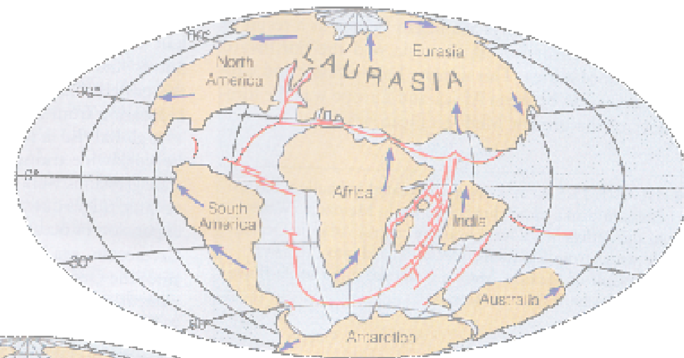
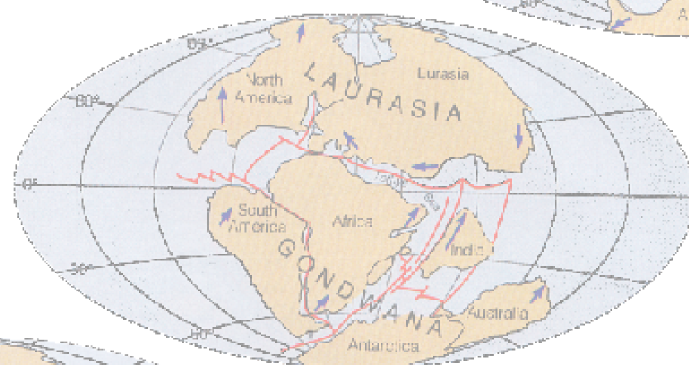
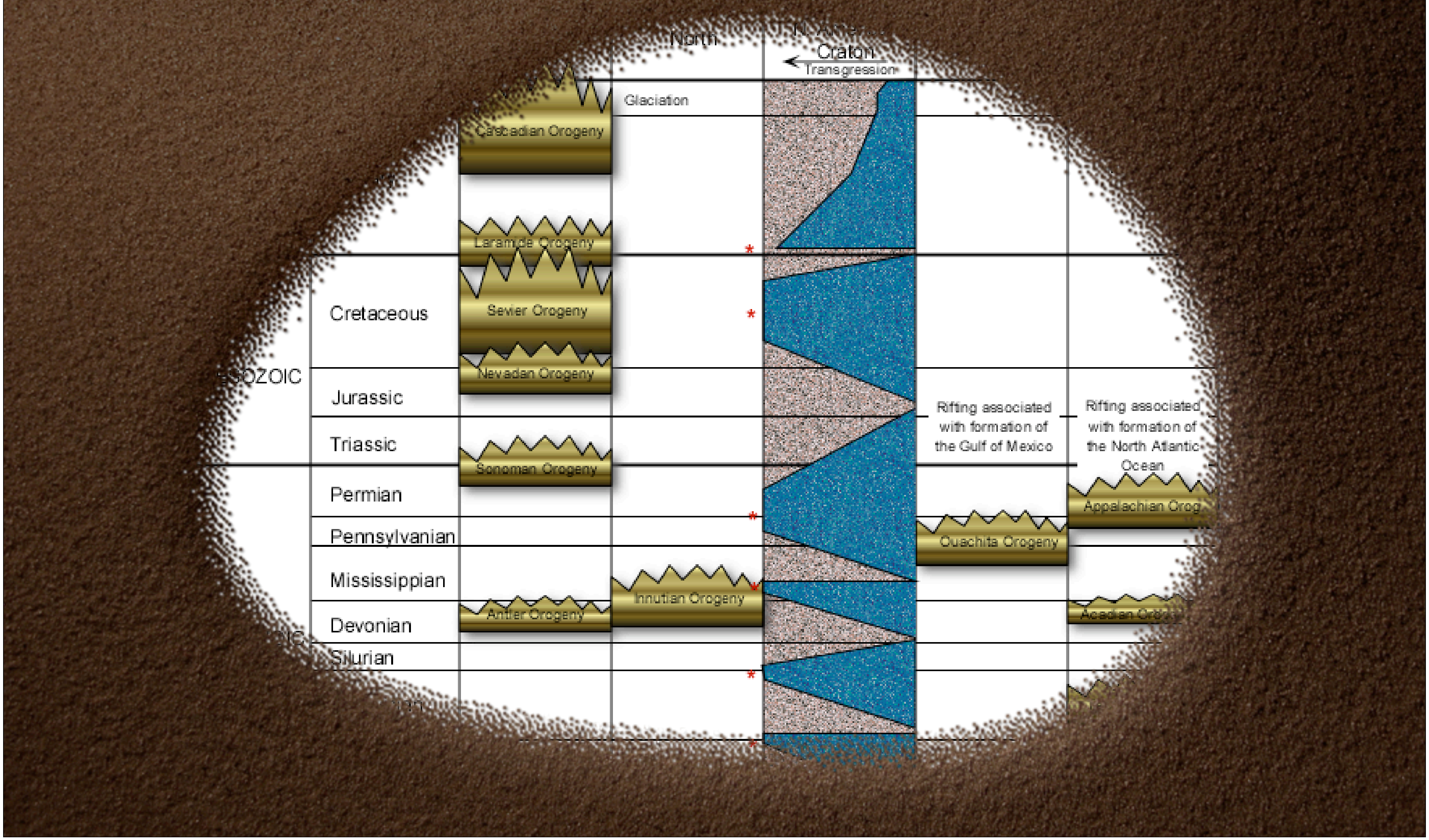
Mesozoic

Rocks and environments

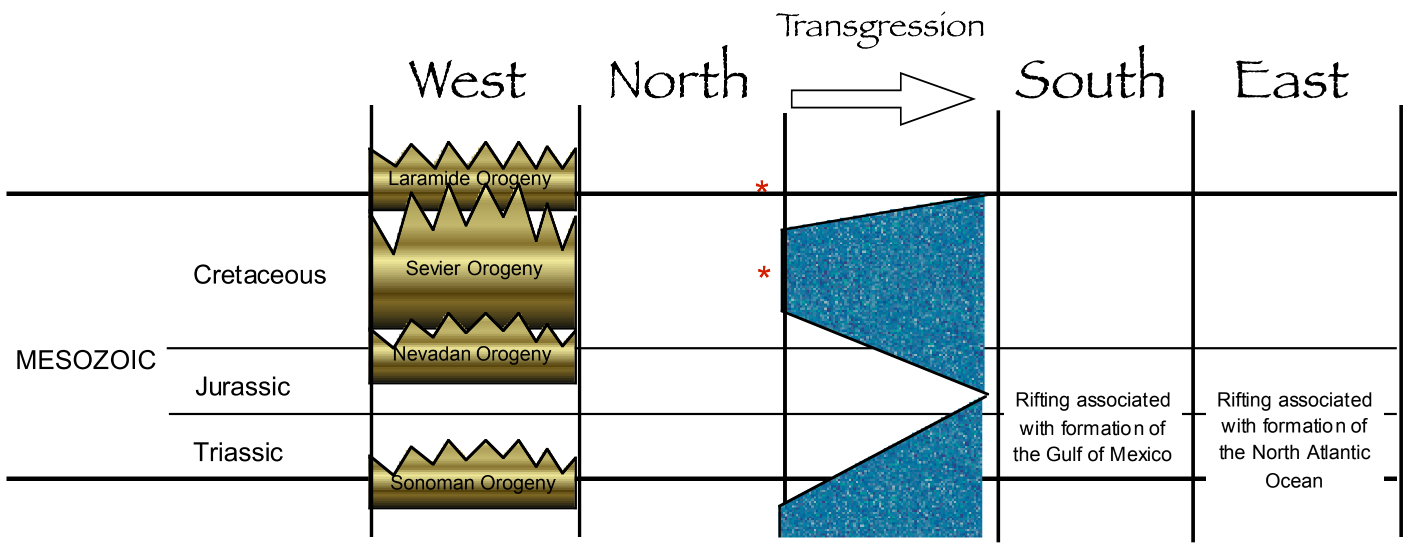




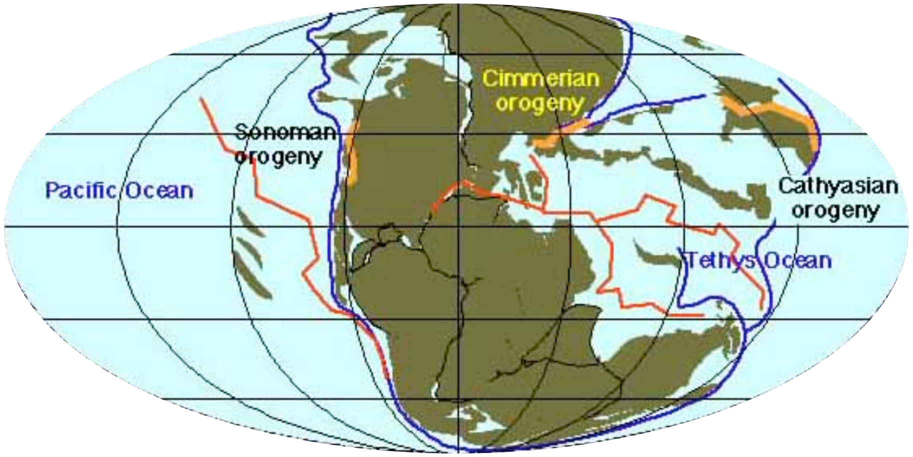
Geologic Events



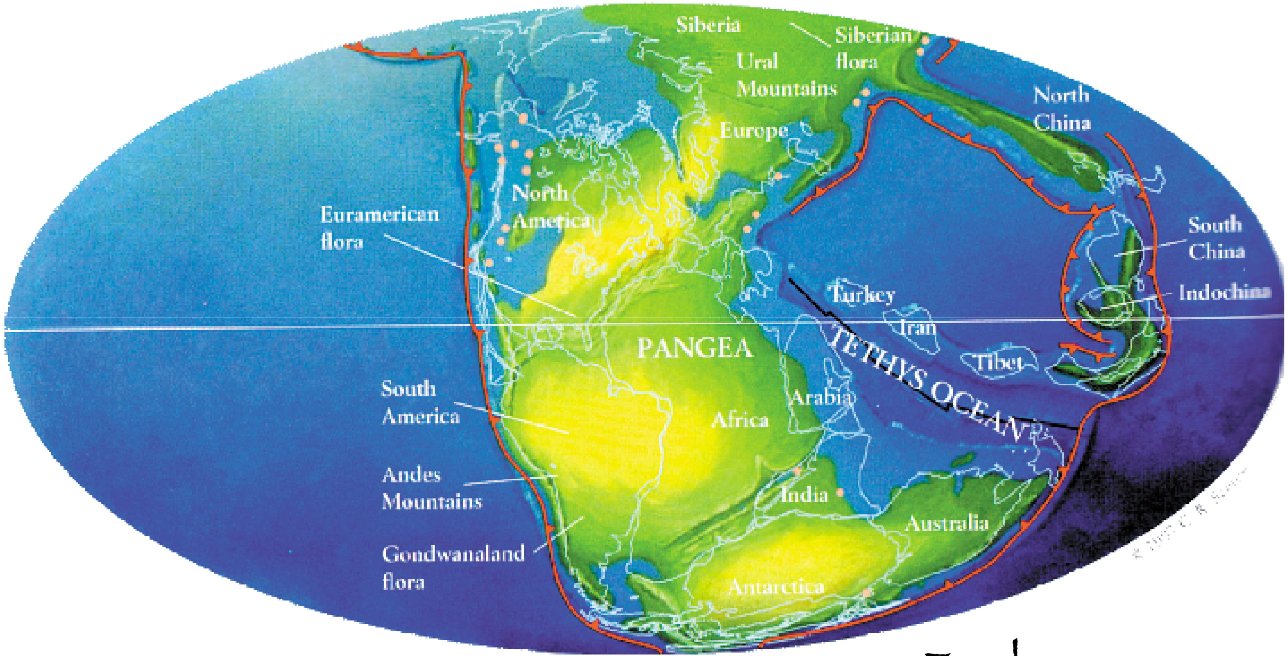
Mesozoic Events



The Triassic World

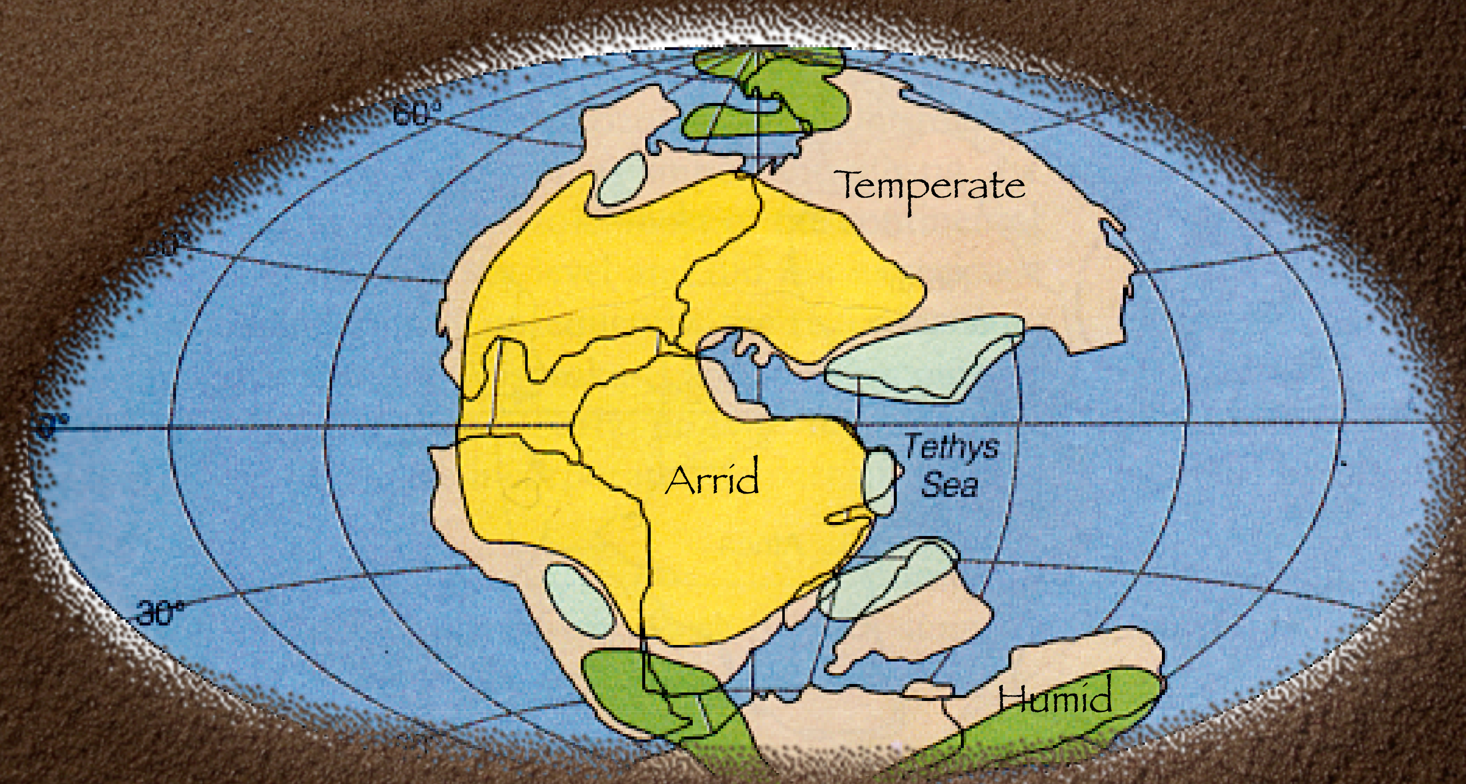


Late



Early

Triassic Environments

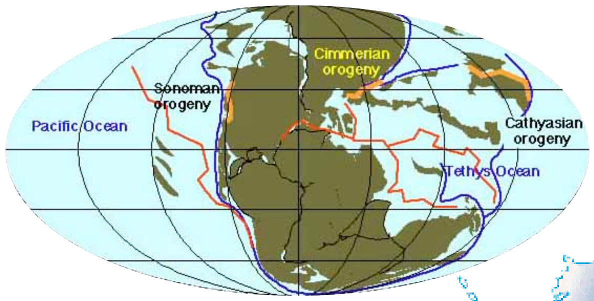


The Triassic, particularly the first half of the Triassic, was dry and highly seasonal, with particularly large annual temperature variations in the vast continental interior of Pangea. Low sea levels probably exaggerated these temperature extremes. Water acts as a heat sink -- it takes much more heat to warm a cup of water than it does to warm a cup of rock. Water also circulates, so that heat doesn't build up in one place. The net result is that water tends to stabilize temperatures. Land areas near the ocean are warmed or cooled by winds which pass over the ocean and by rains from evaporated ocean waters. It is generally agreed:

(a) that the low sea levels of the Triassic contributed to temperature extremes in the interior of Pangea, and
(b) that the interior of Pangea probably included huge areas of desert.

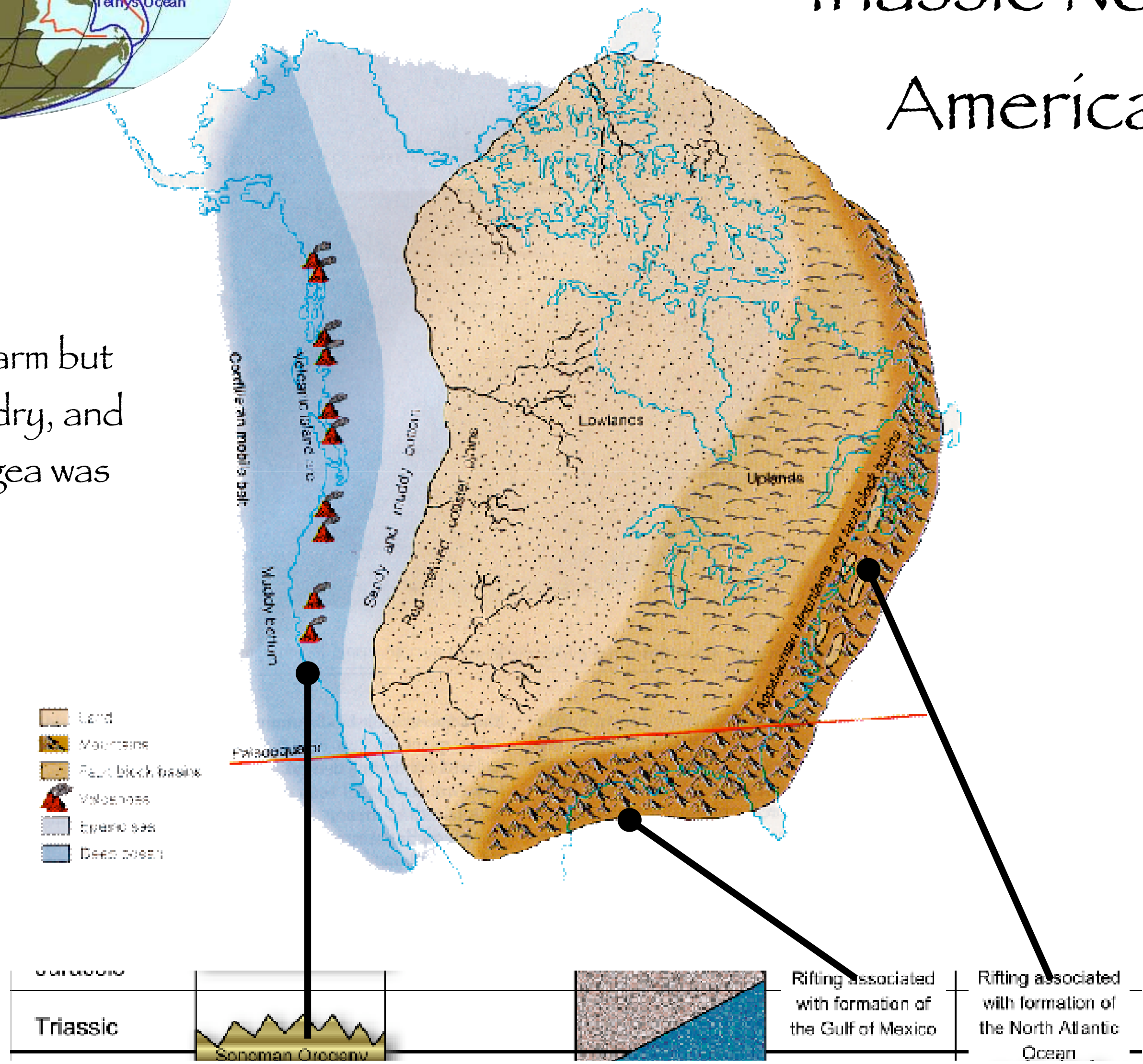
An Interesting Problem

If temperature extremes in the Triassic were as great as general circulation models predict, one would expect rather hefty ice-build-up in at least some polar regions. Glaciers leave a rather distinct geological signature, and we simply don't have any evidence of Triassic glaciers or polar caps.

