus
• Coelophysis
• Peteinosaurus
• Postosuchus
• Placerias
• Cynodont
Stegosaurus •
Diplodocus •
Brachiosaurus •
Allosaurus •
Ornitholestes •
Anurognathus •
ASSIC
CRETACEOUS
150 million years ago
100 million years ago
65 million years ago
CHAPTER 2 •
• CHAPTER 3
• CHAPTER 4
• CHAPTER 5
CHAPTER 6 •
Torosaurus •
CERATOPSIANS
Horned dinosaurs
PACHYCEPHALOSAURS
Domed-headed dinosaurs
Anatotitan •
Edmontosaurus •
HADROSAURS
Duck-billed dinosaurs
• Iguanodon
• Muttaburrasaurus
• Leaellynasaura
Stegosaurus •
IGUANODONTIDS
HYPSILOPHODONTIDS
• Polacanthus
STEGOSAURS
Diplodocus •
Brachiosaurus •
Ankylosaurus •
ANKYLOSAURS
Armored dinosaurs
SAUROPODS
Allosaurus •
Ornitholestes •
• Eustreptospondylus
• Utahraptor
Tyrannosaurus •
THEROPODS
• Iberomesornis
BIRDS
Anurognathus •
• Rhamphorhynchus
• Tapejara
• Ornithochieris
Quetzalcoatlus •
PTEROSAURS
CROCODILES
• Liopleurodon
• Ophthalmosaurus
• Cryptoclidus
Didelphodon •
MAMMALS
TURTLES





Phytosaur body plan. Sprawling.

Dinosaur body plan, Upright stance: *Coelophysis*.

Triassic Summary

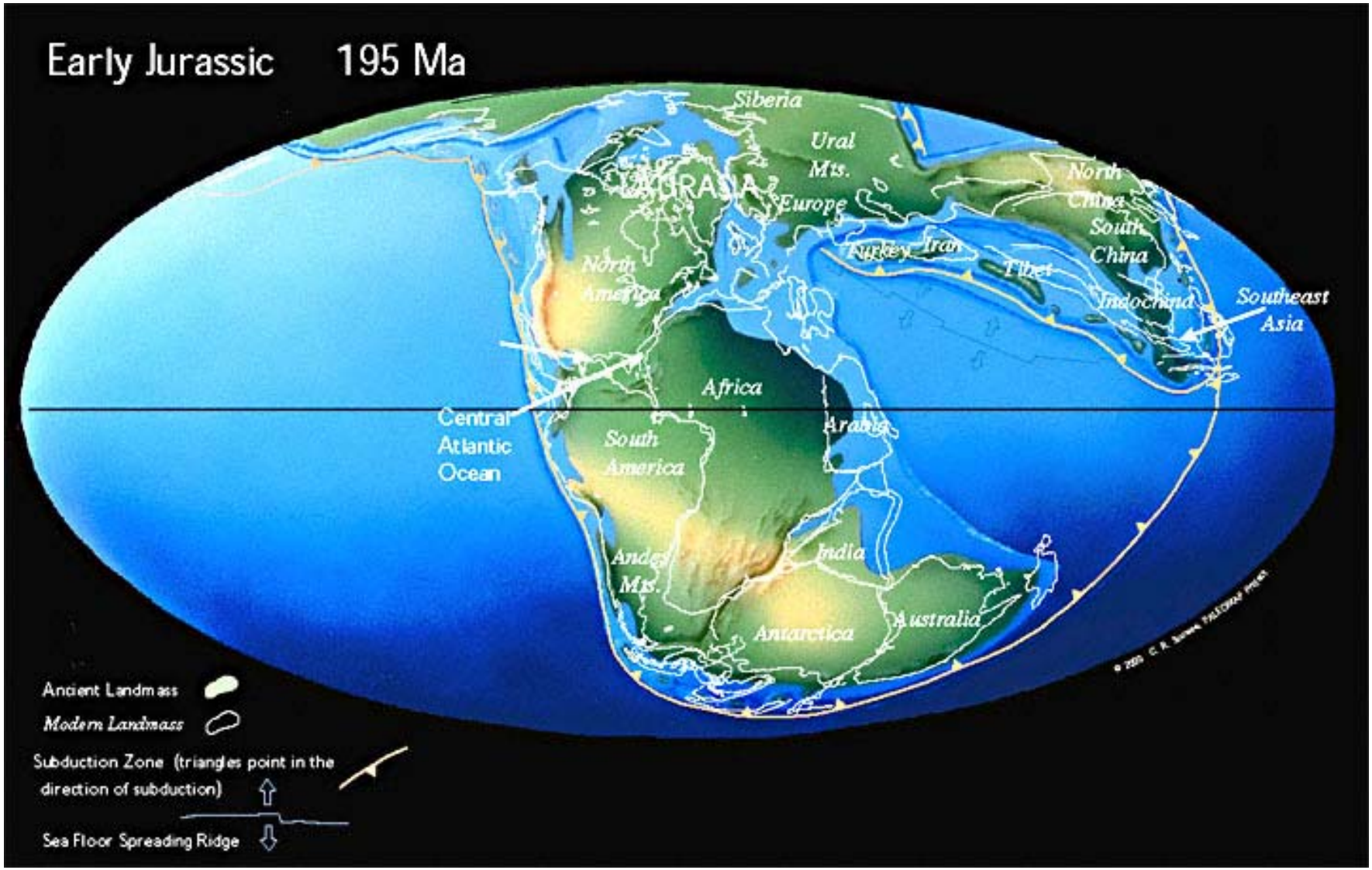
Pangaea assembled until ~ Triassic/Jurassic boundary.

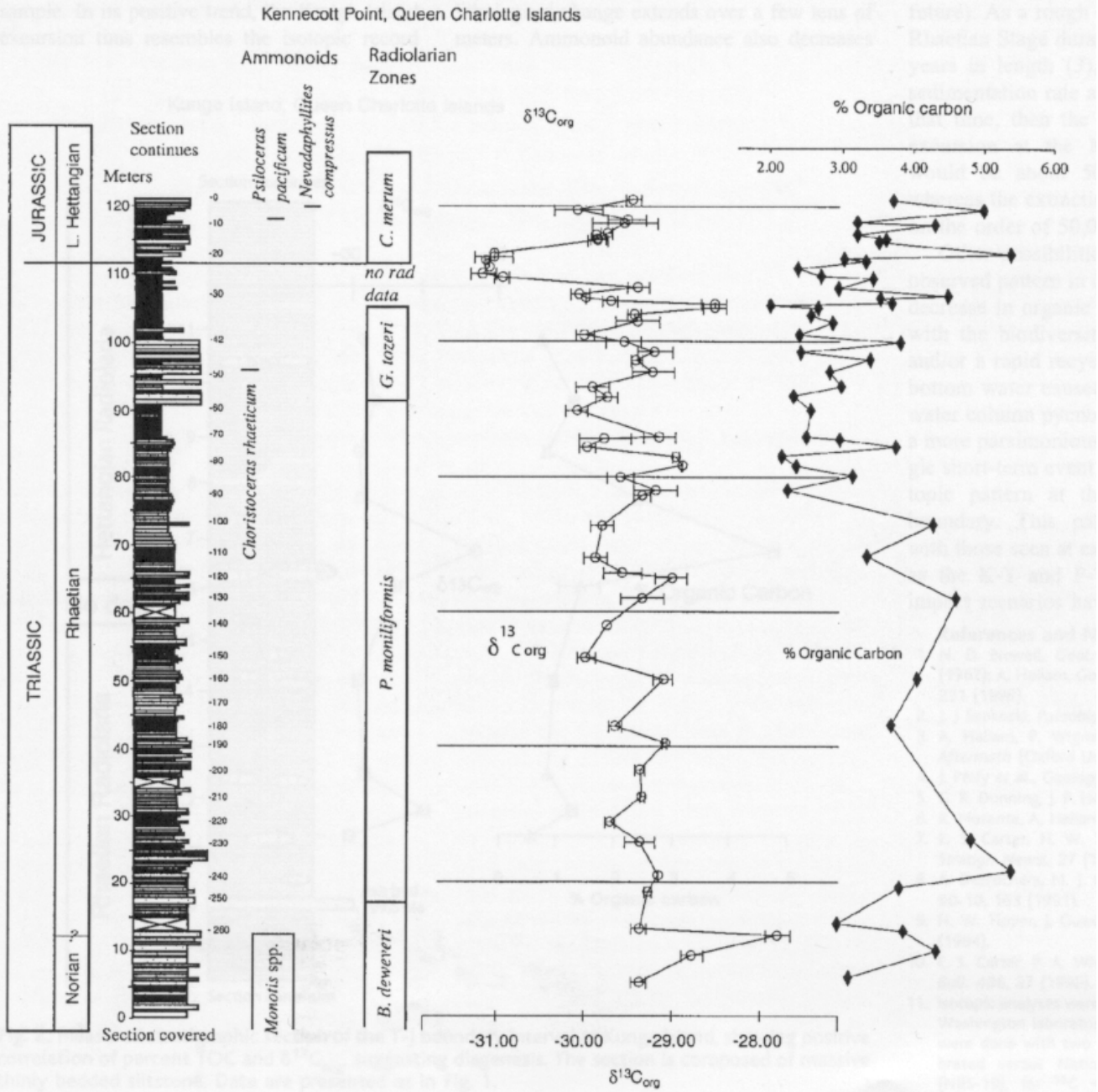
Relatively stable climate until ~ Triassic/Jurassic boundary. Very dry in continental interior, vast deserts.