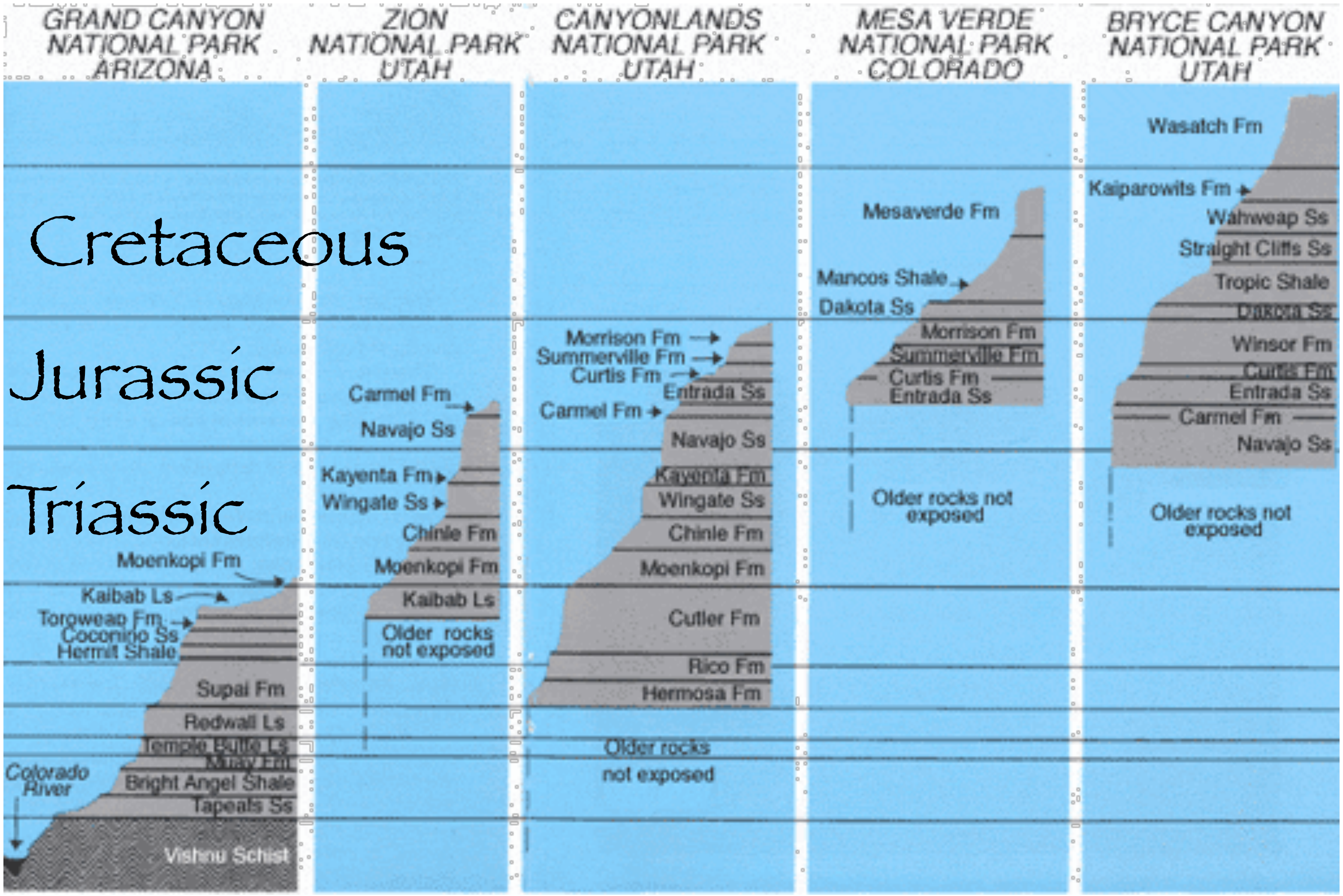


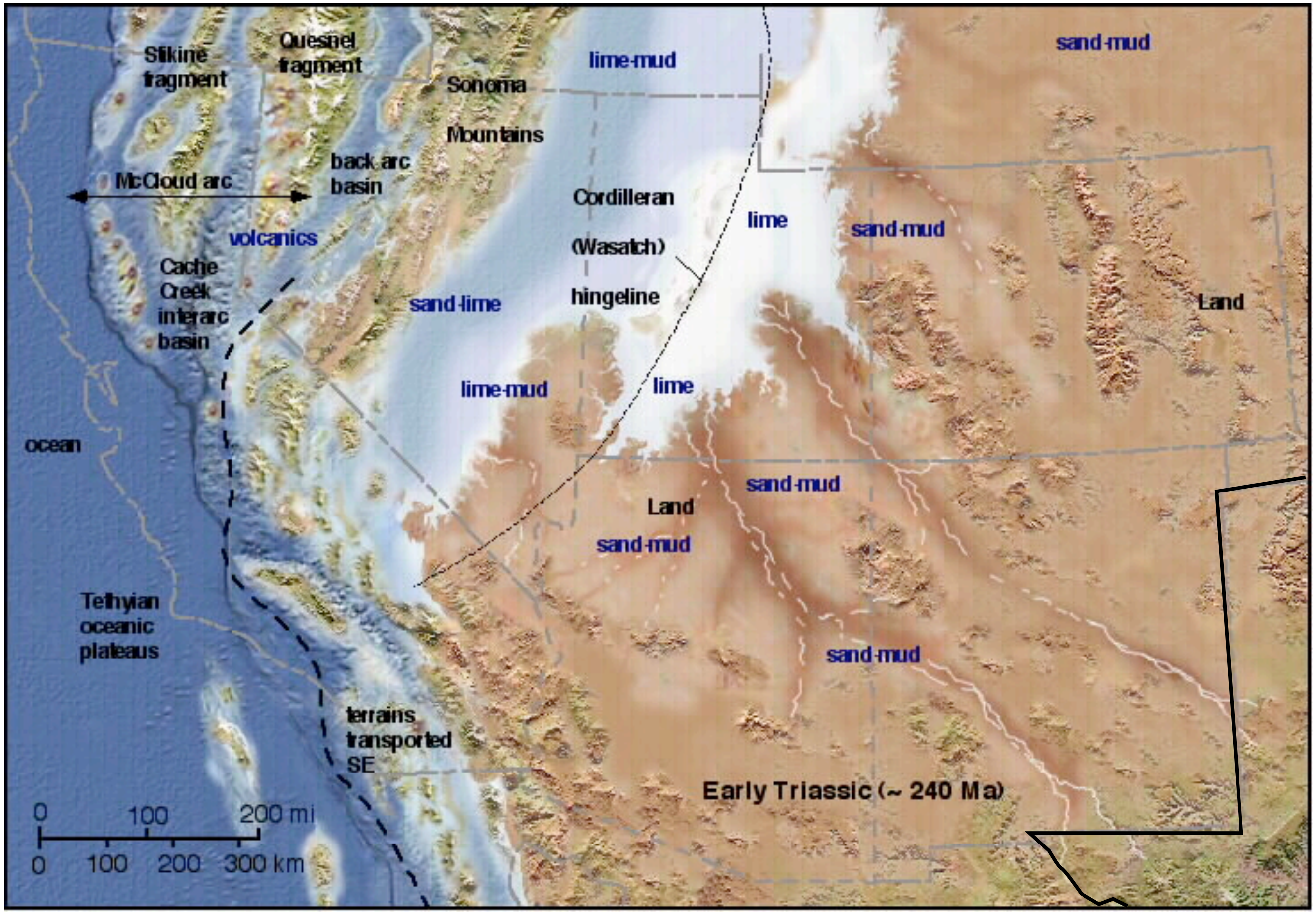
Triassic North America

The climate was warm but for the most part dry, and the middle of Pangea was very arid.



Colorado Plateau Stratigraphy



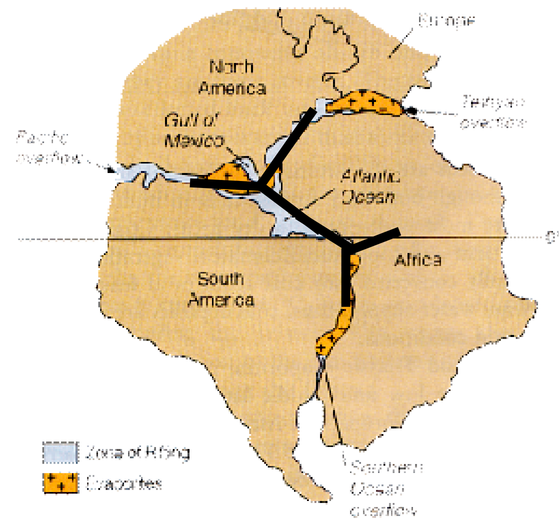


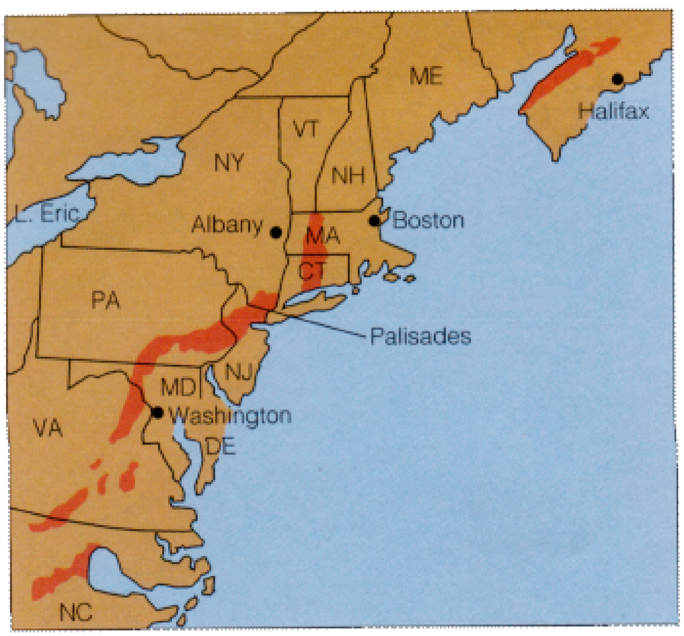
Moenkopi Formation (Early Triassic)

Chinle Formation (Late Triassic)

Triassic Rifting

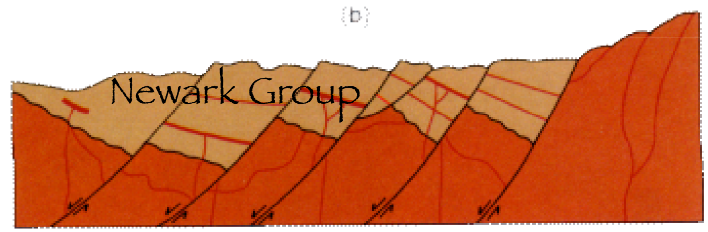
Basins contain the 5k to 16K feet thick Newark Group. This Groups consists of conglomerates, sandstones, shales, basalt flows and sills. There are numerous freshwater lake deposits.





(a)

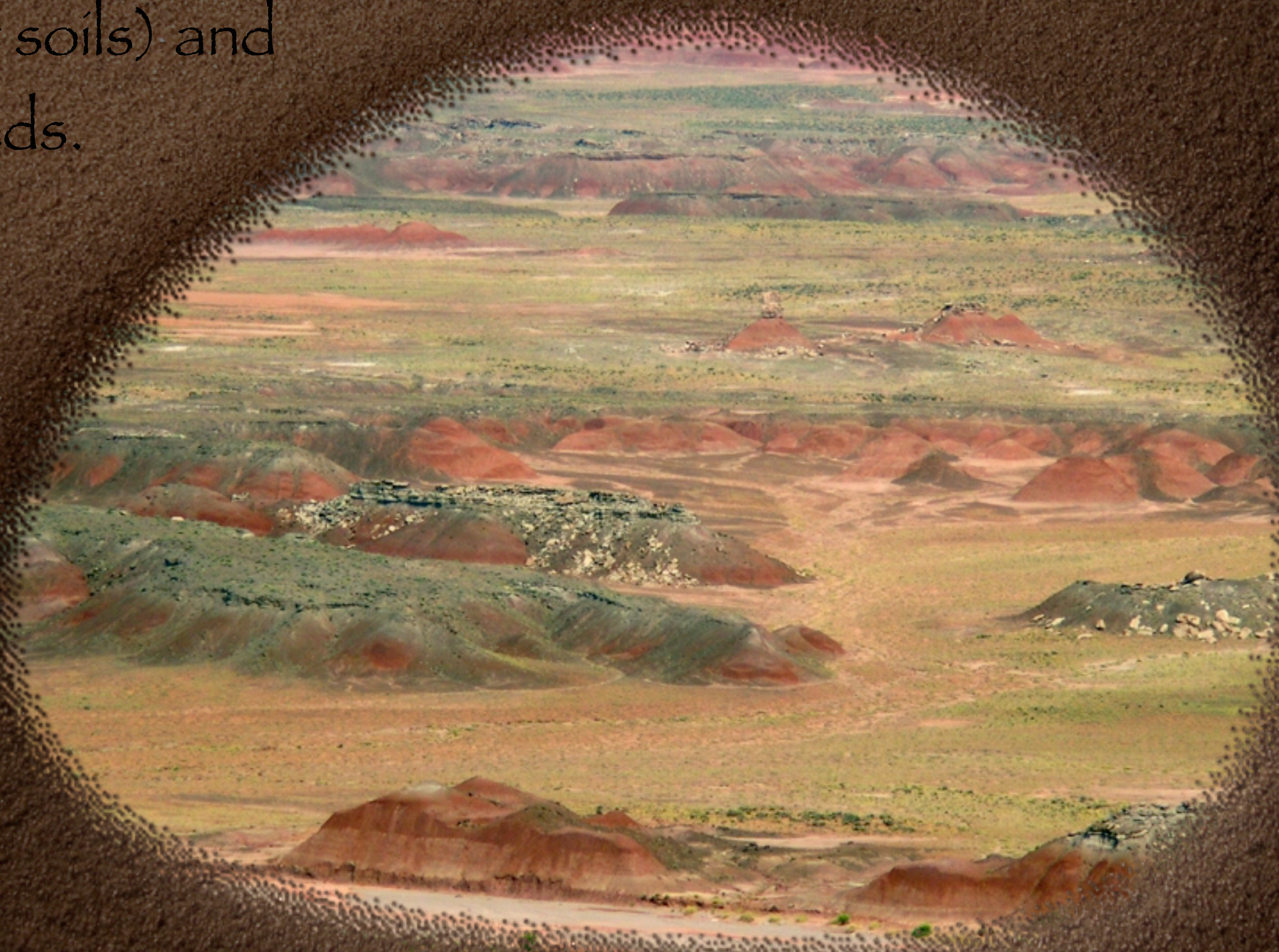
(b)

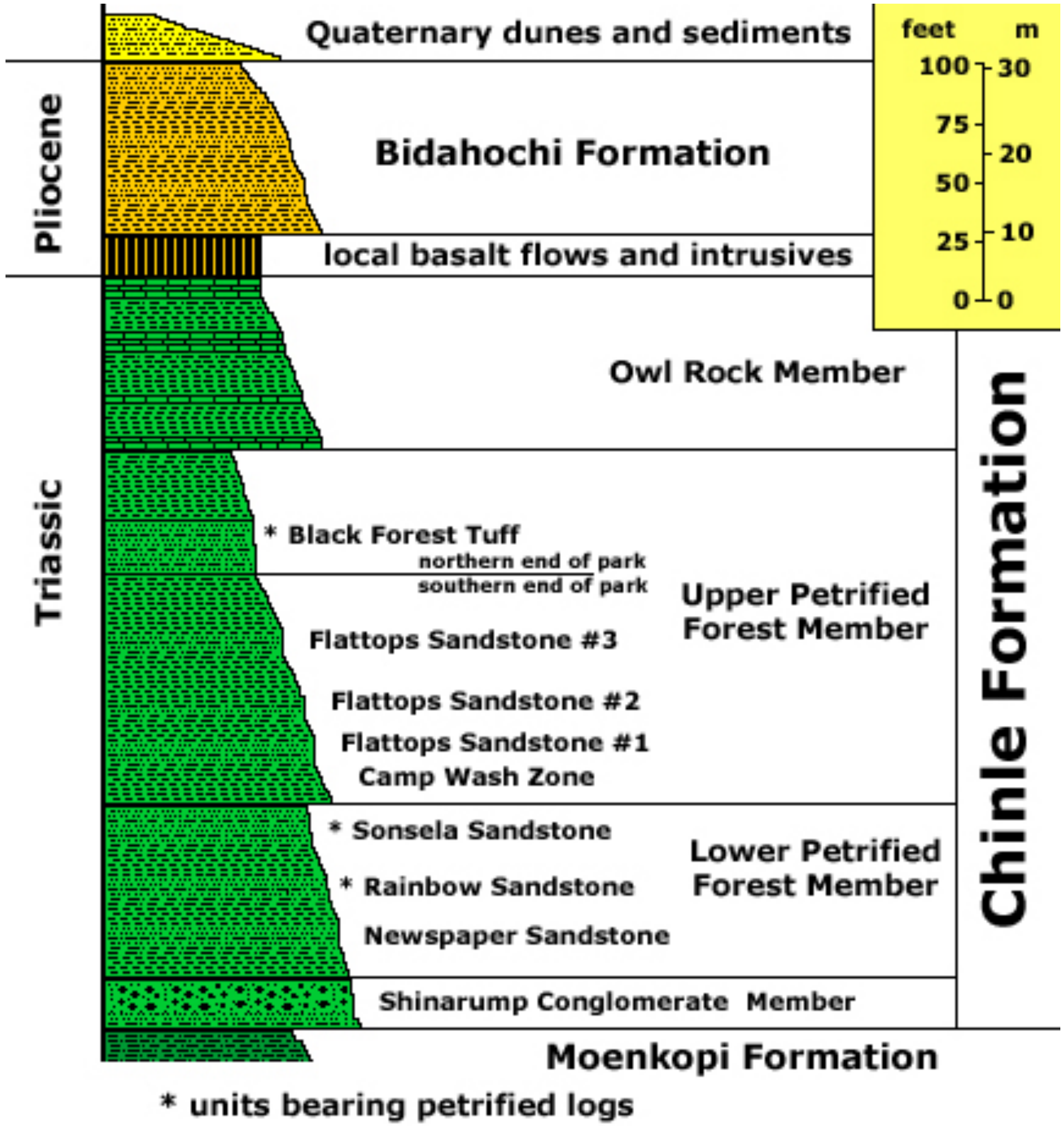


(c)

Painted Desert
Chinle Formation

Sequence of paleosols (ancient soils) and fluvial seds.