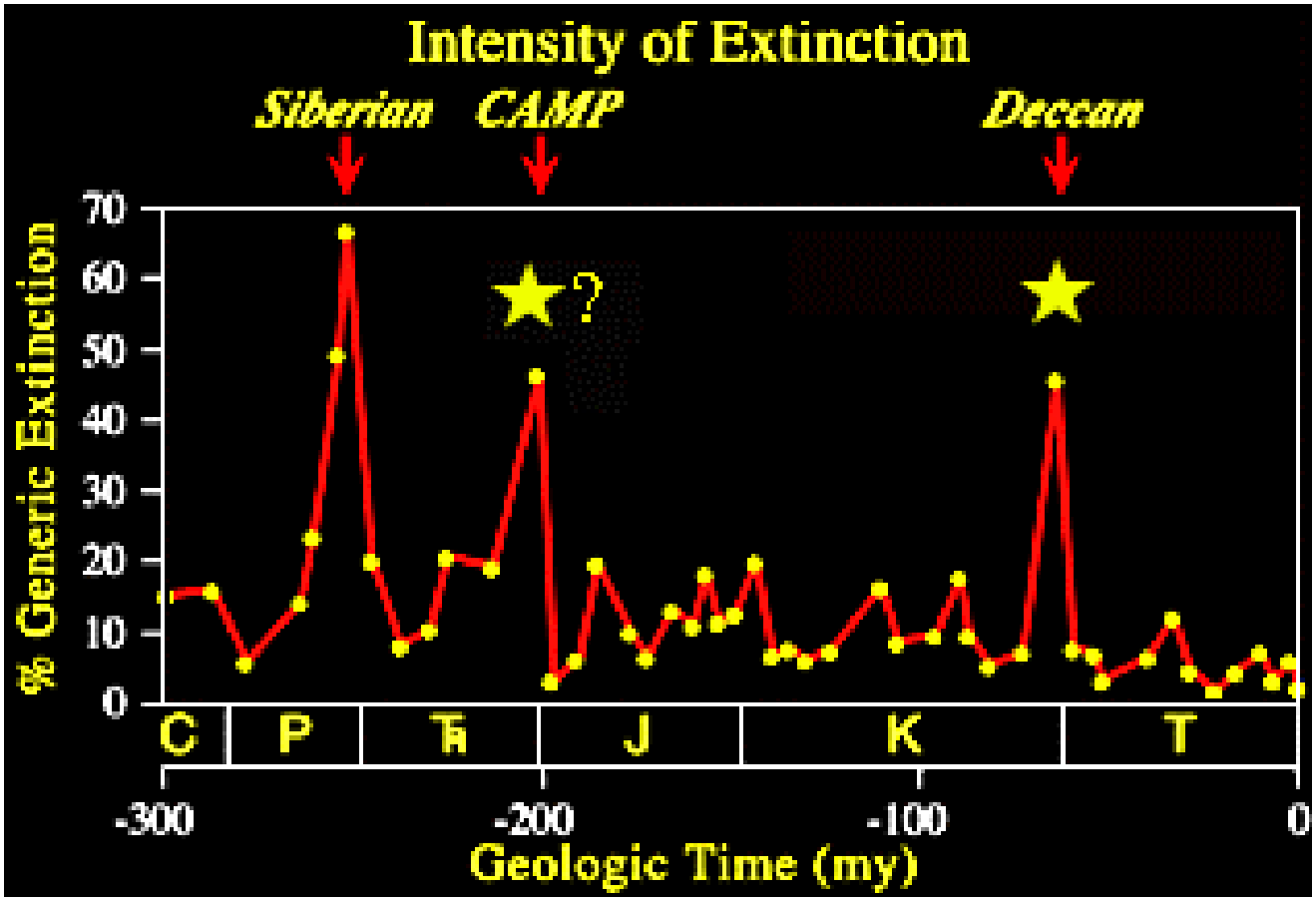
Appearance of first dinosaurs, evolved from within the Archosaur group.

Of all the archosaur groups, dinosaurs have the best body plan for locomotion on land.

Dinosaurs are not dominant vertebrates, are of small size, and co-exist with other groups of Archosaurs.

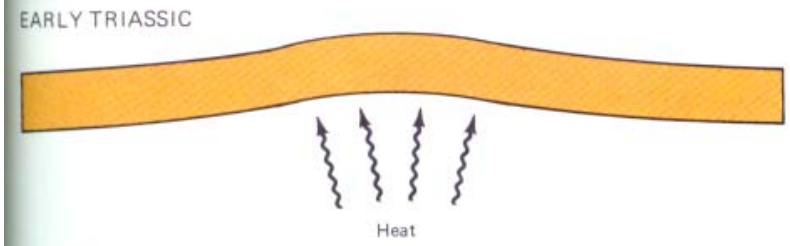

Early Jurassic 195 Ma
Siberia
Ural Mts.
LAURASIA
Europe
North China
South China
Turkey
Iran
Tibet
Indochina
Southeast Asia
North America
Africa
Central Atlantic Ocean
Arabia
South America
India
Andes Mts.
Antarctica
Australia
Ancient Landmass
Modern Landmass
Subduction Zone (triangles point in the direction of subduction)
Sea Floor Spreading Ridge

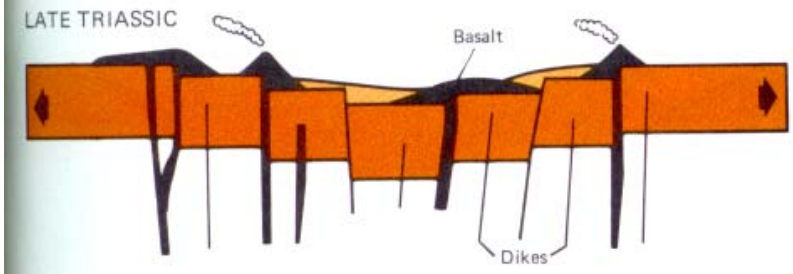

Kennecott Point, Queen Charlotte Islands
Ammonoids
Radiolarian Zones
Section continues
Meters
JURASSIC
TRIASSIC
L. Hettangian
Rhaetian
Norian
Psiloceras pacificum
Nevadaphyllites compressus
Choristoceras rhaeticum
Monotis spp.
C. merum
no rad data
G. tozeri
P. moniliformis
B. deweveri
Section covered
δ13Corg
% Organic carbon
2.00
3.00
4.00
5.00
6.00
δ 13 C org
% Organic Carbon
-31.00
-30.00
-29.00
-28.00
δ13Corg

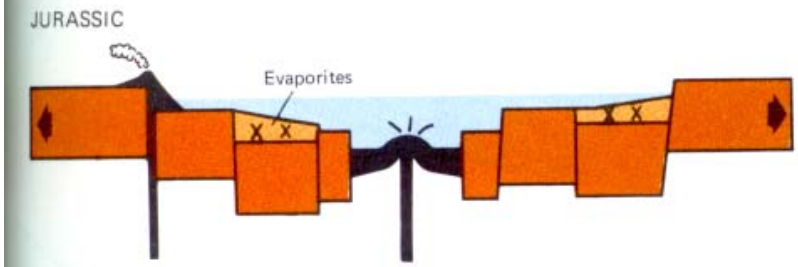


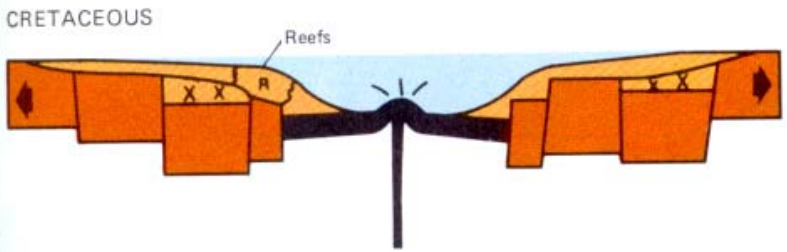
Theories

- Outgassing of CO_2 caused global warming.
- Outgassing of SO_2 caused global cooling and acid rain.
- Multiple asteroid impacts created extra pressure on ecosystems at this time.
- Variation in sea level and the extent of shallow shelf environments.



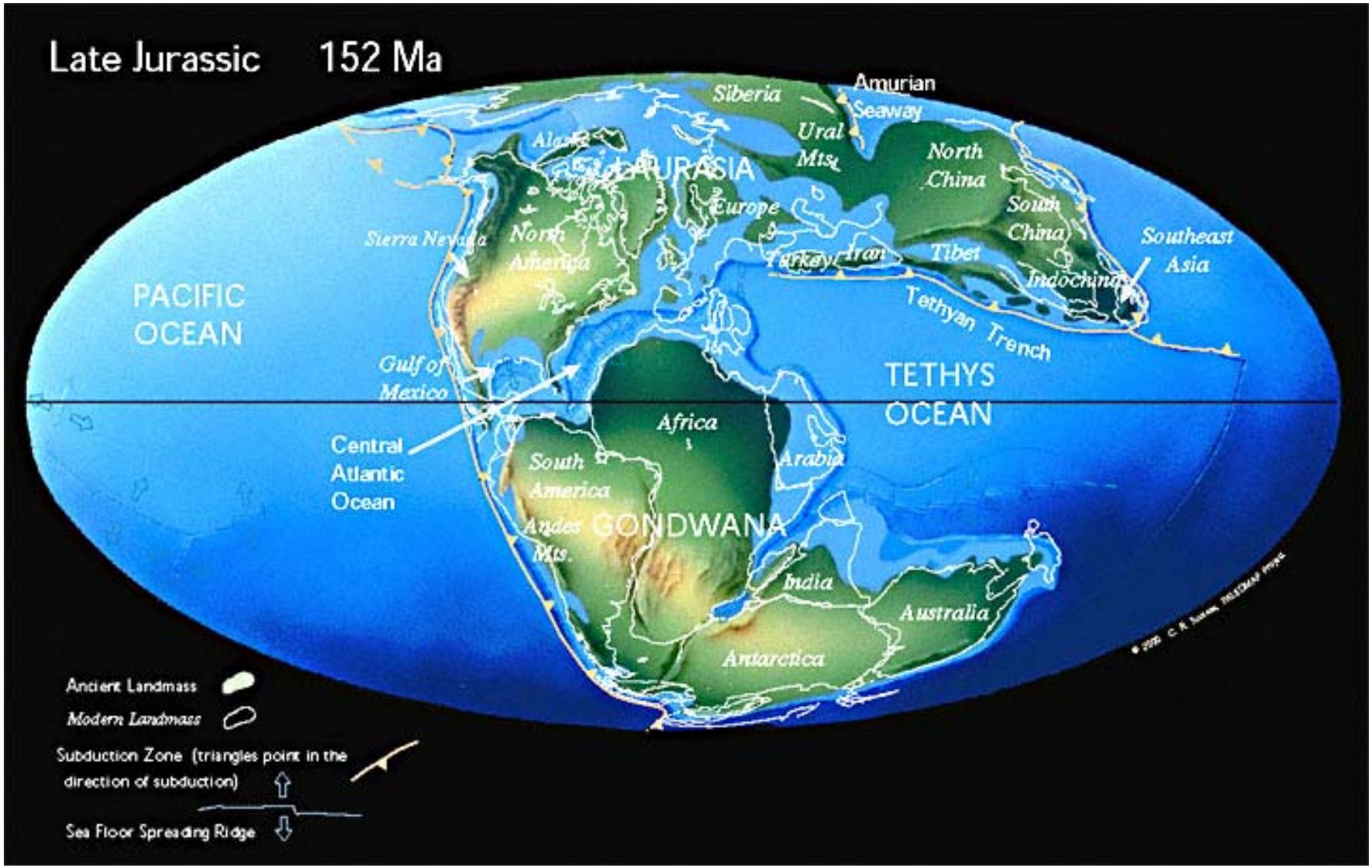


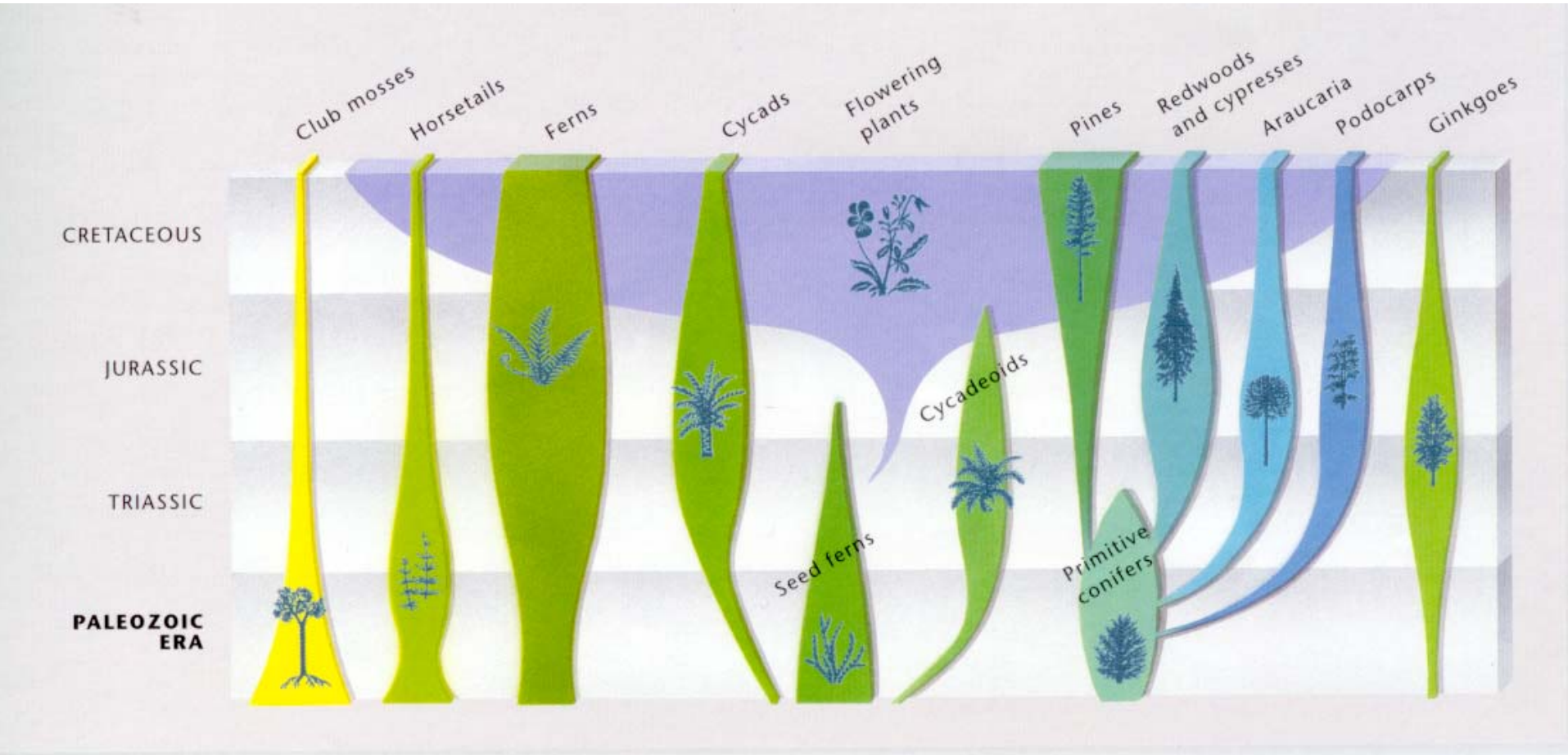




Doming causes relative sea level fall, restricting shelf environments

Shallow seas flood newly created continental shelf, Anoxia may impinge on shelf environments.


Late Jurassic 152 Ma
Siberia
Amurian Seaway
Ural Mts.
LAURASIA
North China
South China
Southeast Asia
Indochina
Tibet
Iran
Turkey
Europe
Sierra Nevada
North America
PACIFIC OCEAN
Tethyan Trench
TETHYS OCEAN
Gulf of Mexico
Central Atlantic Ocean
Africa
Arabia
South America
Andes Mts.
GONDWANA
India
Australia
Antarctica
Ancient Landmass
Modern Landmass
Subduction Zone (triangles point in the direction of subduction)
Sea Floor Spreading Ridge


Club mosses
Horsetails
Ferns
Cycads
Flowering plants
Pines
Redwoods and cypresses
Araucaria
Podocarps
Ginkgoes
CRETACEOUS
JURASSIC
TRIASSIC
PALEOZOIC ERA
Seed ferns
Cycadeoids
Primitive conifers

Plateosaurus, a type of prosauropod grazing on *Araucaria* conifer.

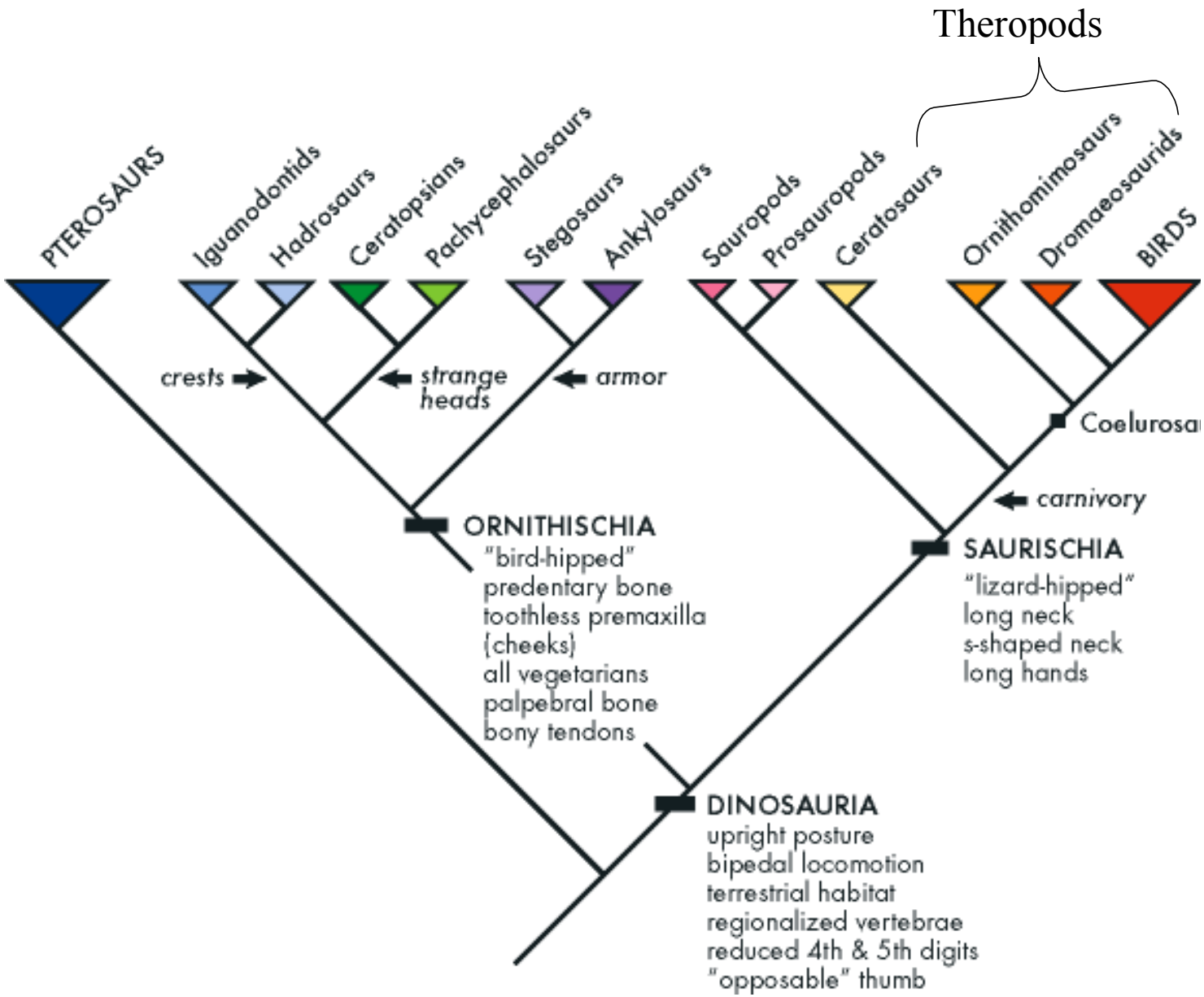
Early Jurassic Summary

Break-up of Pangaea very likely to have caused environmental changes leading to the Trias-Jur extinction.