Quaternary dunes and sediments
feet
m
100
30
75
20
50
25
10
0
0
Pliocene
Bidahochi Formation
local basalt flows and intrusives
Triassic
Owl Rock Member
* Black Forest Tuff
northern end of park
southern end of park
Upper Petrified Forest Member
Flattops Sandstone #3
Flattops Sandstone #2
Flattops Sandstone #1
Camp Wash Zone
* Sonsela Sandstone
* Rainbow Sandstone
Newspaper Sandstone
Lower Petrified Forest Member
Shinarump Conglomerate Member
Chinle Formation
Moenkopi Formation
* units bearing petrified logs

Painted Desert
Chinle Formation

Usually the bright red profiles represent poorly drained soils.

Painted Desert/ Petrified Forest

The purple, mauv, gray and white profiles represent well drained and well developed soils.

Fossil tree remains.

Painted Desert/ Petrified Forest

Fossil tree remains.

Painted Desert/ Petrified Forest

Fossil tree remains.

Painted Desert/ Petrified Forest

Here wood has been replaced with silica, destroying all original internal anatomy, but making beautiful fossils.


Painted Desert/
Petrified Forest

Painted Desert/ Petrified Forest

This 'natural bridge' was formed when a gully eroded the soft sediments out from under a long fossil log.

Herbivorous Therapsid

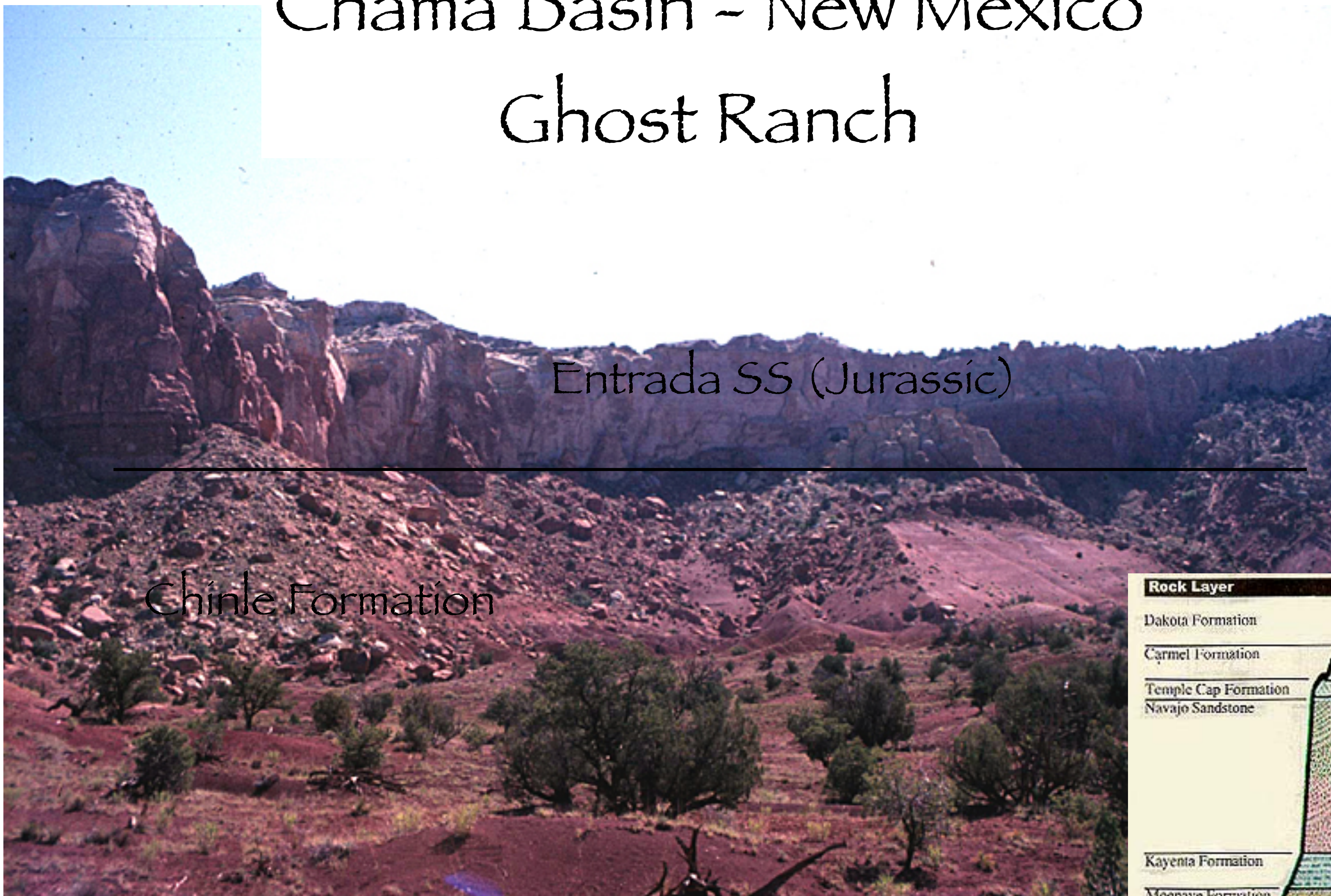
The Chinle Formation and Petrified Forest are full of vertebrate fossils.

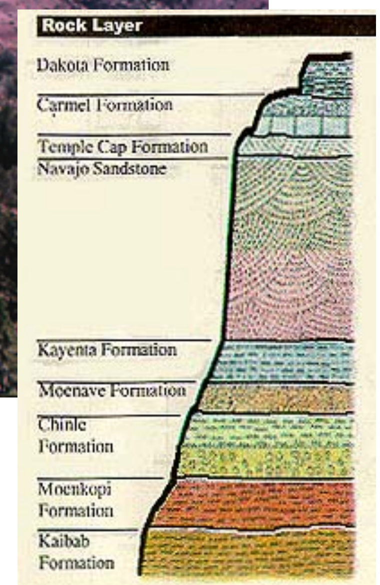
Carnivorous Diapsid

Chama Basin - New Mexico
Ghost Ranch

Late Paleozoic through Cretaceous sediments.

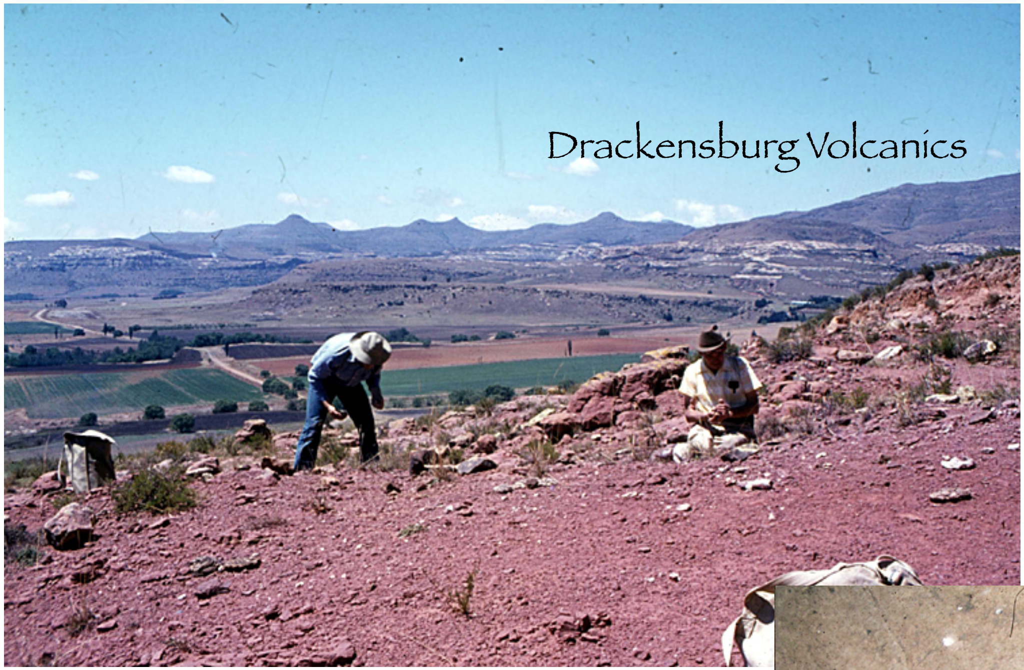
Chama Basin - New Mexico
Ghost Ranch





Triassic Rocks

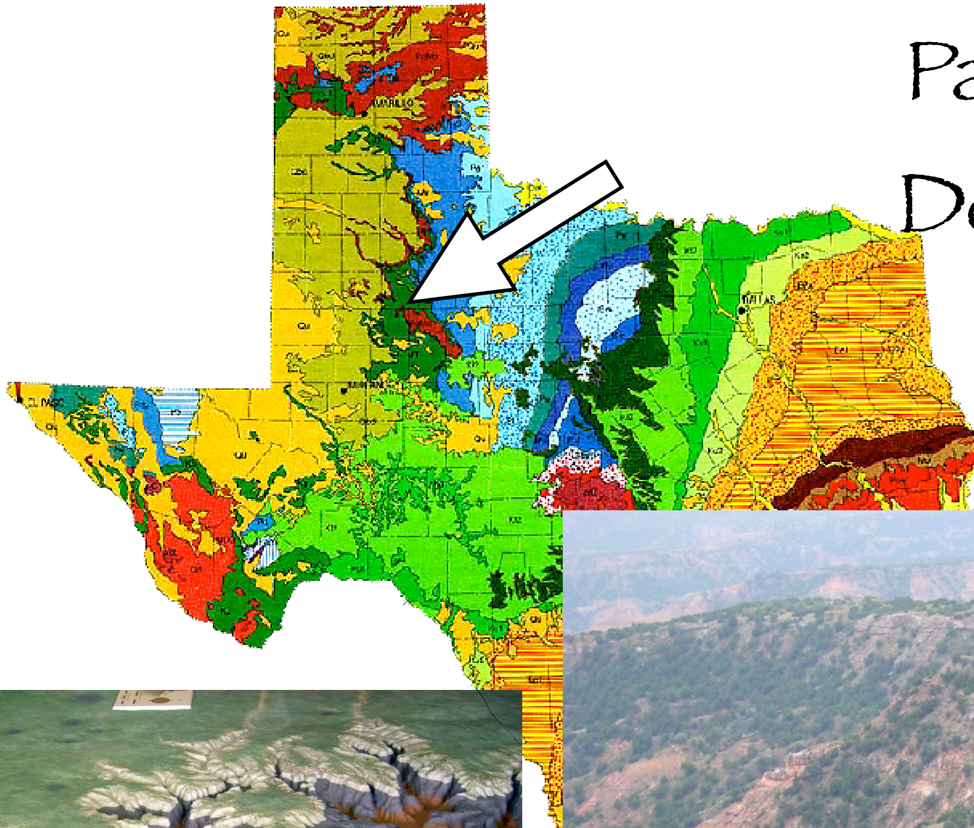
South Africa

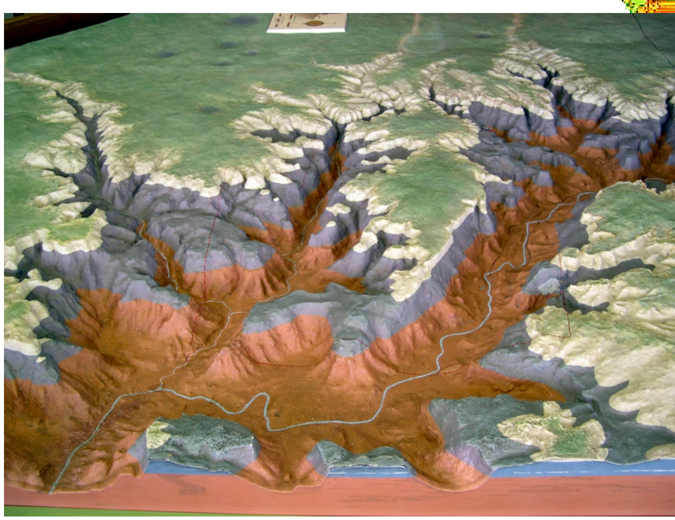


Clarens Formation

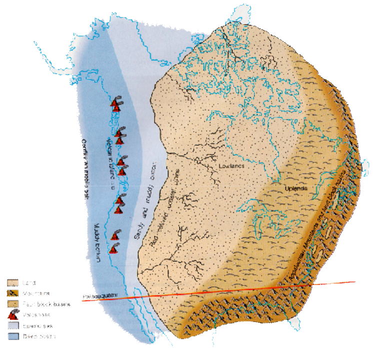
Foot of a Prosauropod dinosaur

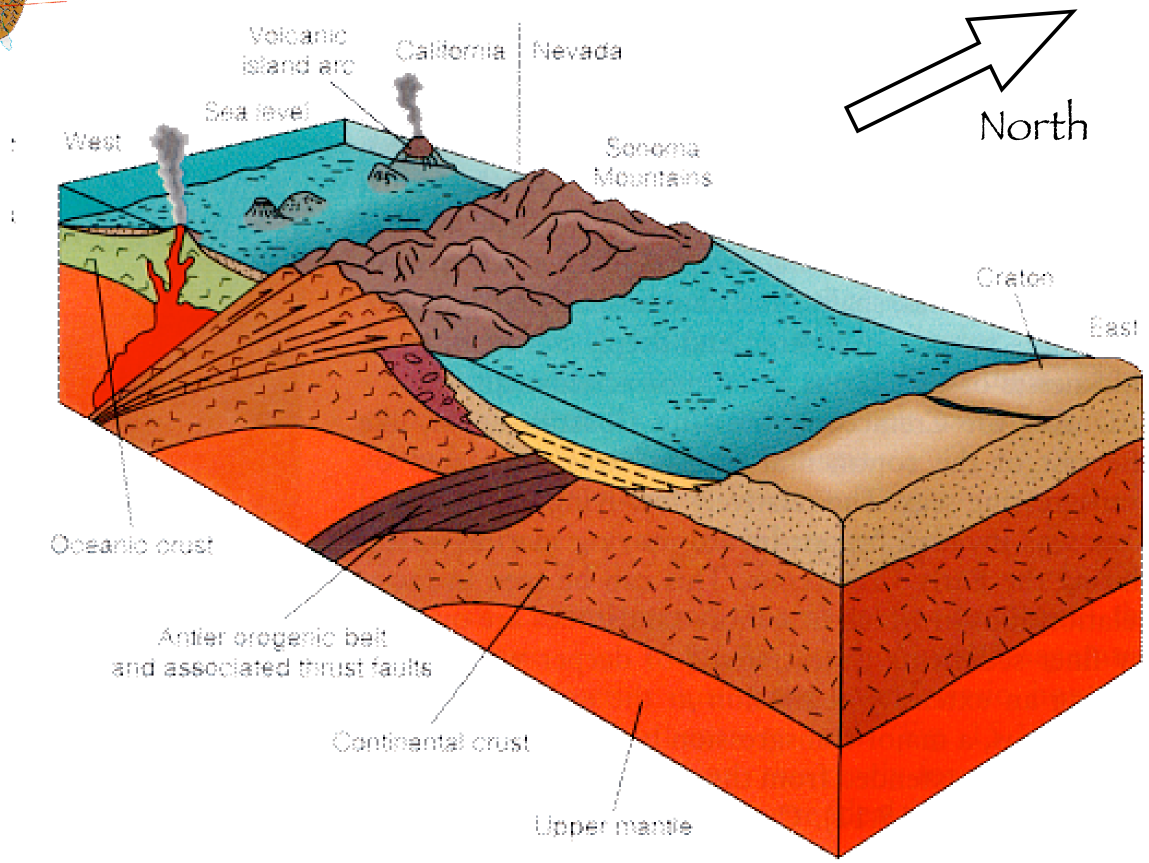
Palo Duro Canyon
Dockum Formation



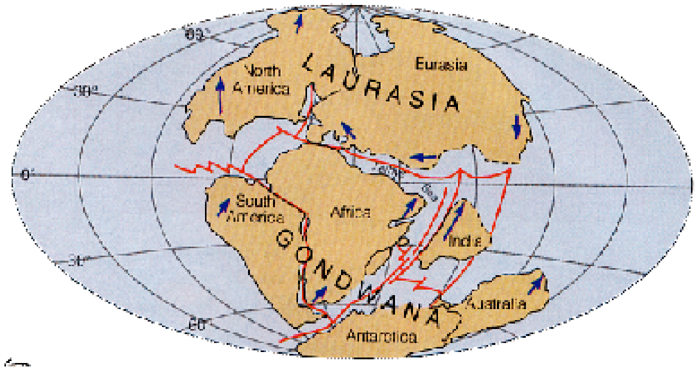


Sonoman Orogeny

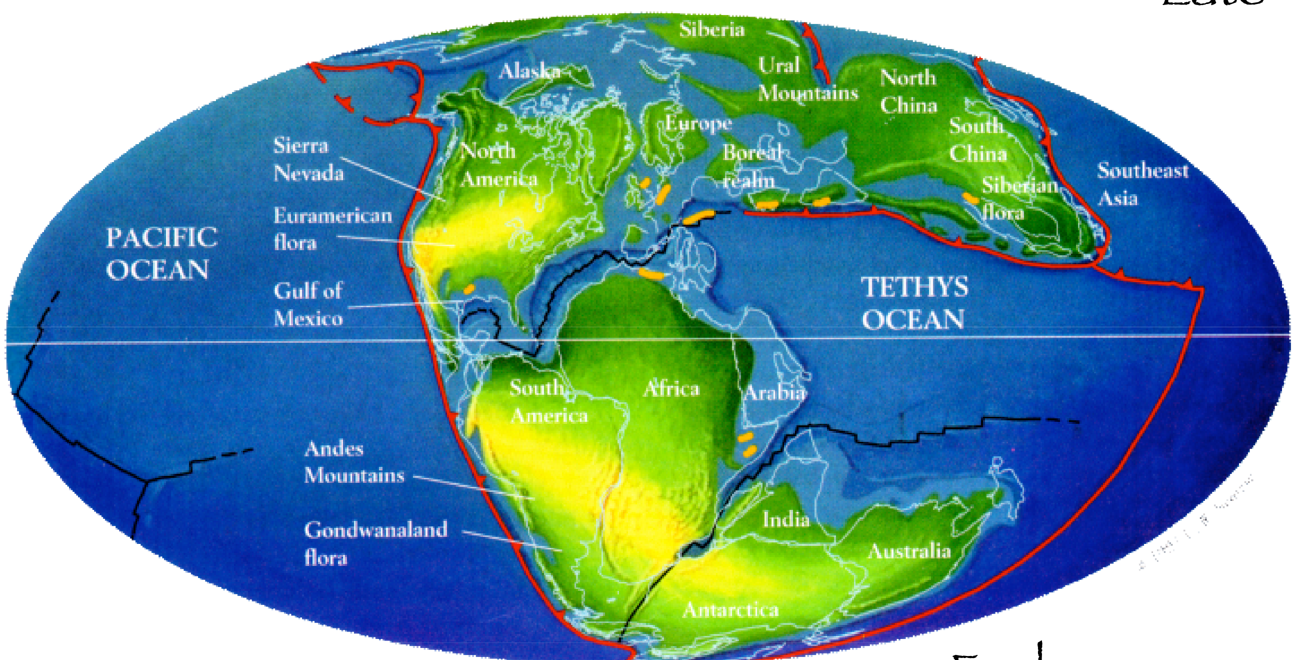




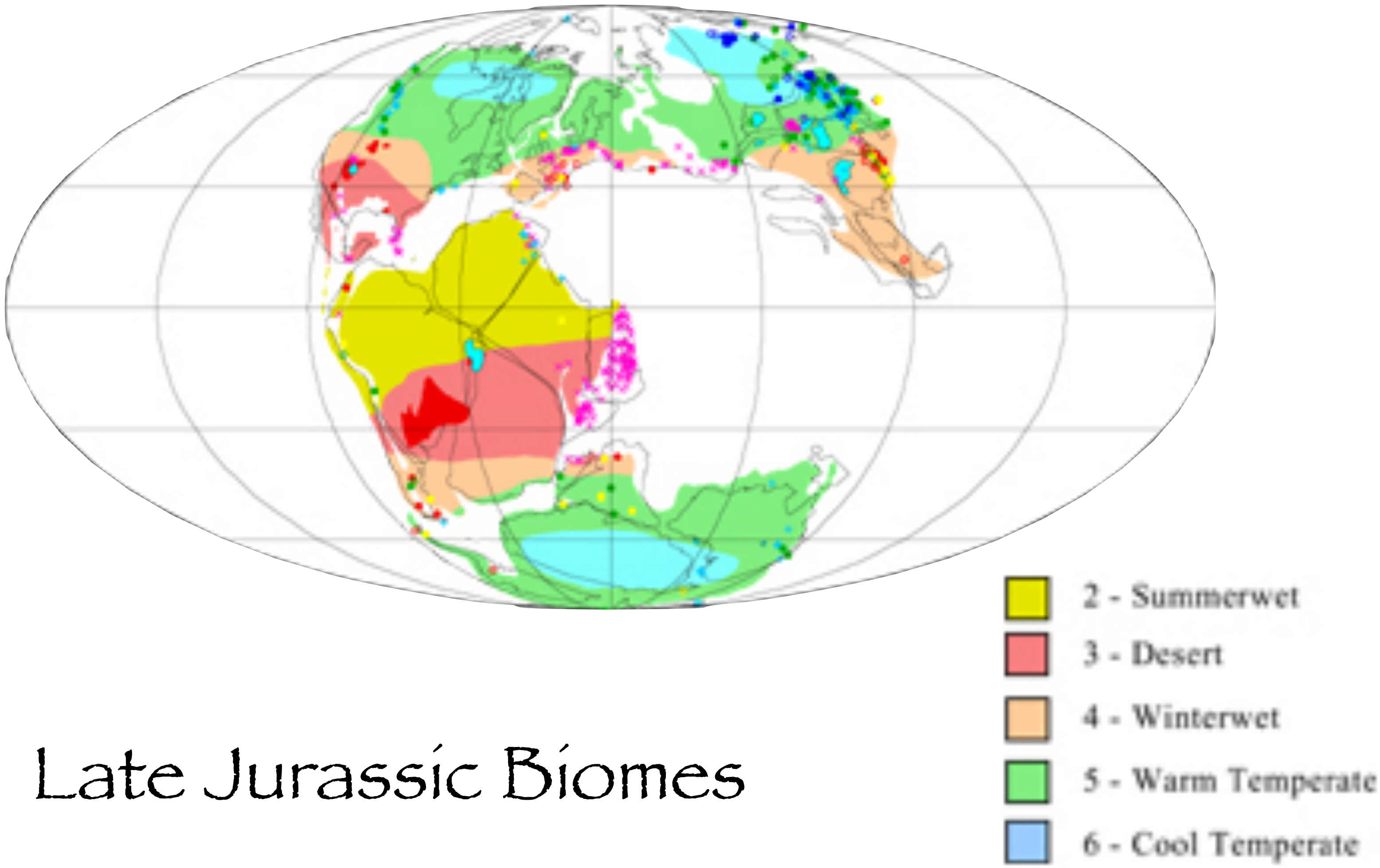
The Jurassic World



Late



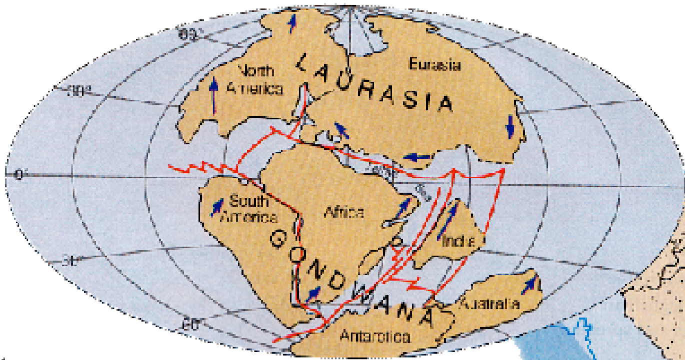
Early



Late Jurassic Biomes

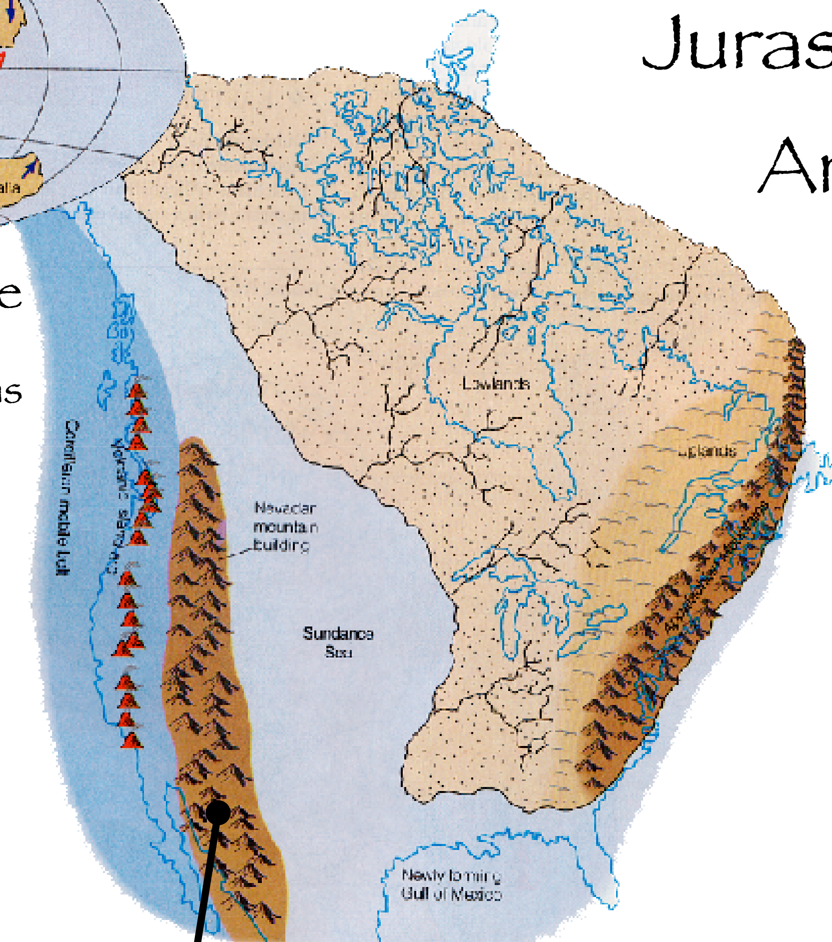
During the Jurassic, sea levels began to rise, probably due to an increase in sea-floor spreading. This caused flooding of large areas of the continents. As a result, the deserts began to retreat and continental temperatures stabilized. Pangea also began to break up into smaller units, which brought more land area in contact with the ocean. The presence of nearby oceans also increased humidity, so that climates worldwide became wetter as well as warmer.

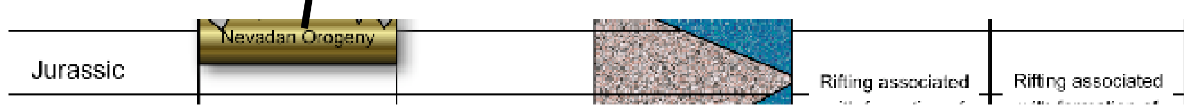
Jurassic North America

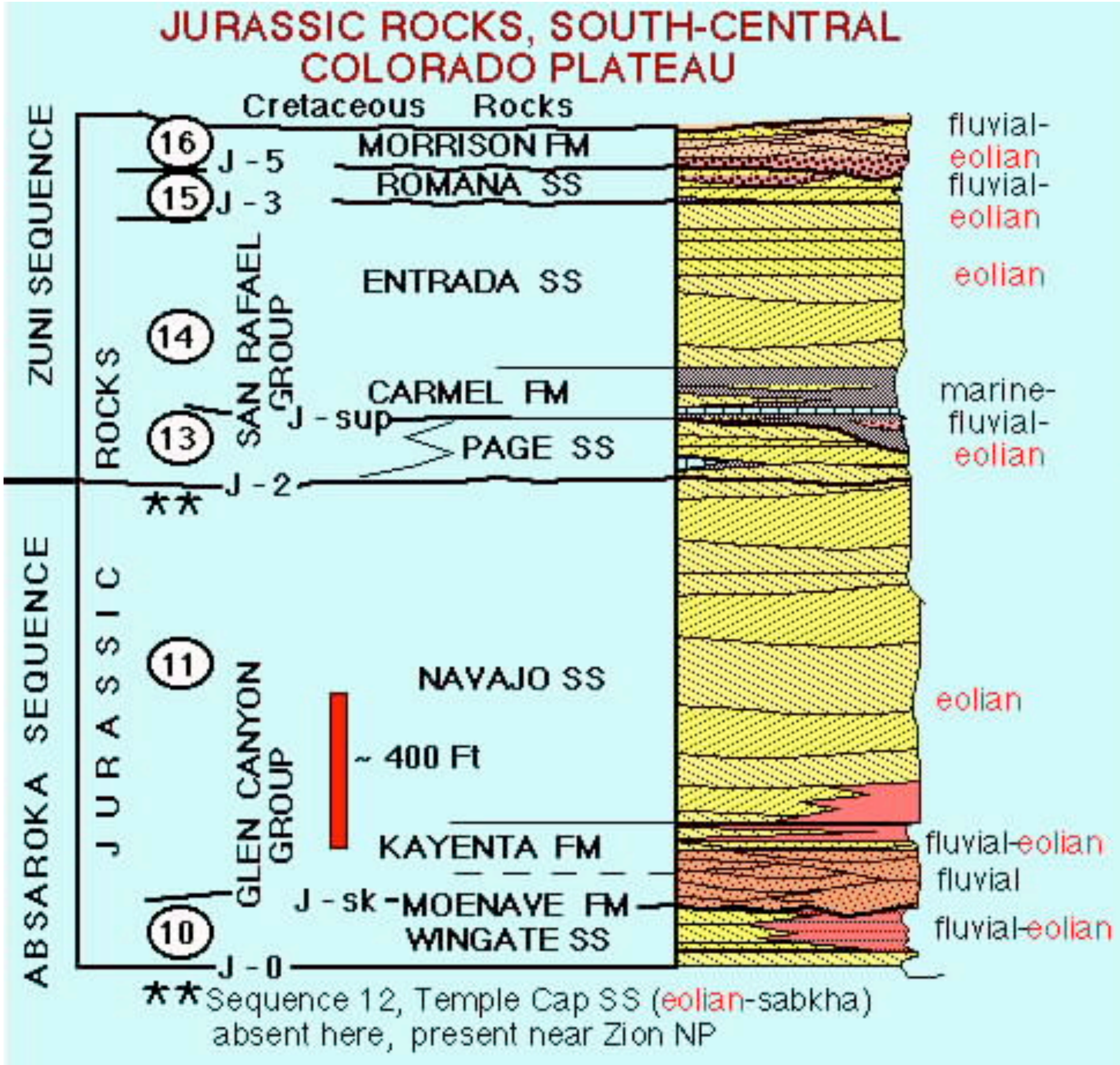


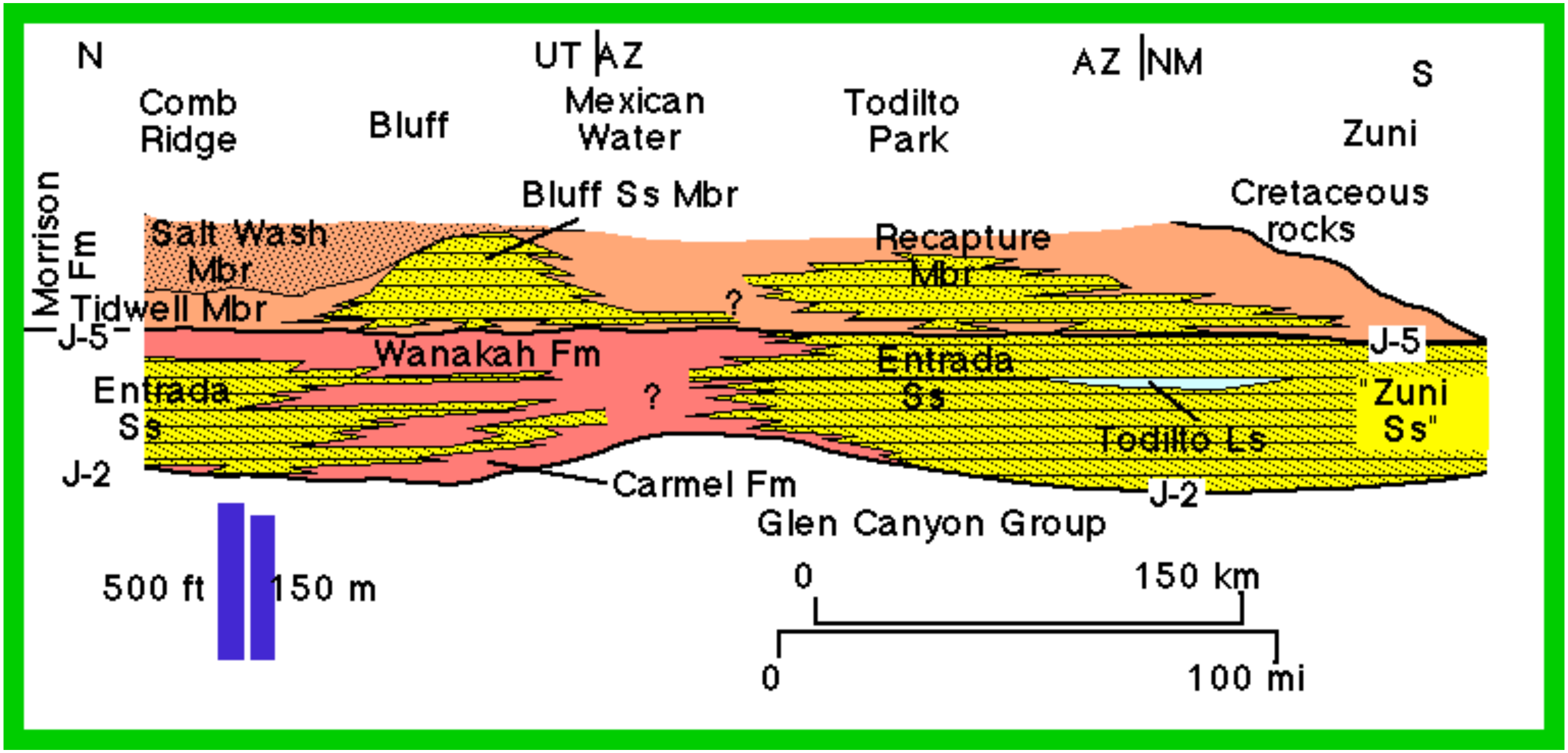
Late

Granitic stocks and plutons in the Sierra Nevada represent the Nevadan Orogeny.

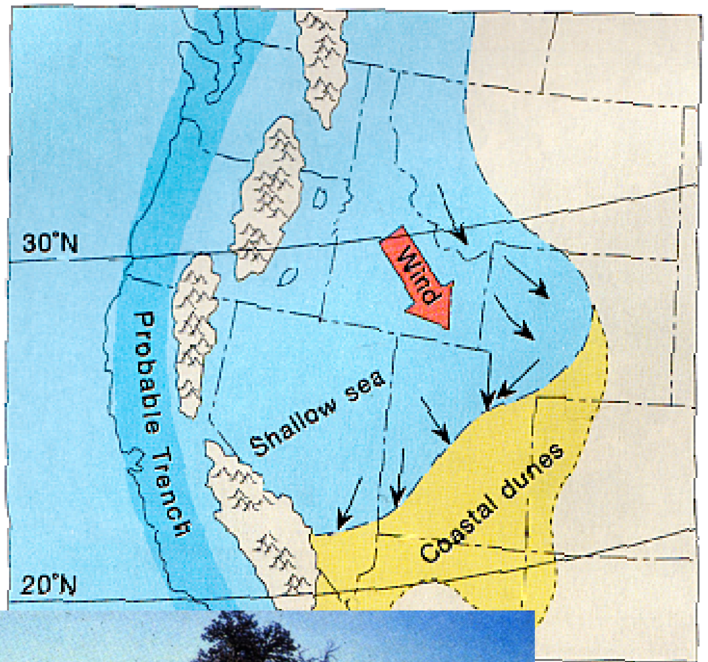





JURASSIC ROCKS, SOUTH-CENTRAL COLORADO PLATEAU
Cretaceous Rocks
ZUNI SEQUENCE
ABSAROKA SEQUENCE
JURASSIC ROCKS
SAN RAFAEL GROUP
GLEN CANYON GROUP
16
15
14
13
11
10
J - 5
J - 3
J - sup
J - 2
J - sk
J - 0
MORRISON FM
ROMANA SS
ENTRADA SS
CARMEL FM
PAGE SS
NAVAJO SS
~ 400 Ft
KAYENTA FM
MOENAVE FM
WINGATE SS
fluvial-eolian
fluvial-eolian
eolian
marine-fluvial-eolian
eolian
fluvial-eolian
fluvial
fluvial-eolian
** Sequence 12, Temple Cap SS (eolian-sabkha) absent here, present near Zion NP