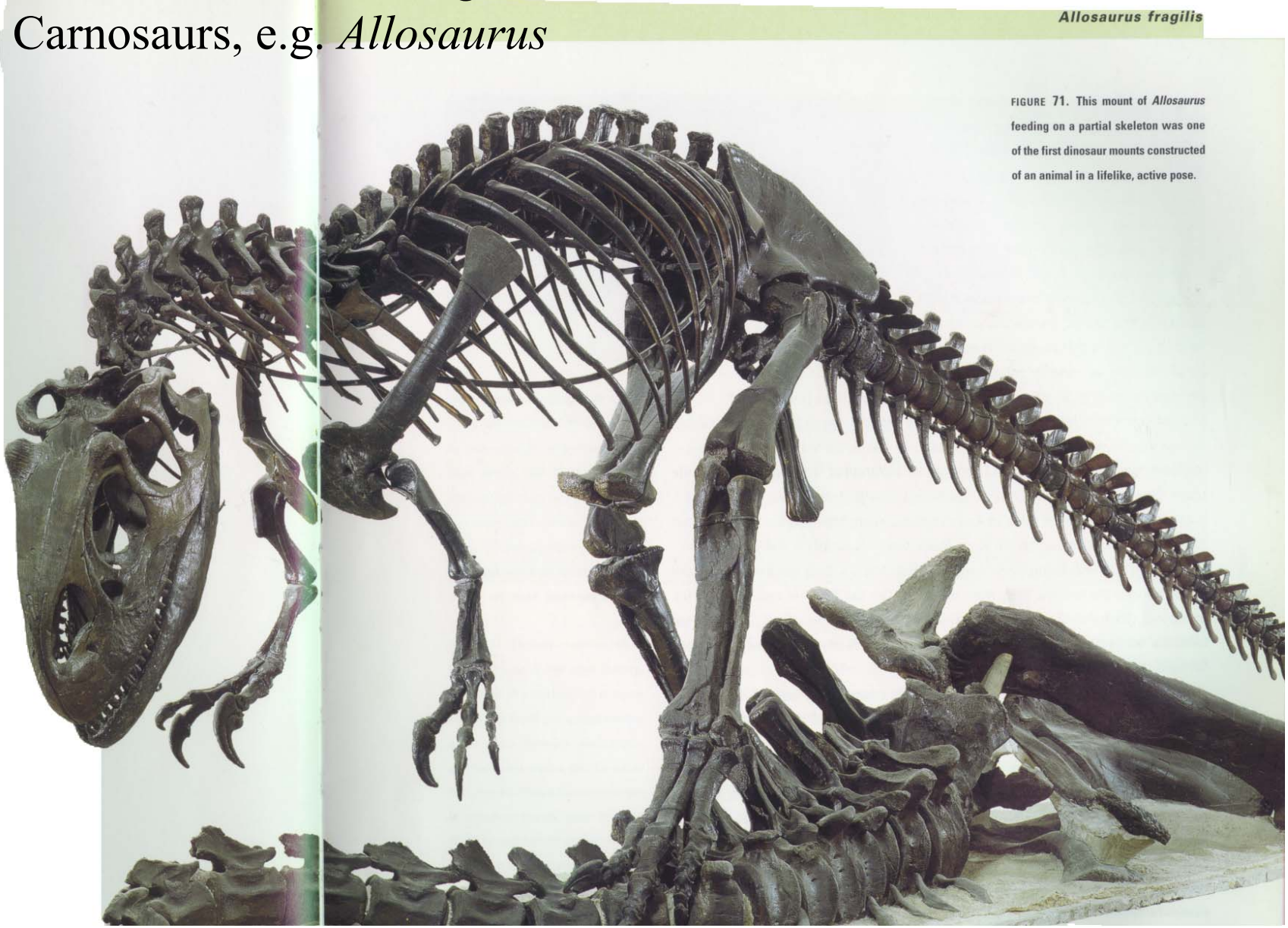
Trias-Jur extinction resets vertebrate evolutionary trends.

Dinosaurs find themselves best adapted to survive these environmental changes, possibly because of their body plan.

Evolutionary niches previously filled by other archosaurs become available to the dinosaurs. Herbivores start to increase in size.


Theropods
PTEROSAURS
Iguanodontids
Hadrosaurs
Ceratopsians
Pachycephalosaurs
Stegosaurs
Ankylosaurs
Sauropods
Prosauropods
Ceratosaurs
Ornithomimosaurs
Dromaeosaurids
BIRDS
crests
strange heads
armor
Coelurosa
carnivory
ORNITHISCHIA
"bird-hipped"
predentary bone
toothless premaxilla
(cheeks)
all vegetarians
palpebral bone
bony tendons
SAURISCHIA
"lizard-hipped"
long neck
s-shaped neck
long hands
DINOSAURIA
upright posture
bipedal locomotion
terrestrial habitat
regionalized vertebrae
reduced 4th & 5th digits
"opposable" thumb

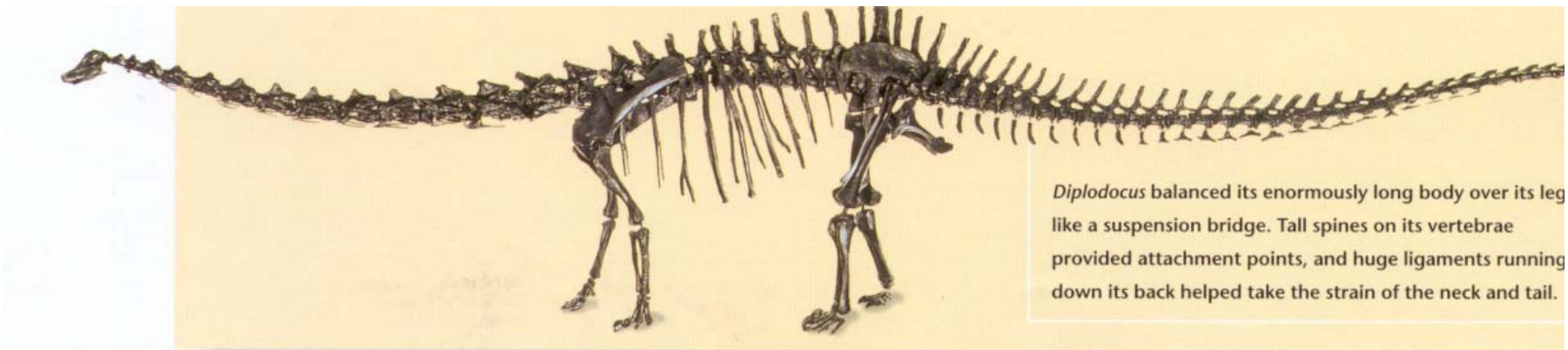
Late Jurassic assemblage.
Carnosaurs, e.g. *Allosaurus*



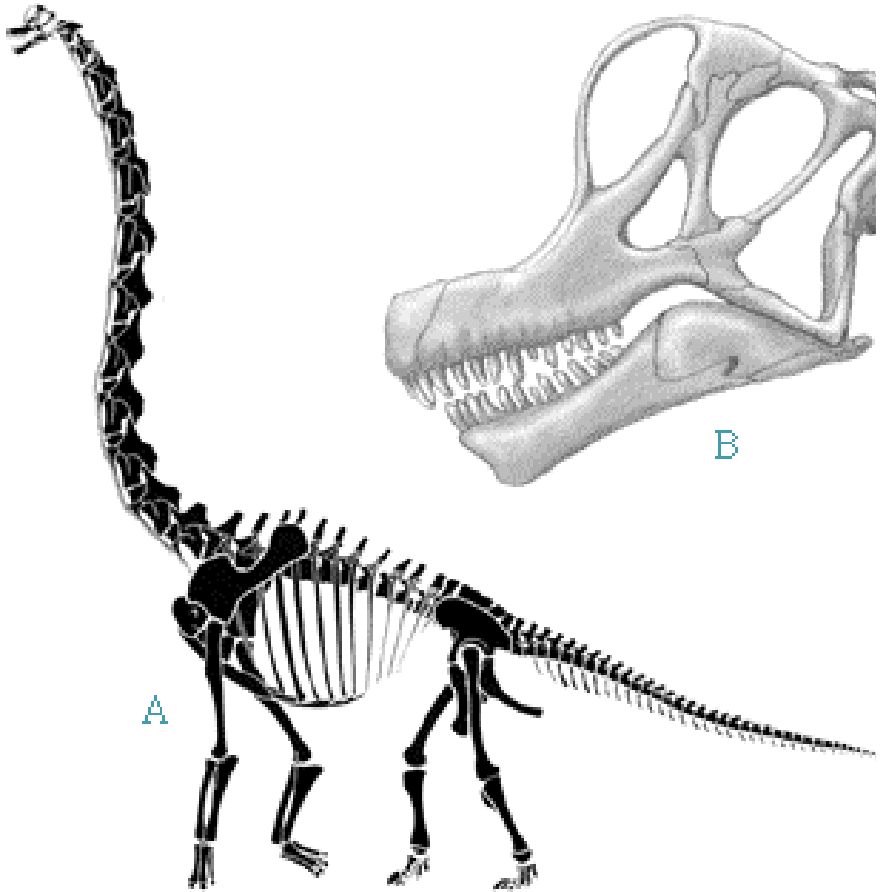
Late Jurassic assemblage.

Stegosaurs e.g.
Stegosaurus

Sauropods e.g.
Diplodocus



Brachiosaurus Late Jurassic specialist grazer



12 m (39 ft = 4 storeys) high to graze branches inacessible to others.

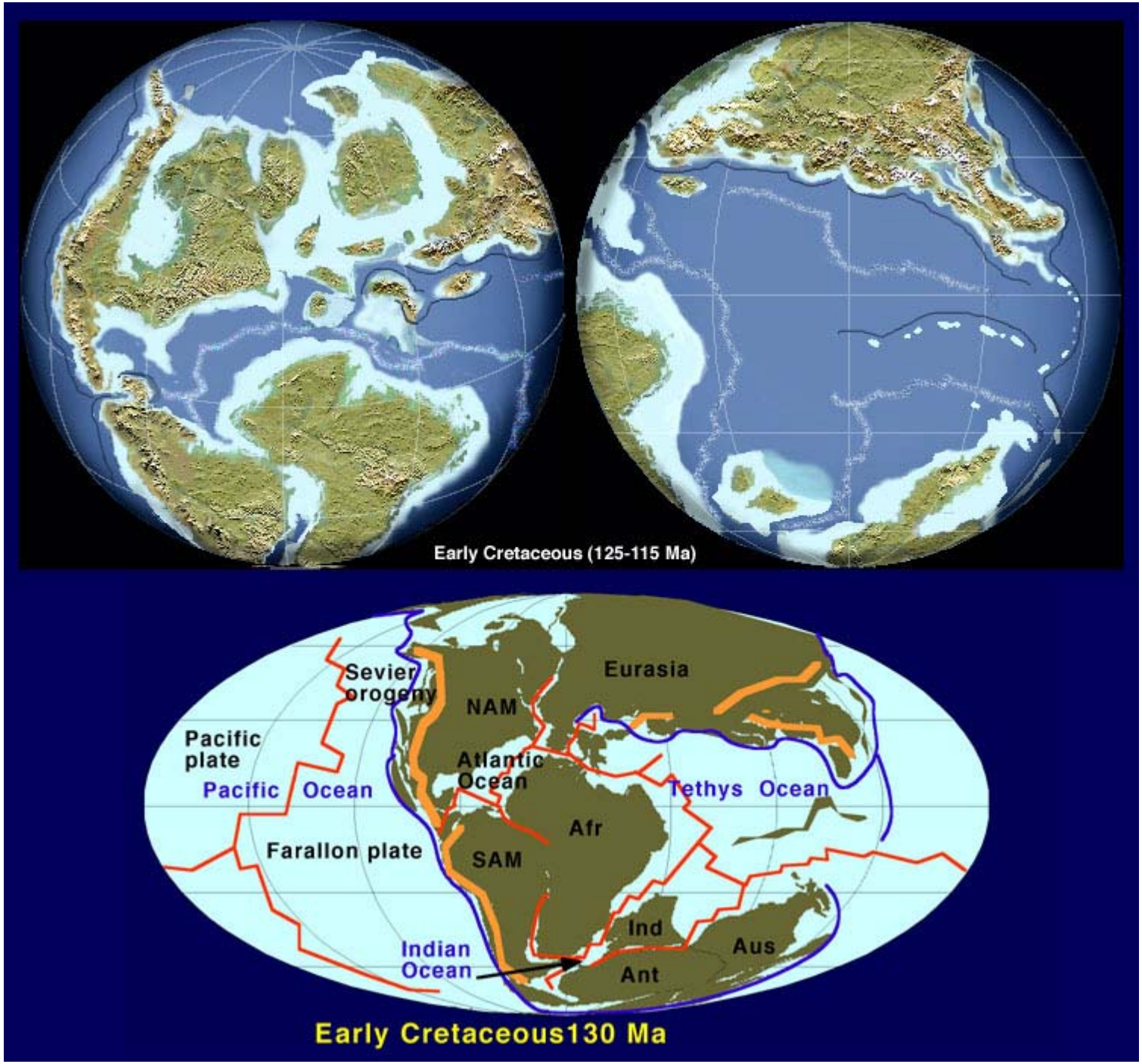
Peg like teeth to strip conifer leaves

Late Jurassic Summary

Central Atlantic continues to open and become fully marine.

Climate becomes wetter and more seasonal.

Dinosaurs diversify to take advantage of abundant land plant food source, and attain giant size.


Early Cretaceous (125-115 Ma)
Sevier orogeny
NAM
Eurasia
Pacific plate
Pacific Ocean
Atlantic Ocean
Tethys Ocean
Afr
Farallon plate
SAM
Ind
Aus
Indian Ocean
Ant
Early Cretaceous130 Ma

Early Cretaceous assemblage, Laurasia.

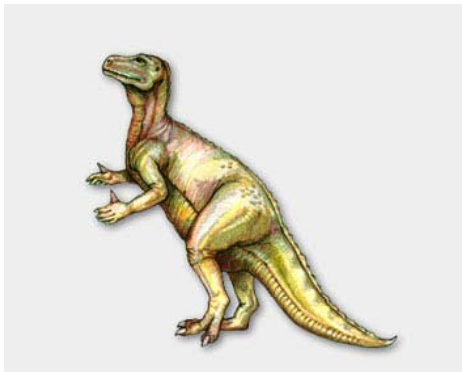
Iguanodontids

Ankylosaurs

Maniraptors. *Deinonychus*.

Another example of carnosuar diversification. *Baryonyx*, specialized to eat fish ?

1825



~ 1970's

2000

Reconstructions of *Iguanodon.*

An example of how the incomplete fossil record can be misleading.

Evolution of Birds

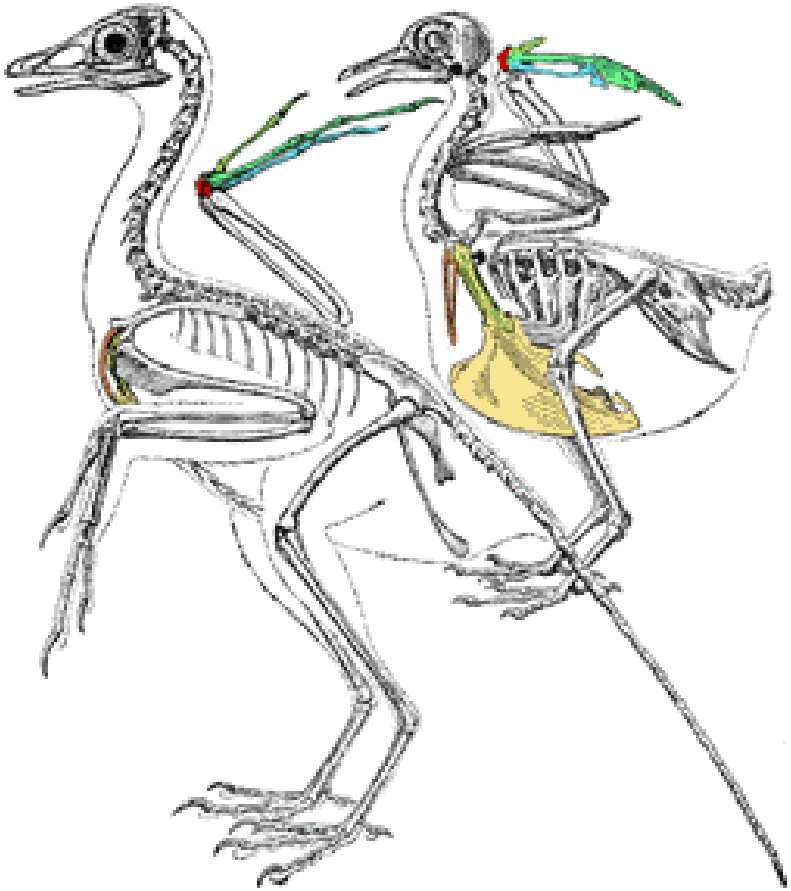
Early Cretaceous *Archaeopteryx*, has morphological features similar to both non-avian-dinosaurs and birds.

Fits into phylogeny of theropods.

Was evolution of flight 'trees-down' e.g. from gliding dinosaurs like *Archaeopteryx.*

Or 'ground-up', from fast running and jumping small theropods. **Lack of geological evidence.**

Birds held a unique niche, which may have ensured that they were the only dinosaurs to survive the K-T extinction ?