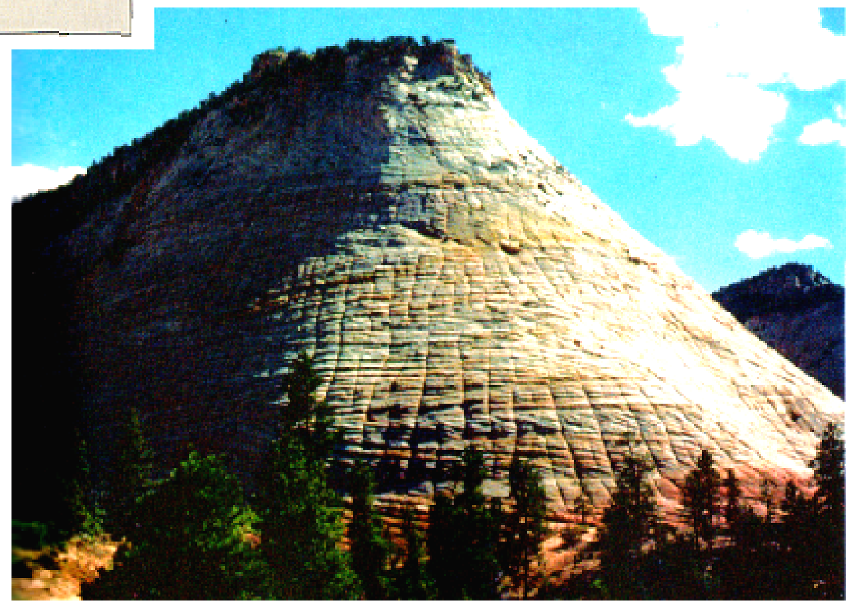


N
UT AZ
AZ NM
S
Comb Ridge
Bluff
Mexican Water
Todilto Park
Zuni
Bluff Ss Mbr
Cretaceous rocks
Morrison Fm
Salt Wash Mbr
Recapture Mbr
Tidwell Mbr
?
J-5
J-5
Wanakah Fm
Entrada Ss
Entrada Ss
?
"Zuni Ss"
Todilto Ls
J-2
Carmel Fm
J-2
Glen Canyon Group
500 ft
150 m
0
150 km
0
100 mi

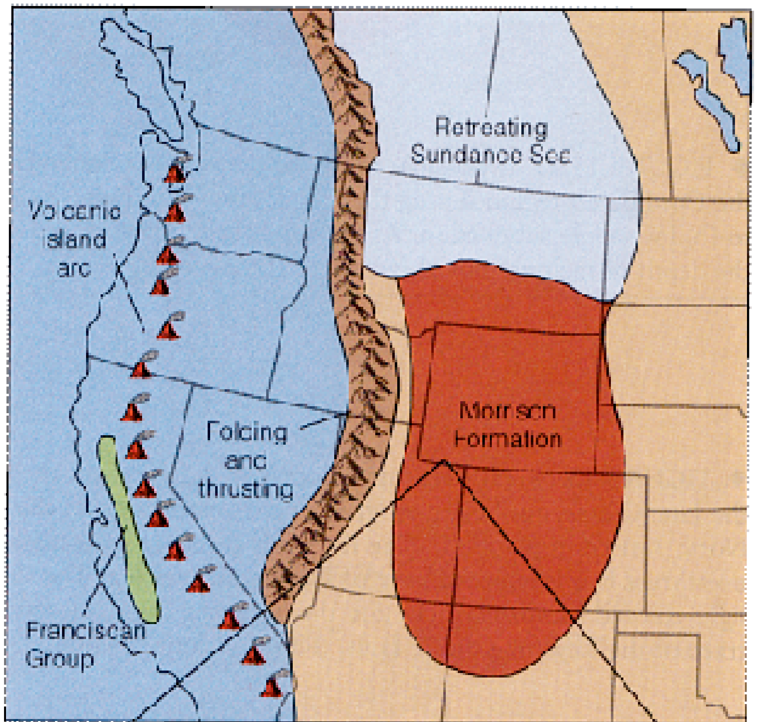


Early Jurassic

Navajo Sandstone



Chama Basin-New Mexico
Ghost Ranch



Early Jurassic

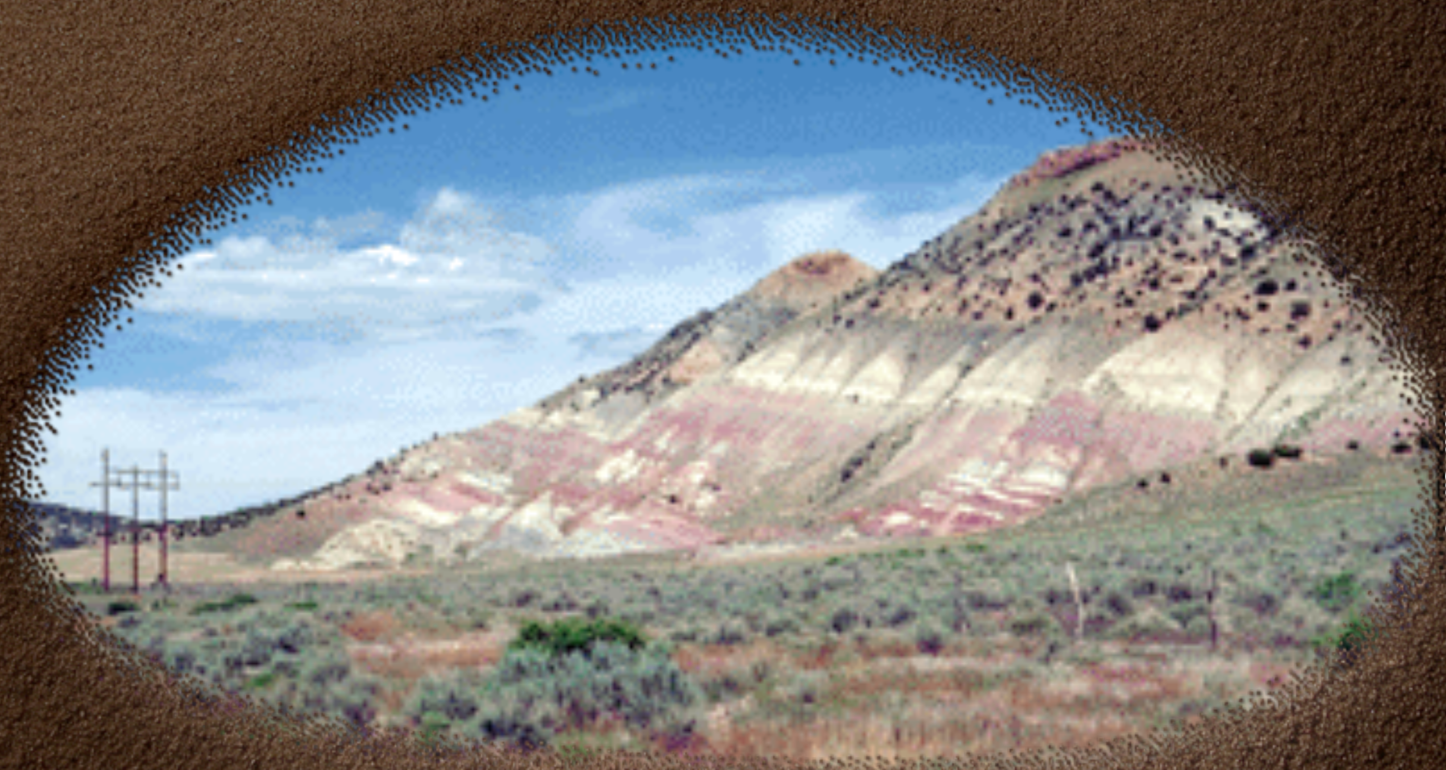
Morrison Formation

Morrison Fm.

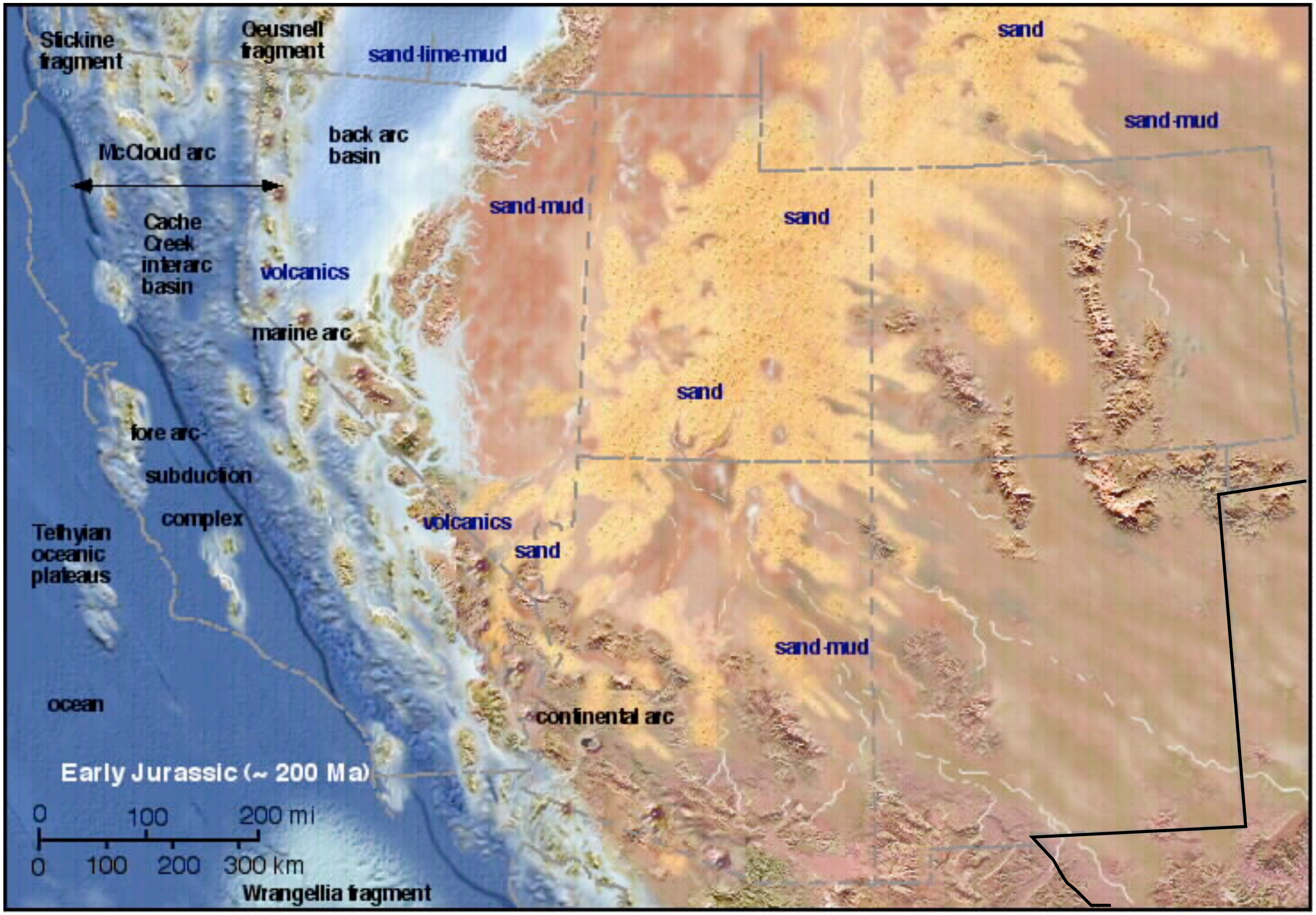
Dinosaur National Monument

Chama Basin-New Mexico
Ghost Ranch

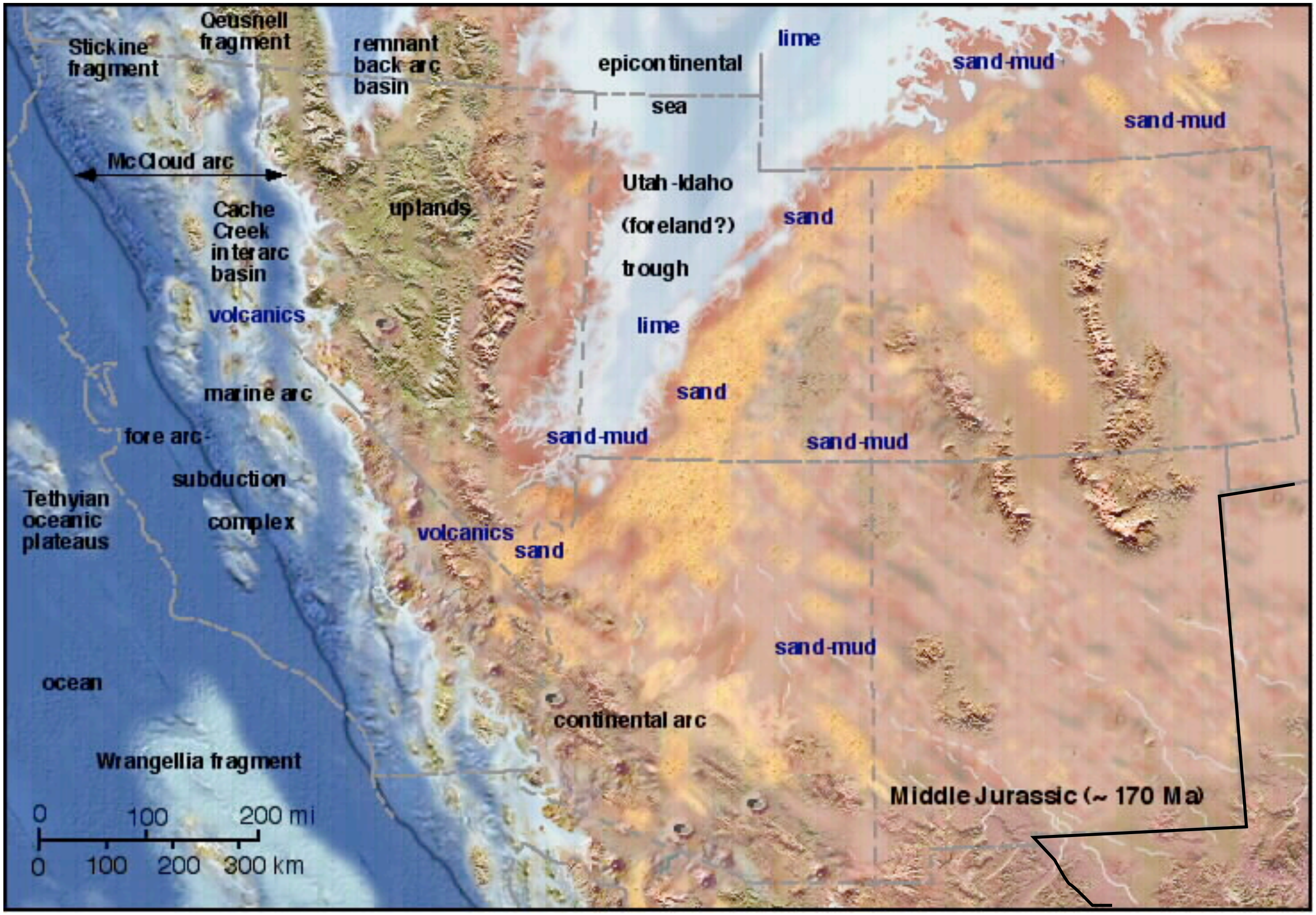
Morrison Formation in Utah



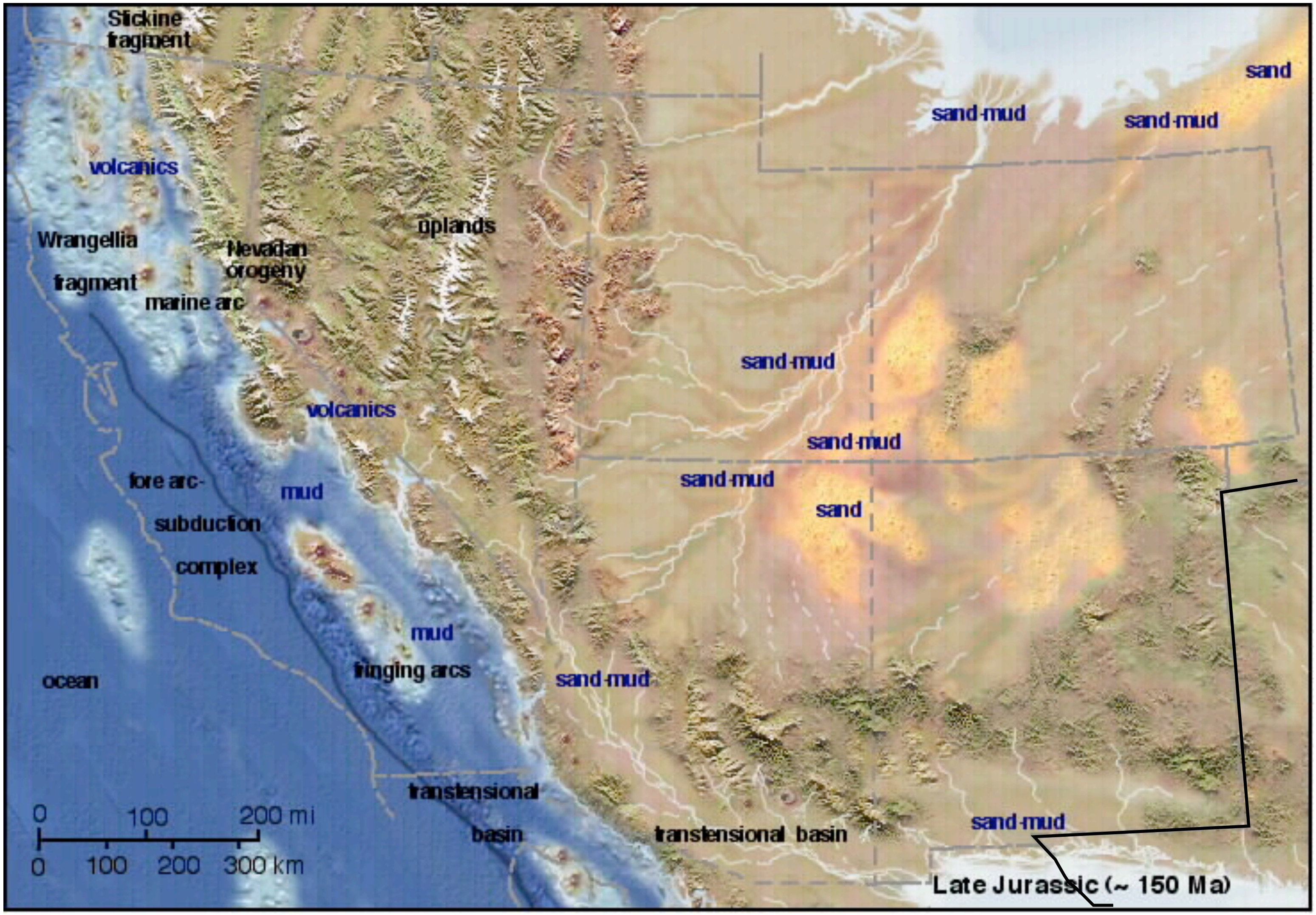
Termite Nest



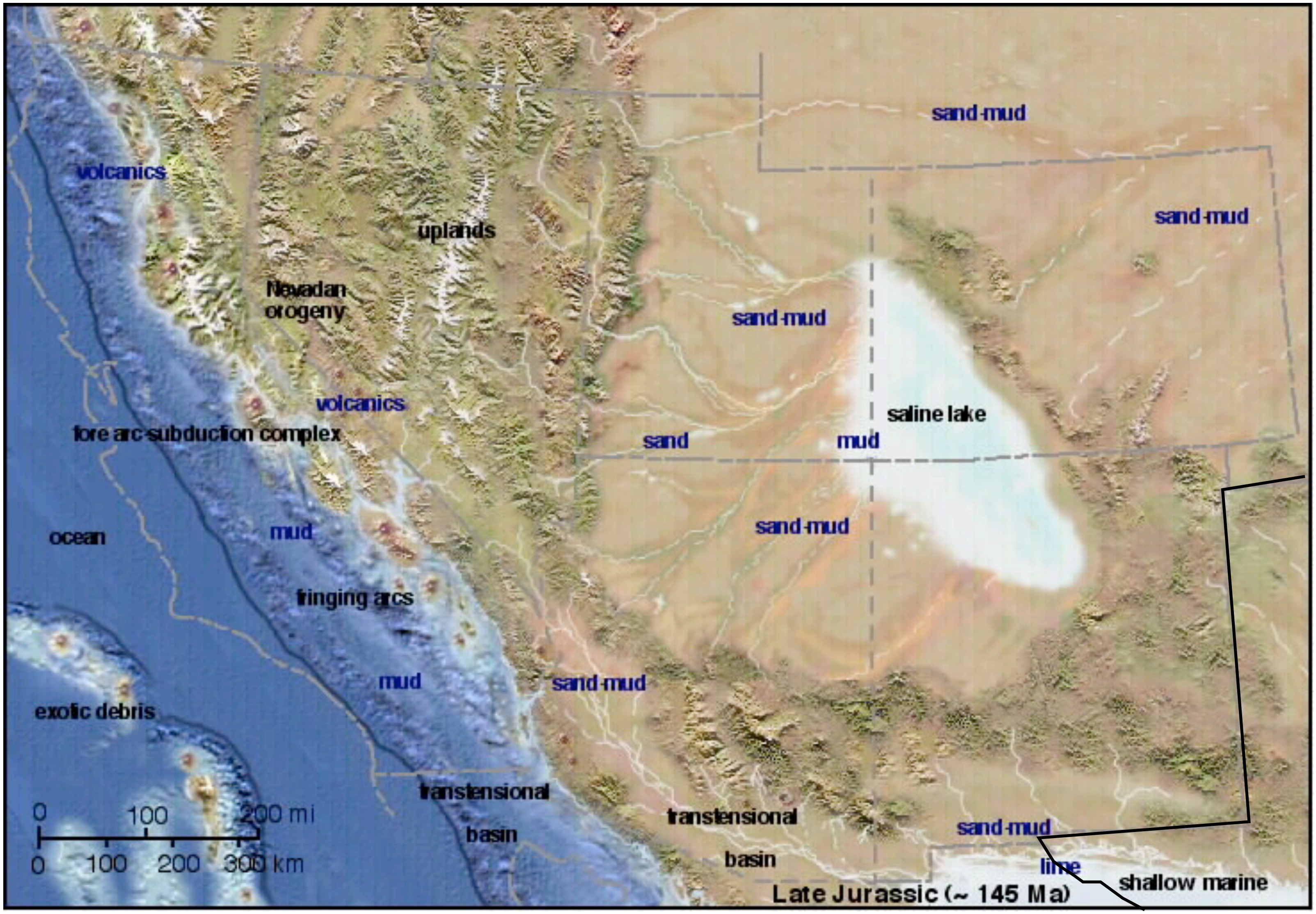
Navajo Fm. (Early Jurassic)



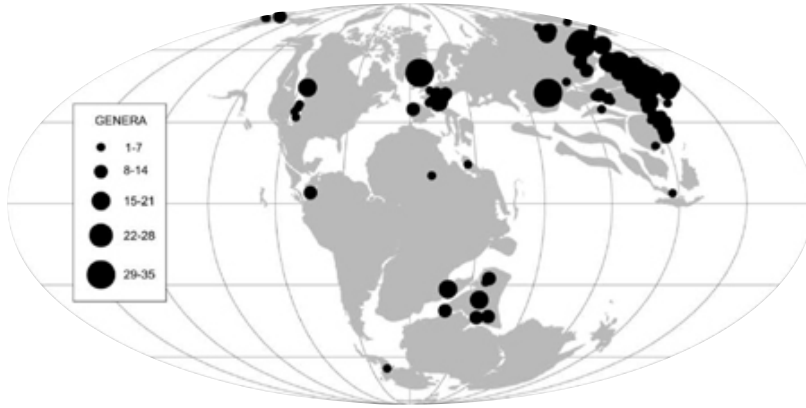
Middle Jurassic



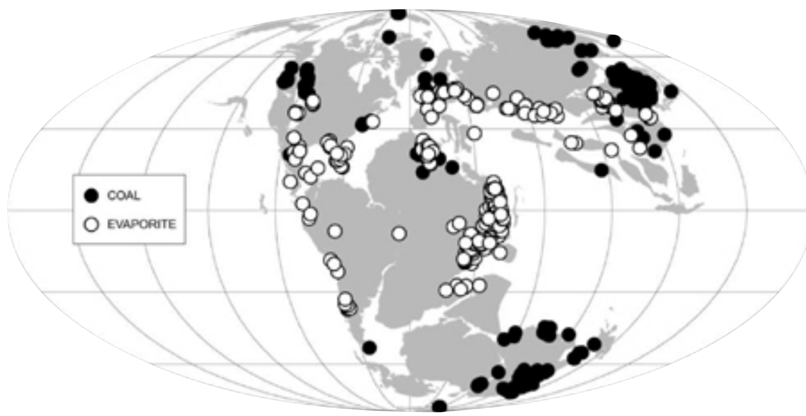
Morrison Fm. (Late Jurassic)



Morrison Fm. (Latest Jurassic)



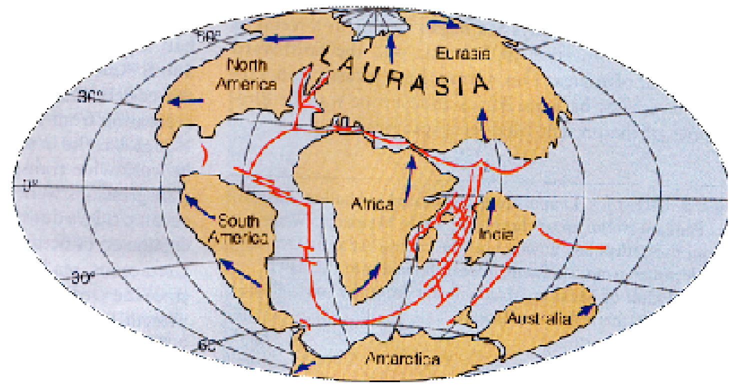
Plants

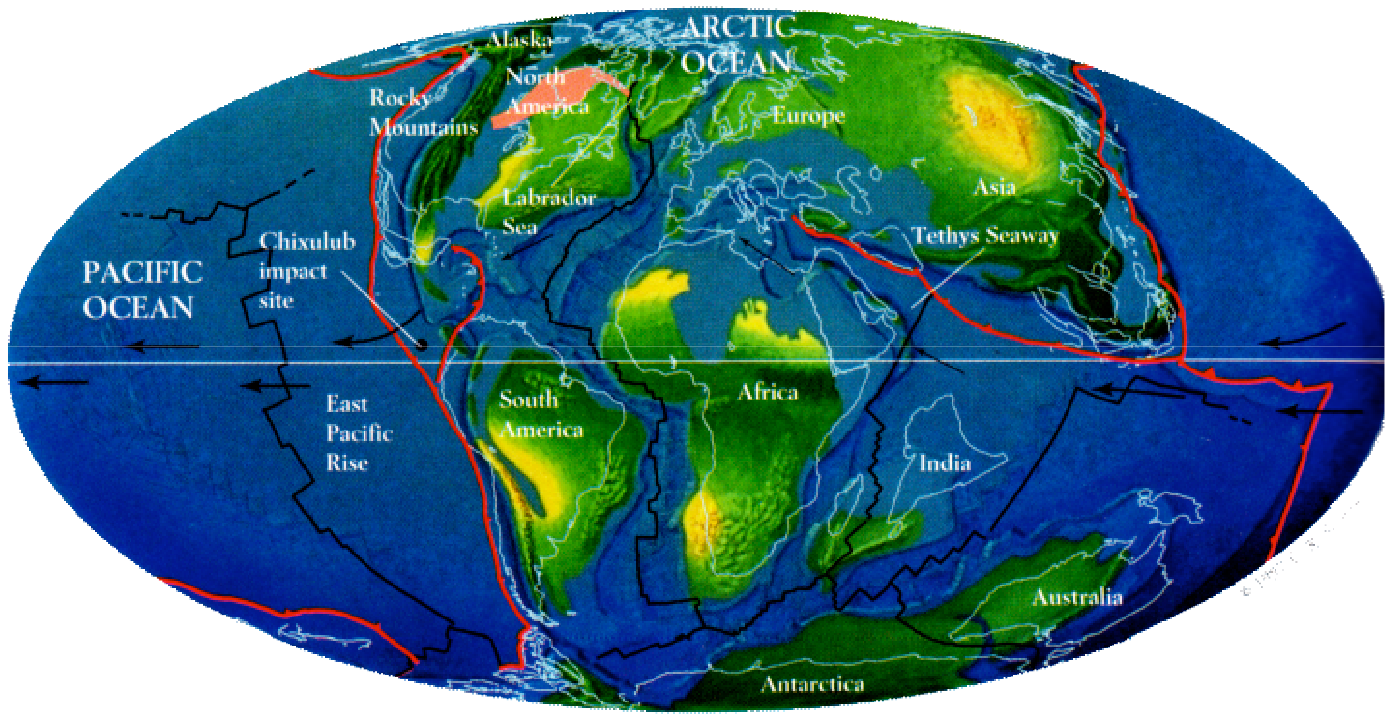


Sediments

Dinosaurs

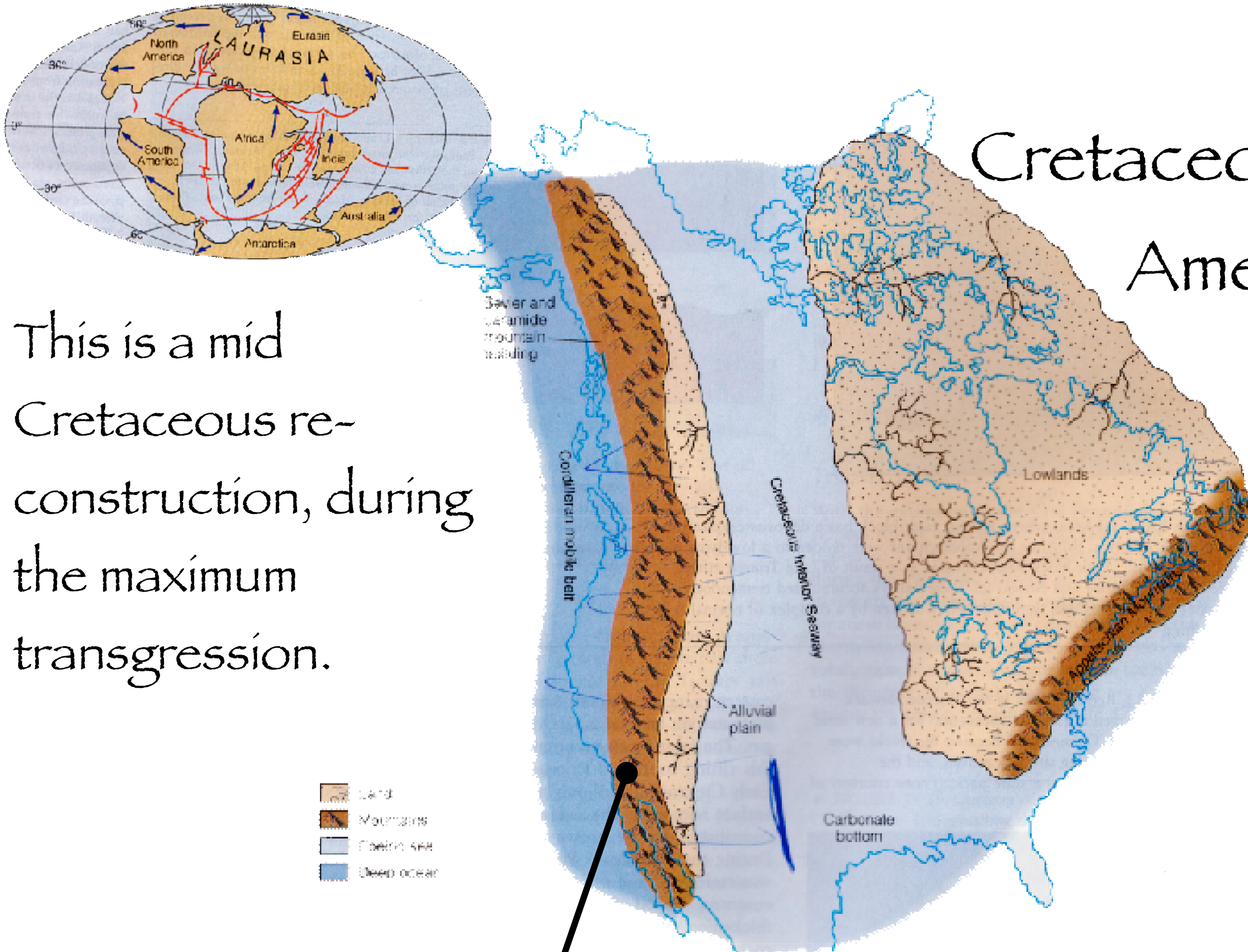
The Cretaceous World

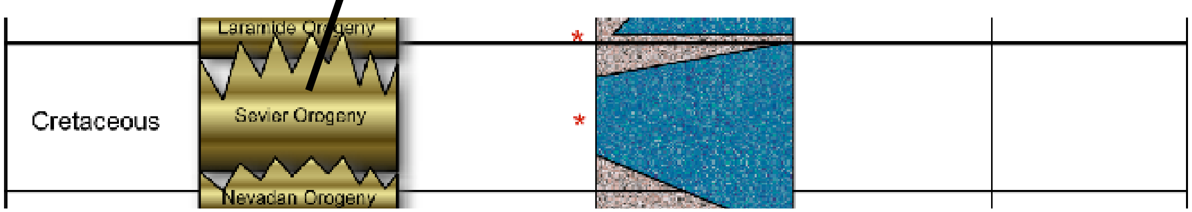




Cretaceous North America

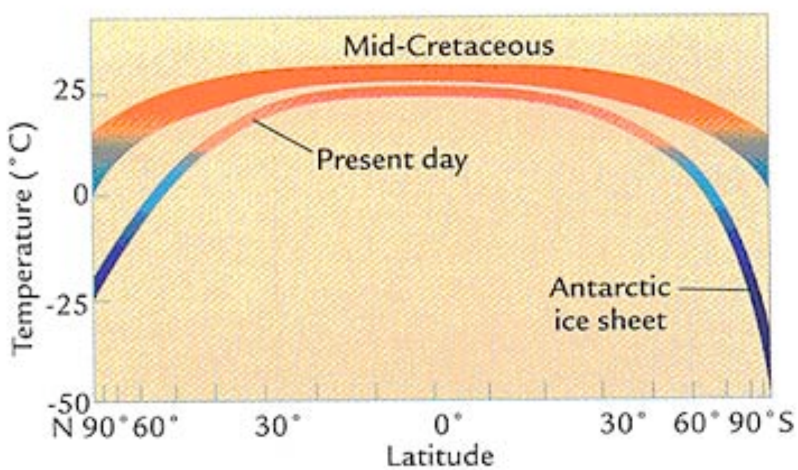
This is a mid Cretaceous re-construction, during the maximum transgression.



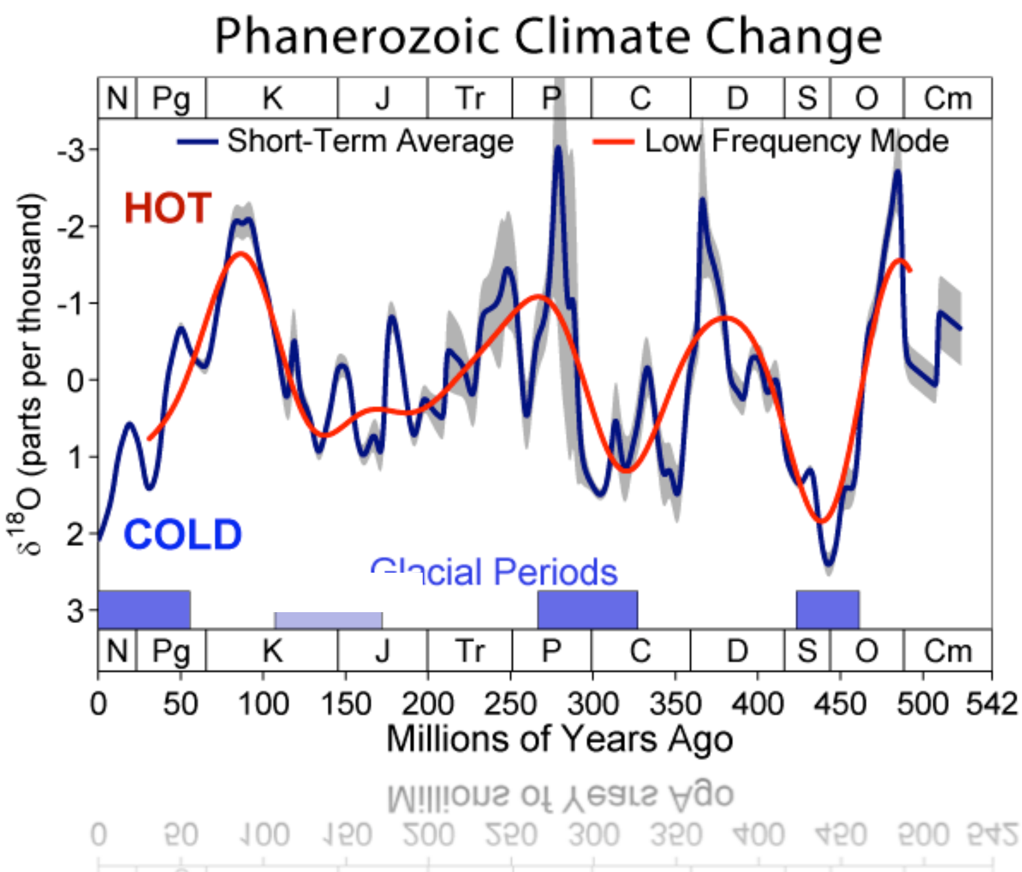


During the first half of the Cretaceous, the processes seen in the late Jurassic continued. In addition, two climate trends which began in the Jurassic became quite pronounced in the Cretaceous. The mechanism for these events is not fully understood.

First, the temperature gradient from North to South became almost flat -- much more so than would be predicted from ocean circulation models. In other words, average temperatures were about the same everywhere on Earth, from the poles to the equator.



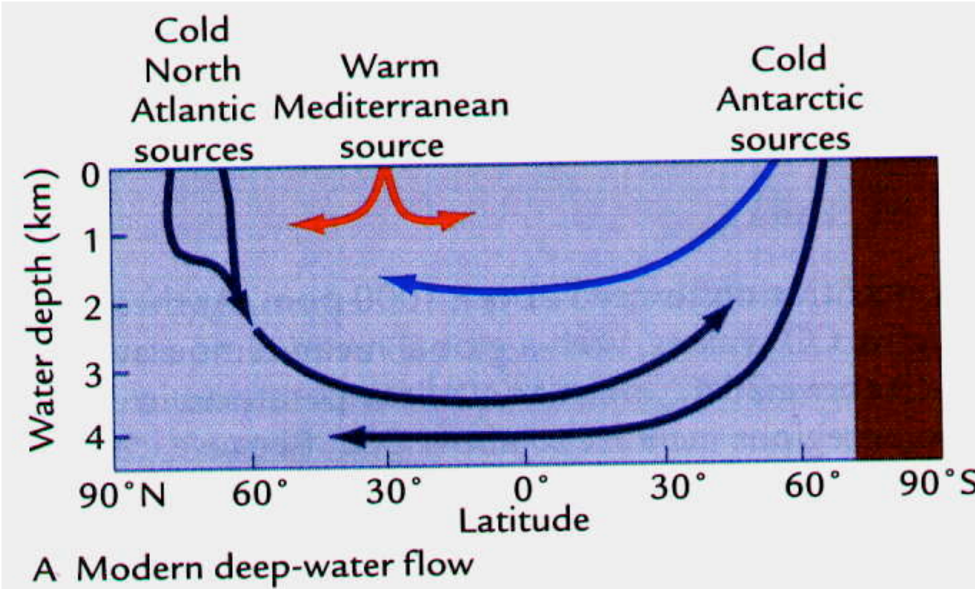
Second, average temperatures were much higher than today, probably by about 10C°. Higher CO_2 (carbon dioxide) levels certainly played a part, but the paleoclimate data do not match theoretical predictions.