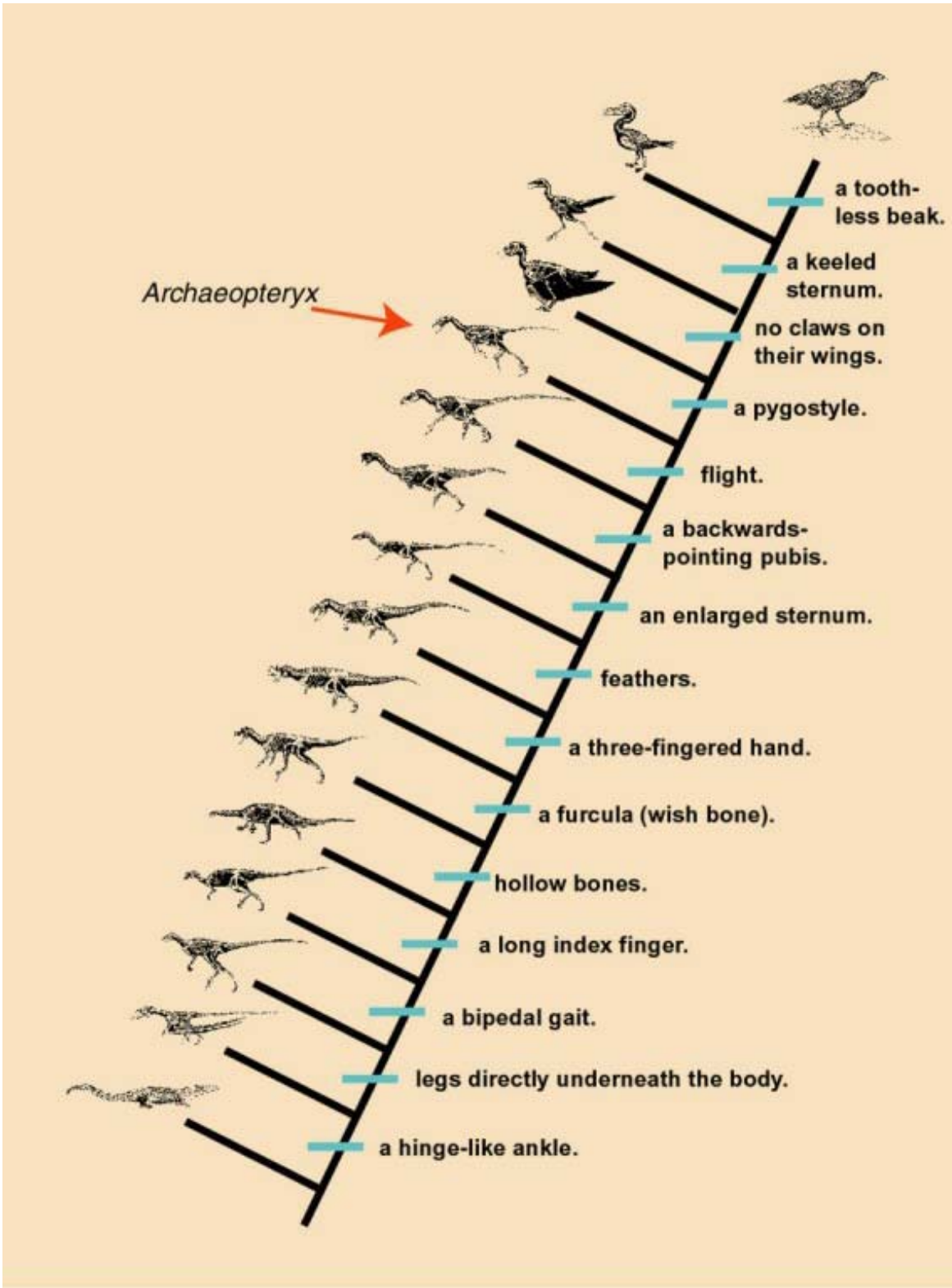


Archaeopteryx

Deinonychus

Archaeopteryx and modern bird:

wishbone, breastbone, fused fingers


Archaeopteryx
a tooth-less beak.
a keeled sternum.
no claws on their wings.
a pygostyle.
flight.
a backwards-pointing pubis.
an enlarged sternum.
feathers.
a three-fingered hand.
a furcula (wish bone).
hollow bones.
a long index finger.
a bipedal gait.
legs directly underneath the body.
a hinge-like ankle.

Early Cretaceous Summary

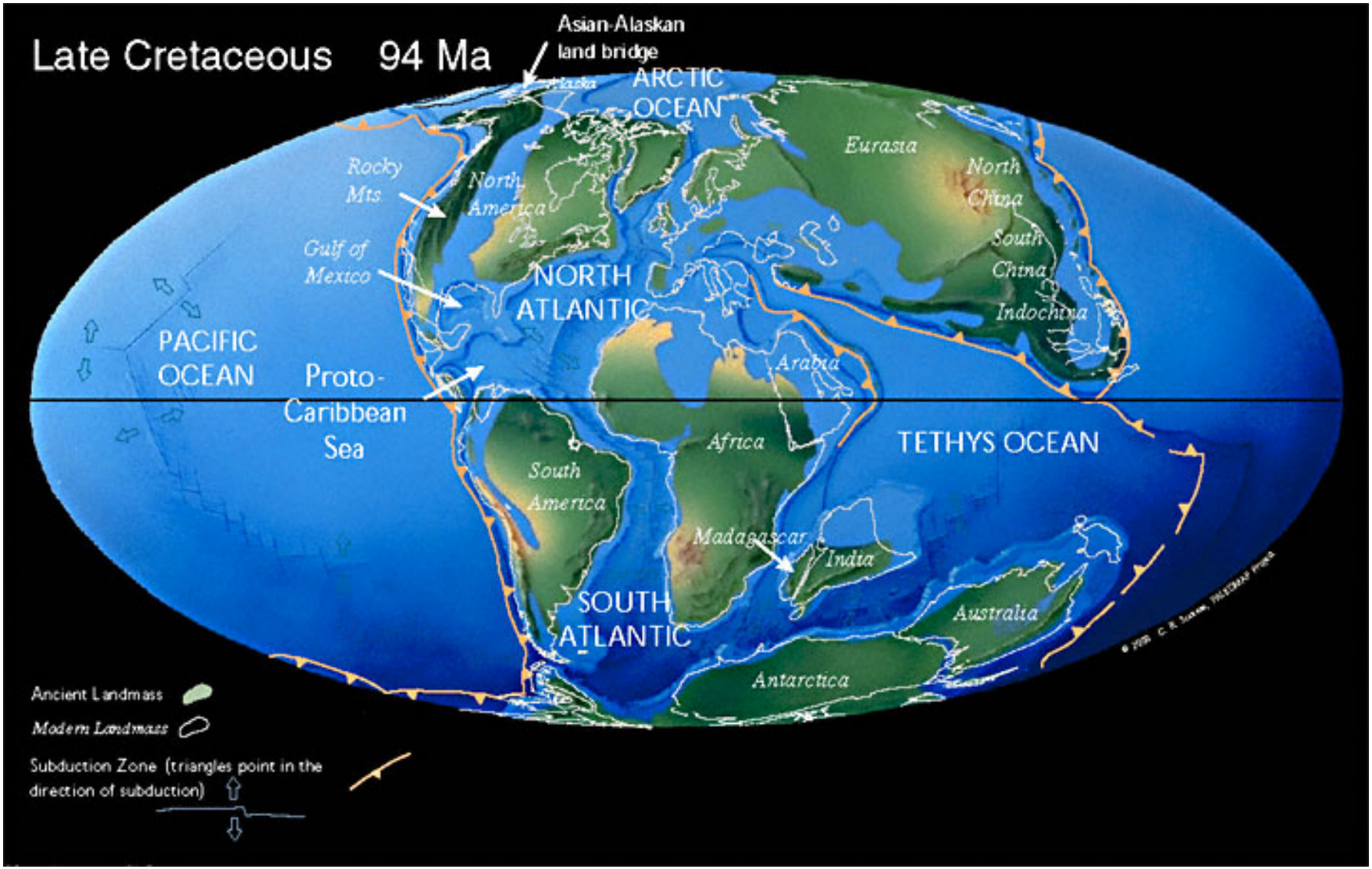
Central Atlantic widening. Seaway develops in N.America. Water begins to dominate globe.

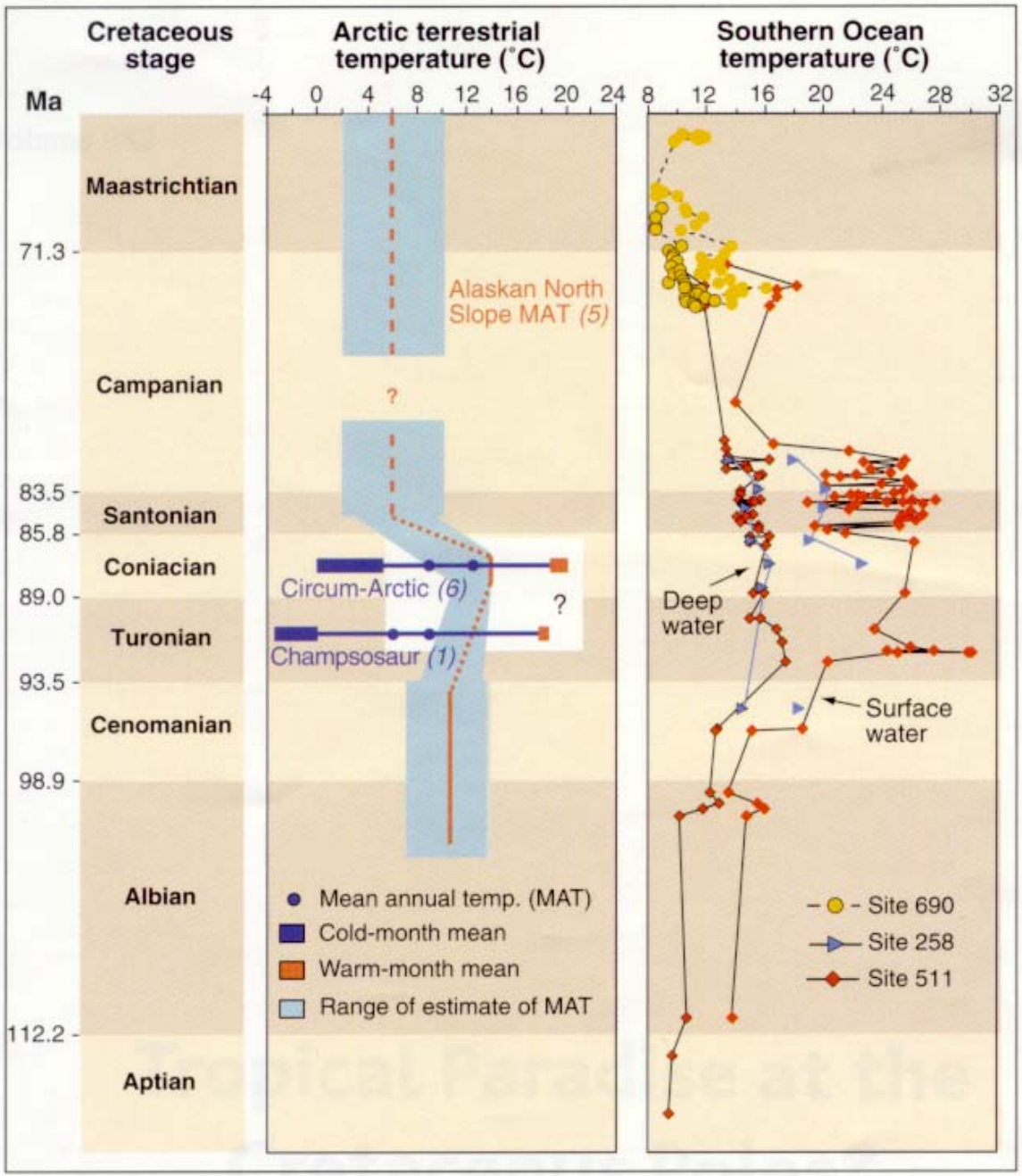
Climate becomes more humid.