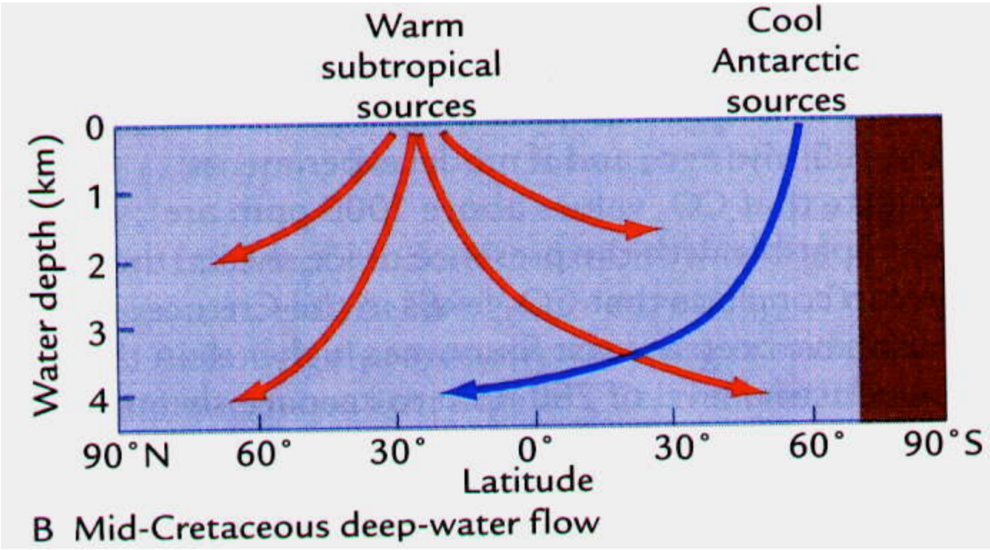
The later Cretaceous story is more complex and more controversial. Many researchers, but not a real consensus, believe that sea temperatures near the equator may have become a bit too warm by the Aptian-Albian, perhaps actually incompatible with ocean life.

In addition, some data suggest that land areas near the equator were not jungle- or forest-covered, that plant diversity was low, and that these regions were arid despite being close to the sea.

Deep ocean circulation may also have broken down. That is, water continued to circulate horizontally, but not vertically. The deep oceans weren't getting oxygen, and "black shales" appeared in the Aptian-Albian and Upper Cretaceous. These are large volumes of organic matter in the oceans which never completely decomposed because of lack of deep ocean oxygen. Similar to the end of the Permian.



A Modern deep-water flow



B Mid-Cretaceous deep-water flow

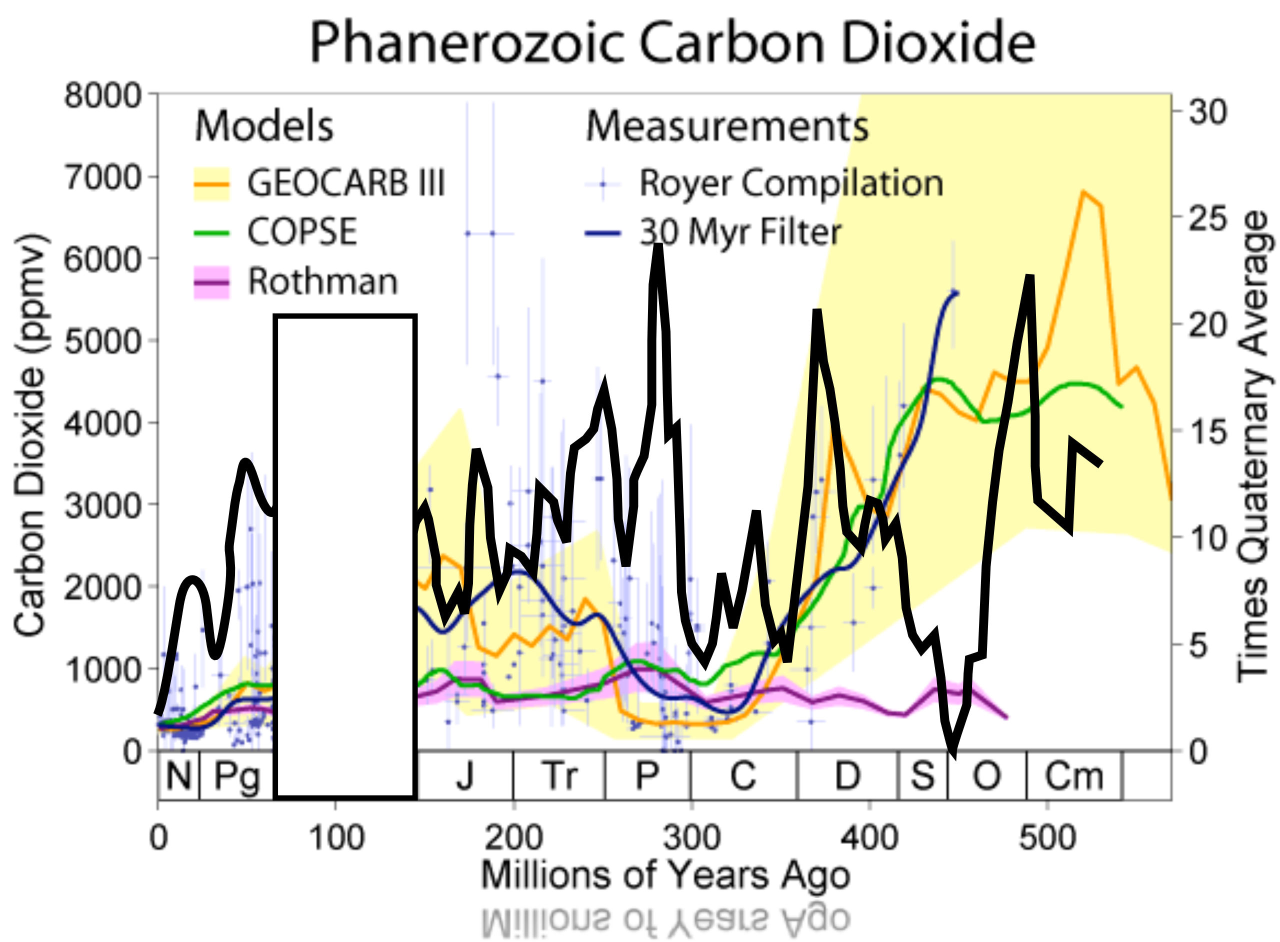
Things cooled off a little during the Terminal-Cretaceous, but it's unclear how much or how regularly. The climate at the very end of the Mesozoic is particularly controversial.

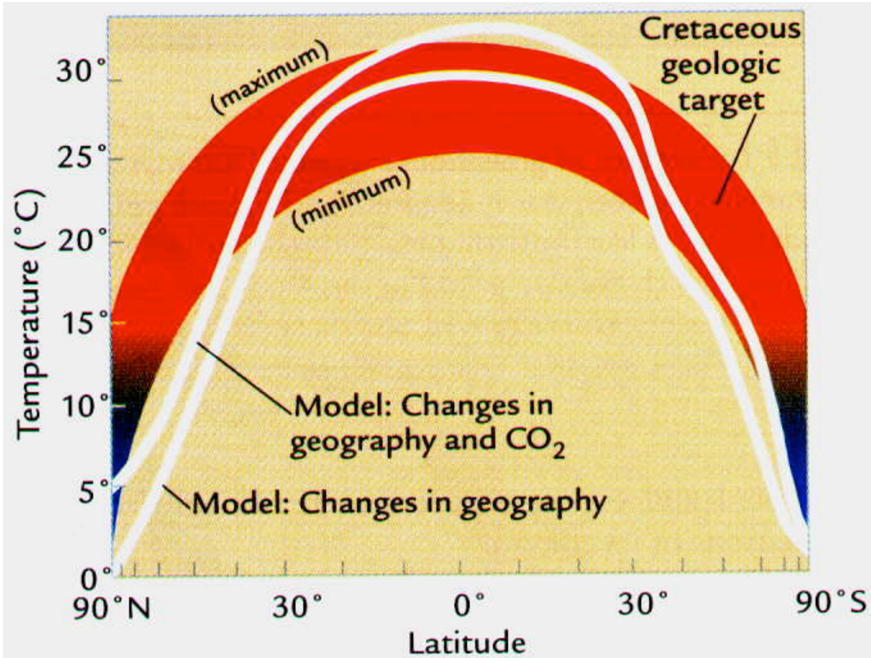
However, there are interesting inconsistencies between what we 'think' the climate should have been and what the data indicate.

Here are a few of the inconsistencies...

1) There is evidence of the kind of rapid sea level changes associated with polar ice in the Mid-Cretaceous, which is rather hard to accept. Miller et al. (2003). However there is absolutely no geological evidence for this ice and it is incompatible with temperature information.

2) CO_2 levels are usually invoked to explain Cretaceous warmth and the flat Cretaceous temperature gradient. This makes sense, since the very active mid-ocean spreading ridges might well have been associated with out-gassing of CO_2 from deep within the Earth. Unfortunately, the geology of the period and stable carbon isotope records, don't really support the idea as well as they might.





3) Even the most sophisticated quantitative models can't reconstruct the flatness of the Cretaceous temperature gradient. Either our temperature estimates are off, or some important factor is missing from the models. Since dinosaurs and semi-tropical vegetation are known from within 10° of the Cretaceous poles, the problem is likely to be with the theory. A recent study of a mid-latitude continental interior (in eastern Russia) -- far from the ocean in even Late Cretaceous times, suggest that temperatures were very even and that these regions were damp and non-seasonal even in the Mid-Cretaceous.

Geological Events

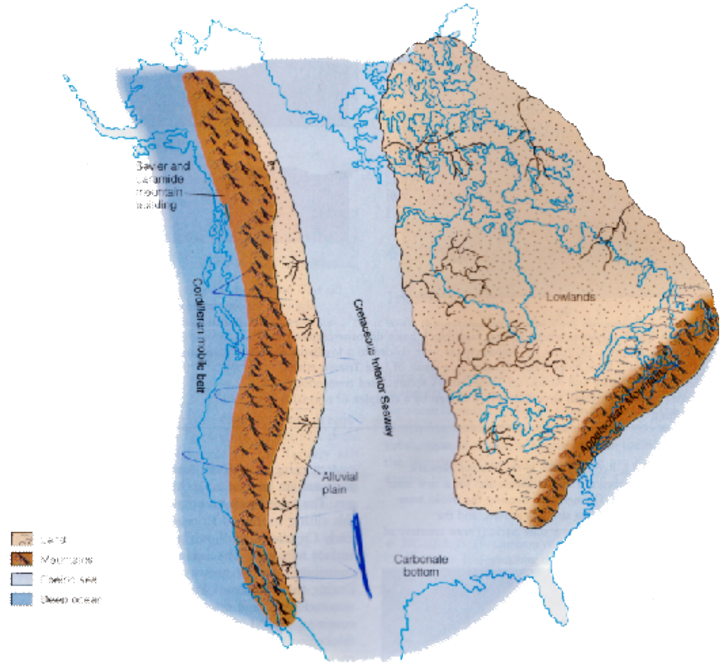
mud
shallow marine
uplands
volcanics
uplands
thrust
belt
sand-mud
sand-mud
fore arc-
subduction
complex
sand-mud
sand-mud
arc
sand
volcanics
ocean
fore arc basin
sand-mud
accretionary
prism-melange
arc
sand-mud
exotic debris
(Wrangellia?)
transtensional
basin
transtensional basin
sand-mud
lime
0 100 200 mi
0 100 200 300 km
Early Cretaceous (~ 130 Ma)
shallow marine

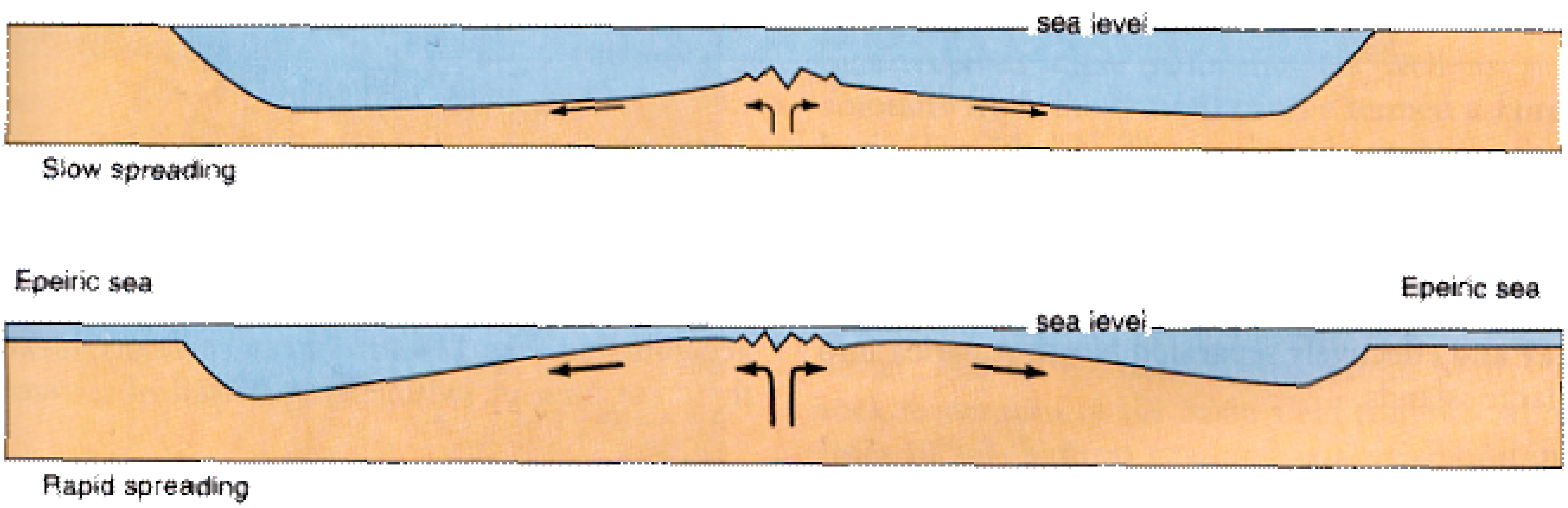

uplands
thrust
Sevier
uplands
belt
fore arc-
subduction
complex
shallow marine
arc
orogeny
sand-mud
plutons
emplaced
throughout arc
sand
sand-mud
mud
lime
fore arc basin
volcanics
accretionary
thrust
prism-melange
belt
sand-mud
sand-mud
sand-mud
ocean
exotic debris
(Wrangellia?)
Mogollon highlands
collision
sand-mud
0
100
200 mi
sand-mud
arc
0
100
200
300 km
Middle Cretaceous (~ 90 Ma)

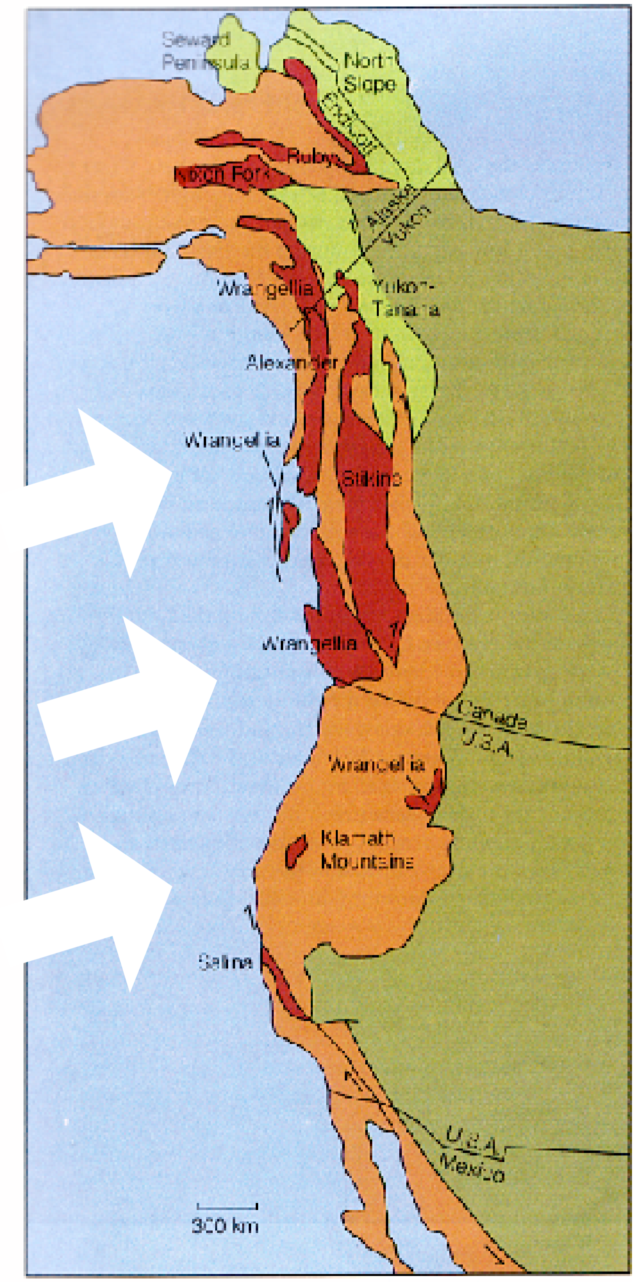

uplands
thrust
belt
sand-mud
shallow marine
mud
sand-mud
Sevier
uplands
sand-mud
E-W compression of Cordillera
orogeny
mud
exotic debris
(Wrangellia?)
fore arc basin
sand
sand-mud
accretionary prism-melange
thrust
belt
sand-mud
sand-mud
ocean
northwest
translation
of terrains
metamorphism
Mogollon highlands
sand-mud
0
100
200 mi
0
100
200
300 km
sand-mud
volcanics
arc
sand-mud
Late Cretaceous (~ 75 Ma)


uplands
thrust
sand-mud
belt
mud
gravel
gravel
gravel
Laramide
sand-mud
uplands
regional
orogeny
sand-mud
exotic debris
(Wrangellia?)
sand-mud
fore arc basin
gravel
accretionary prism-melange
thrust
sand-mud
sand-mud
belt
uplift
northwest
translation
of terrains
ocean
sand-mud
Salinia
Mogollon highlands
metamorphism
0 100 200 mi
0 100 200 300 km
sand-mud
arc
Cretaceous-Tertiary (~ 65 Ma)