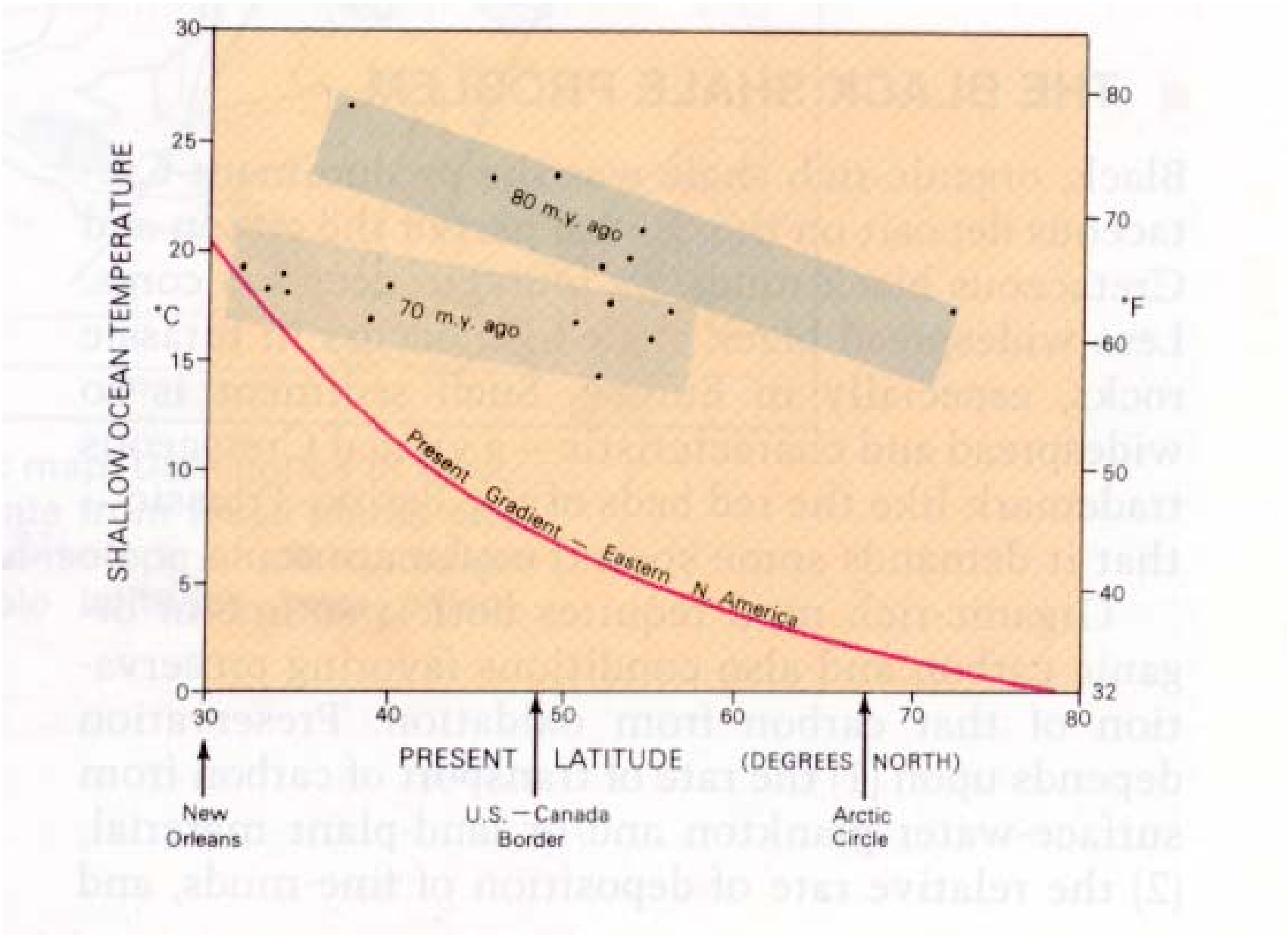
Radiation of angiosperms.

Jur-Cret is a gradual transition in terms of dinosaur evolution.

New forms appear, including birds.

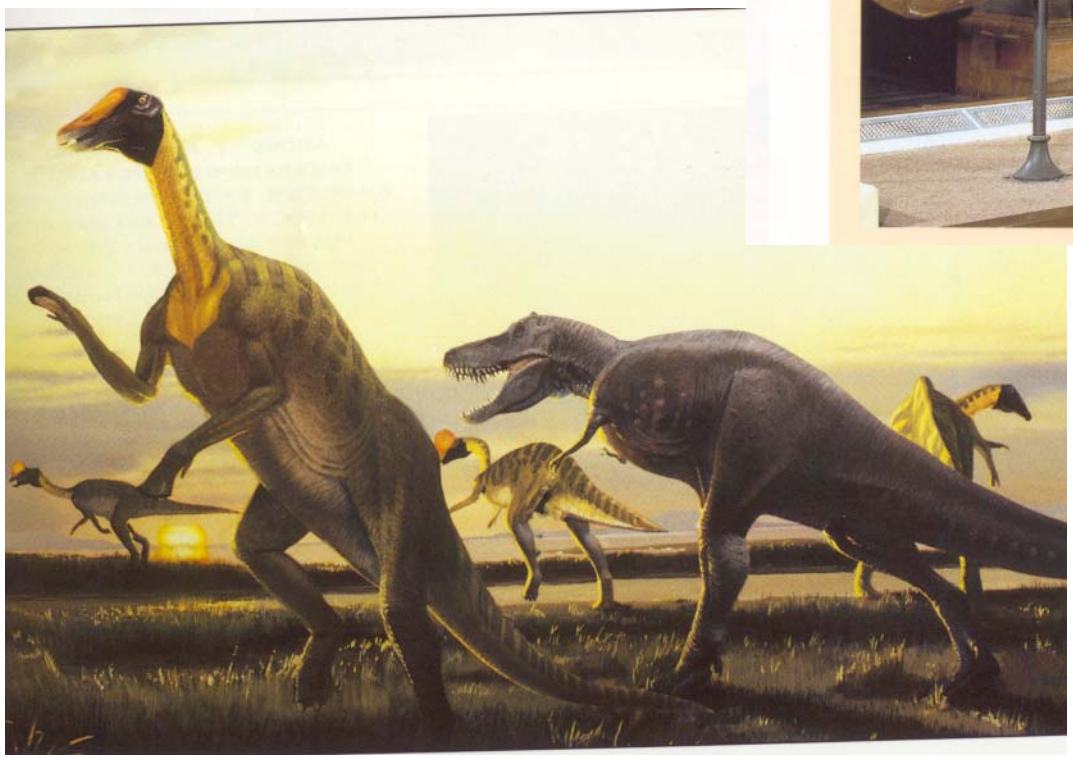

Late Cretaceous 94 Ma
Asian-Alaskan land bridge
ARCTIC OCEAN
Eurasia
North China
South China
Indochina
Rocky Mts.
North America
Gulf of Mexico
NORTH ATLANTIC
PACIFIC OCEAN
Proto-Caribbean Sea
Arabia
Africa
TETHYS OCEAN
South America
Madagascar
India
SOUTH ATLANTIC
Australia
Antarctica
Ancient Landmass
Modern Landmass
Subduction Zone (triangles point in the direction of subduction)


Cretaceous stage
Arctic terrestrial temperature (˚C)
Southern Ocean temperature (˚C)
Ma
-4 0 4 8 12 16 20 24
8 12 16 20 24 28 32
Maastrichtian
71.3
Campanian
83.5
Santonian
85.8
Coniacian
89.0
Turonian
93.5
Cenomanian
98.9
Albian
112.2
Aptian
Alaskan North Slope MAT (5)
?
Circum-Arctic (6)
?
Champsosaur (1)
Deep water
Surface water
Mean annual temp. (MAT)
Cold-month mean
Warm-month mean
Range of estimate of MAT
Site 690
Site 258
Site 511

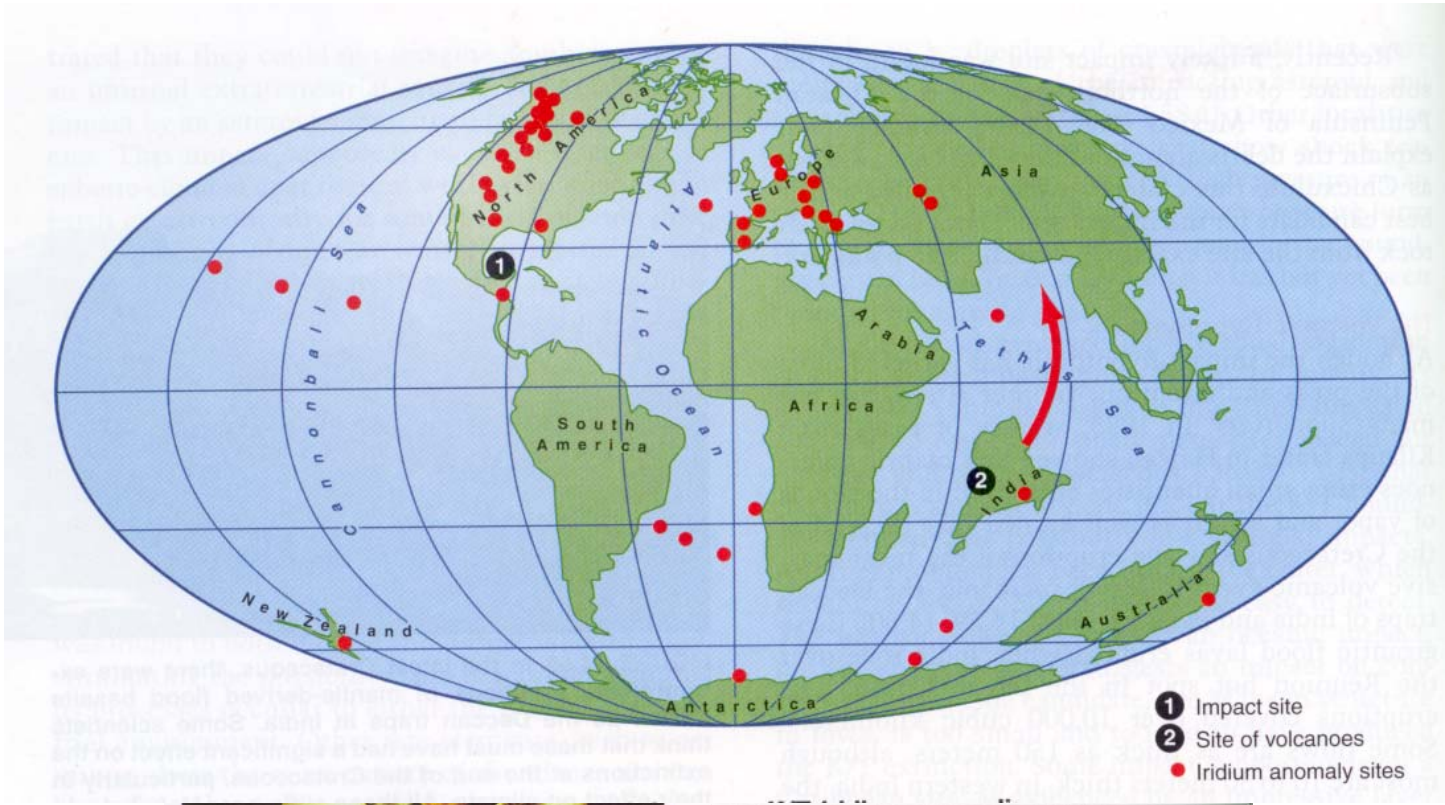

SHALLOW OCEAN TEMPERATURE
°C
°F
30
25
20
15
10
5
0
80
70
60
50
40
32
80 m.y. ago
70 m.y. ago
Present Gradient — Eastern N. America
30
40
50
60
70
80
PRESENT LATITUDE (DEGREES NORTH)
New Orleans
U.S.—Canada Border
Arctic Circle

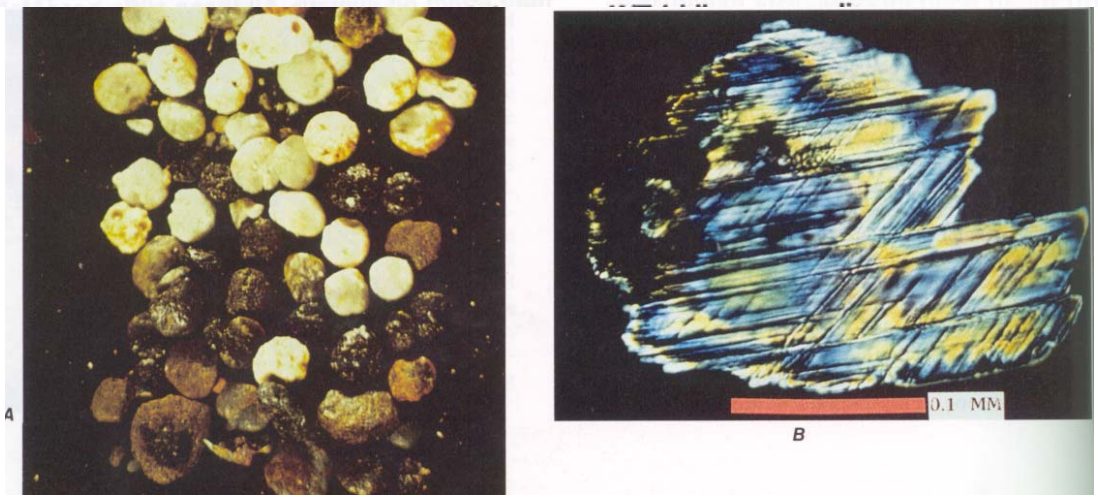
Late Cretaceous assemblage

Hadrosaurs and Tyrannosaurs



Ceratopsians, e.g.
Triceratops


North America
Europe
Asia
Arabia
Africa
South America
India
Australia
New Zealand
Antarctica
Cannonball Sea
Atlantic Ocean
Tethys Sea
1 Impact site
2 Site of volcanoes
Iridium anomaly sites


0.1 MM
B

Late Cretaceous Summary

Pulse of Atlantic seafloor spreading elevates CO_2 content of atmosphere. Indian plate on northwards track

Warm shallow seas dominate globe.

Equator to pole temperature gradient is low.

Birds exploit new niches.

Efficient grazers, e.g. Hadrosaurs, may evolve in response to angiosperm radiation ?

K-T boundary extinction:

Massive sub-aerial volcanism forms Deccan traps as Indian plate rides over hotspot. Rapid cooling ?

Impact of 10km asteroid. The last straw ?

How can we deduce the lifestyle and behavior of dinosaurs ?

1). Geological evidence. Fossil and sedimentary record.

2). Biomechanics

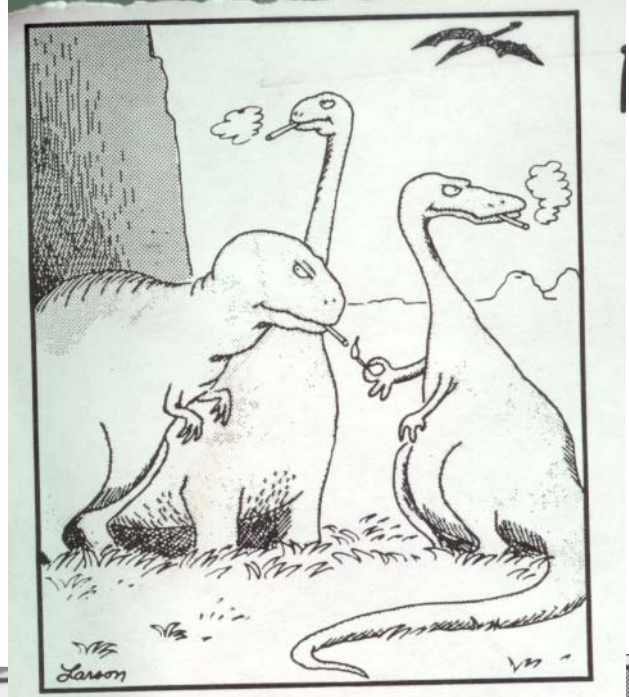
3). Analogy to phylogenetically related modern forms (birds), and non-related forms.

Food

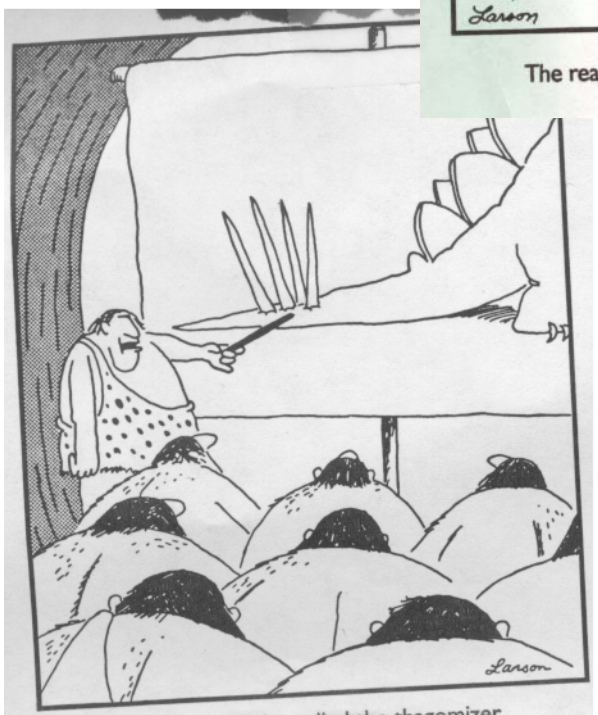
Geo-evidence: Teeth. Coprolites.

Biomechanics: Skull and teeth of *Allosaurus* and *Tyrannosuarus*.

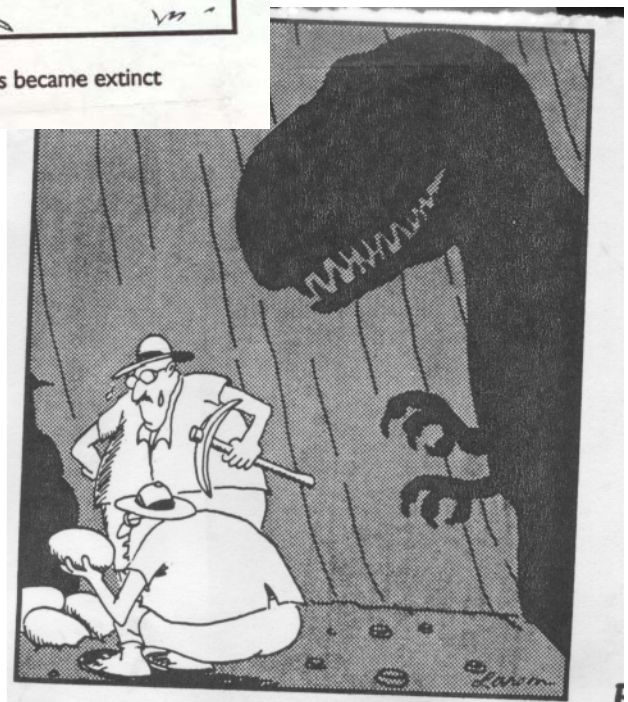
Behavior	**Geological Evidence**
Parental Care	Nest sites - young did not leave immediately?
Competition	Wounded carnosaur skeletons.
Moving in herds	Trace fossils.



The real reason dinosaurs became extinct



"Now this end is called the thagomizer
... after the late Thag Simmons."



"Millions of years old and they look as if
they were laid yesterday!"