Seafloor Spreading and Continental Flooding

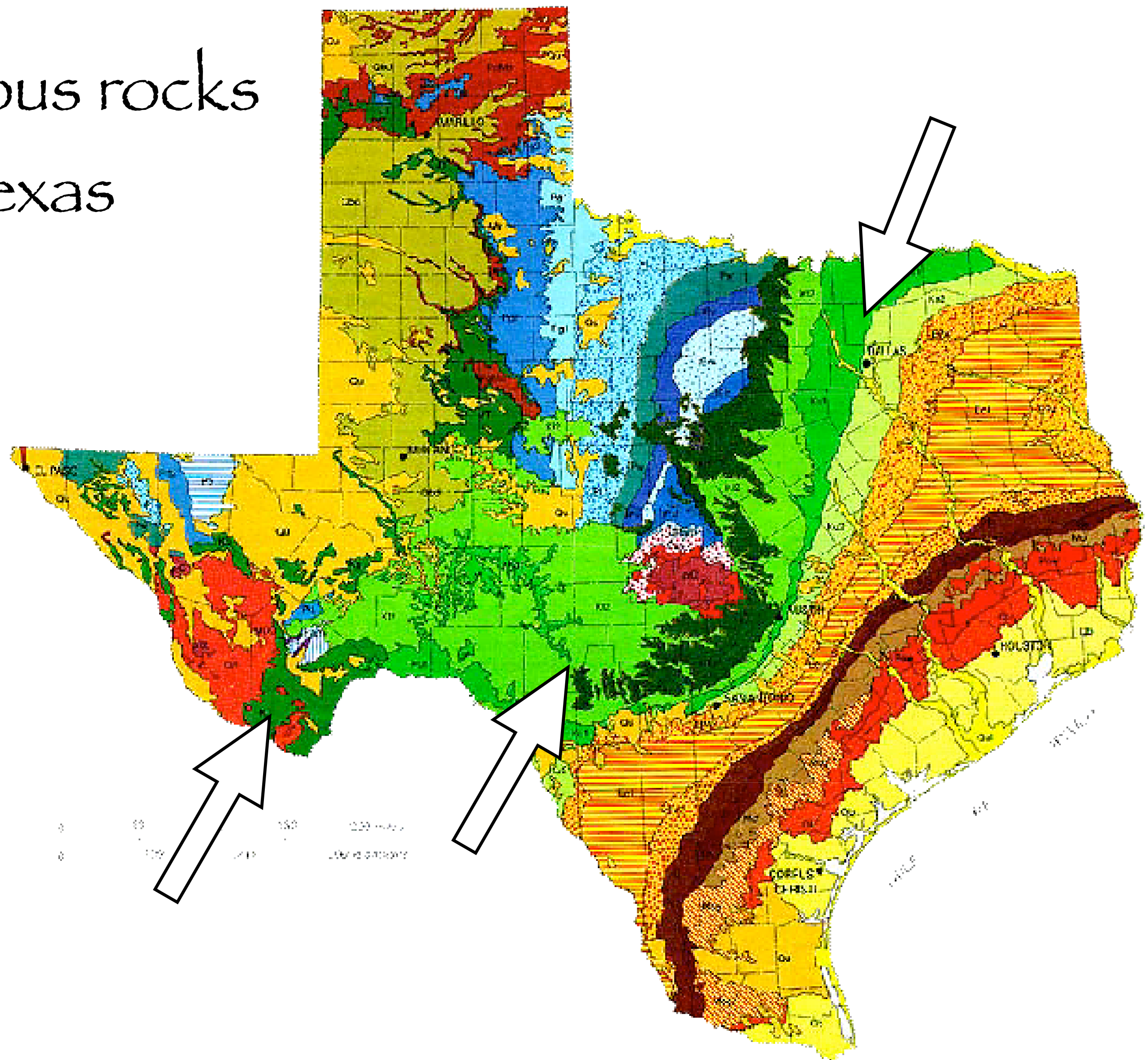






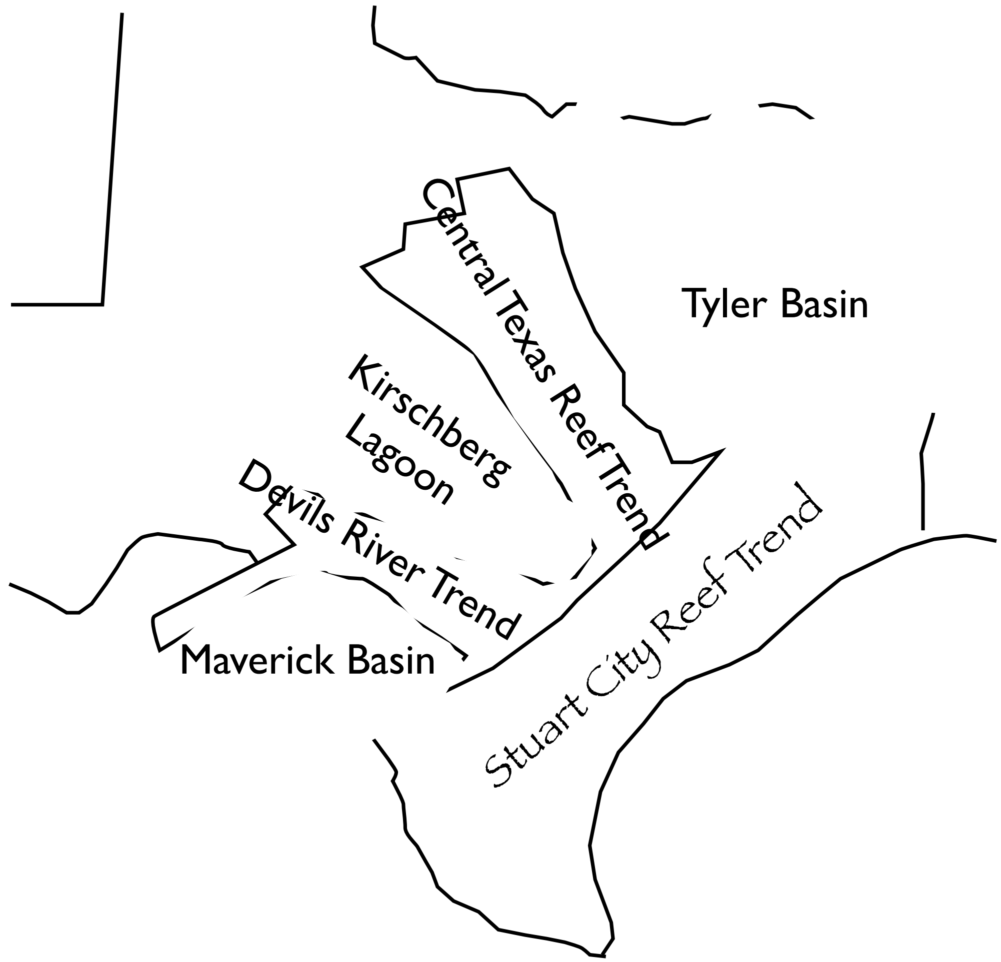
Accreted terrains started in the Jurassic and continued on into the Cretaceous

Cretaceous rocks in Texas



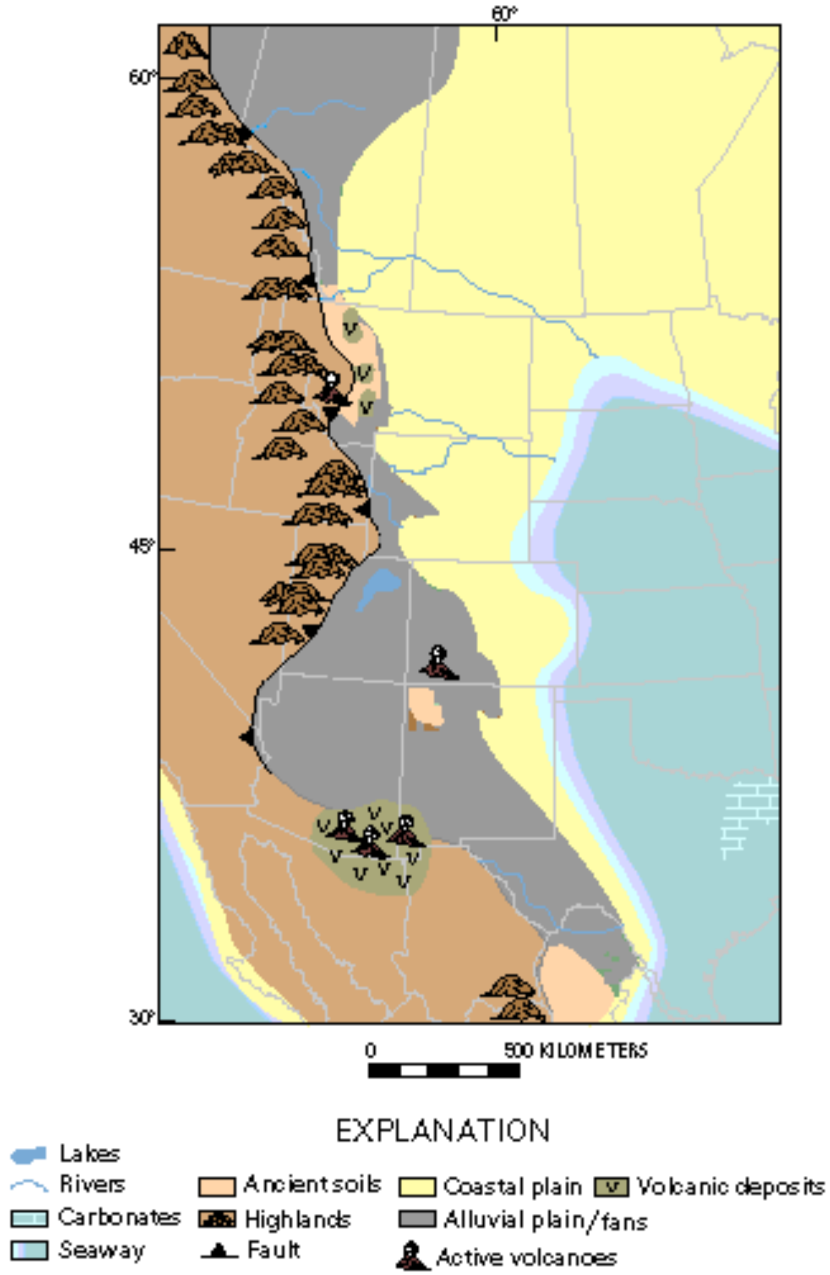
End of the Cretaceous

- Gradual draining of widespread epicontinental seas - major regression.
- Laramide Orogeny puts western US under compression - lifting western edge of the continent. Effects as far east as modern Big Bend National Park.
- The advent of moisture seasonality towards the end of the period.

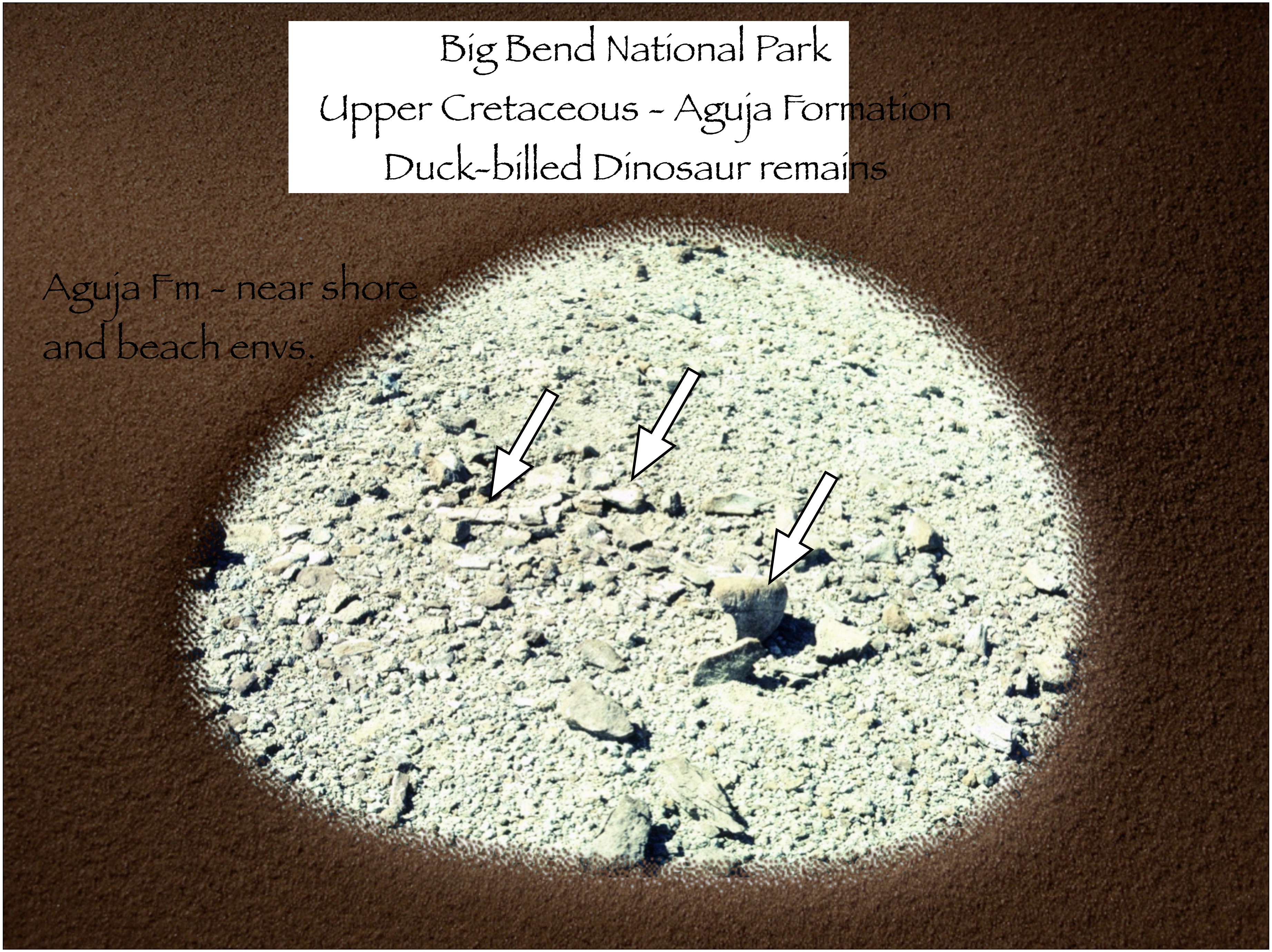


Edwards Paleogeography

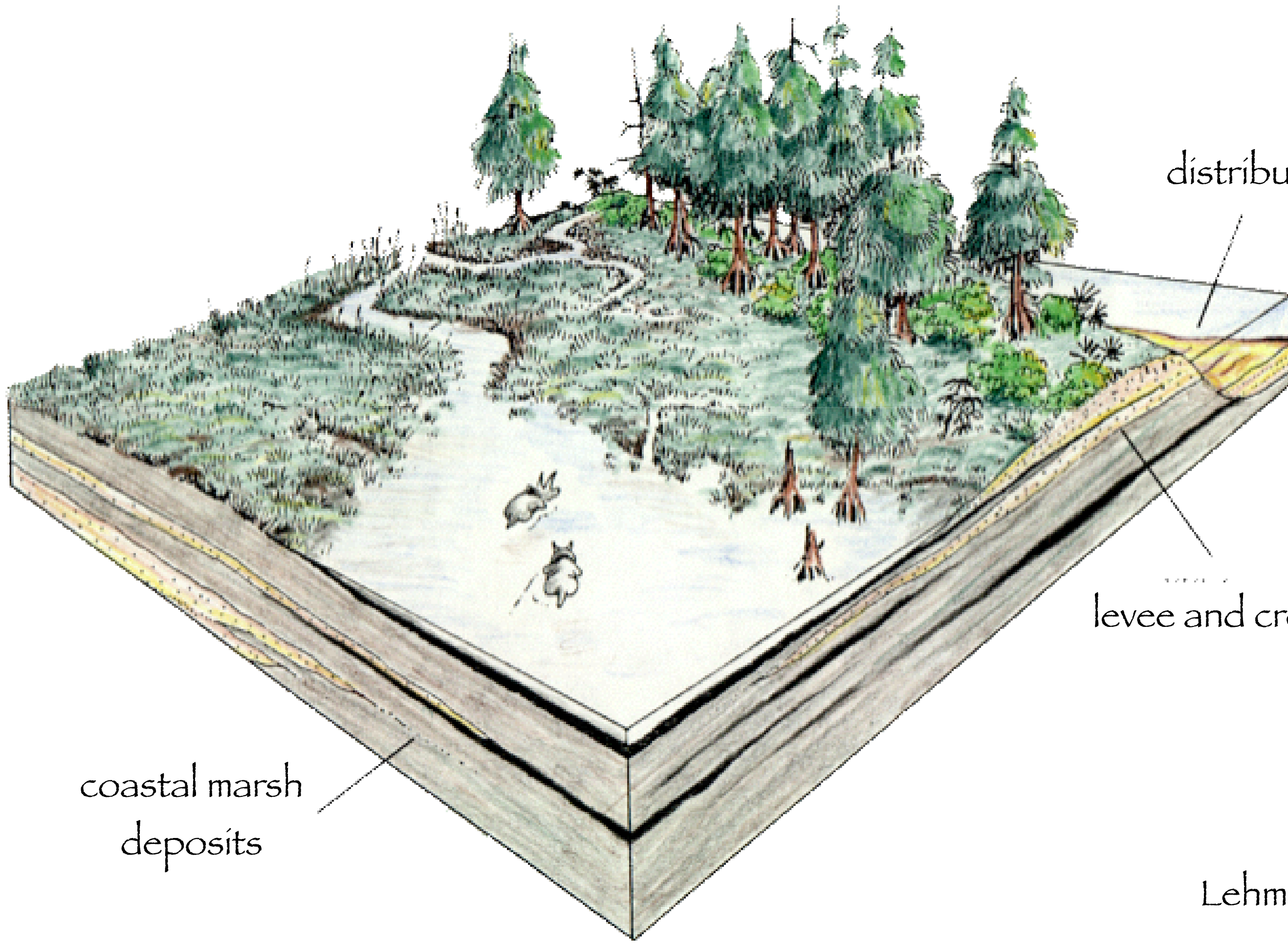
Big Bend National Park - Santa Elena Canyon
Lower Cretaceous Carbonates

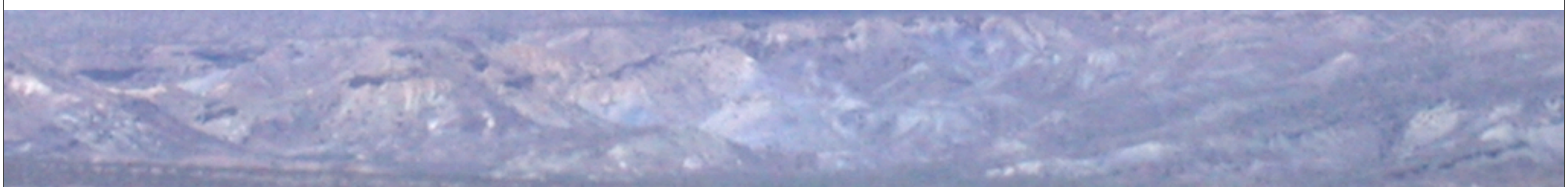


Paleolatitudes shown are estimates taken from recent scientific literature


Big Bend National Park
Upper Cretaceous - Aguja Formation
Duck-billed Dinosaur remains
Aguja Fm - near shore
and beach envs.

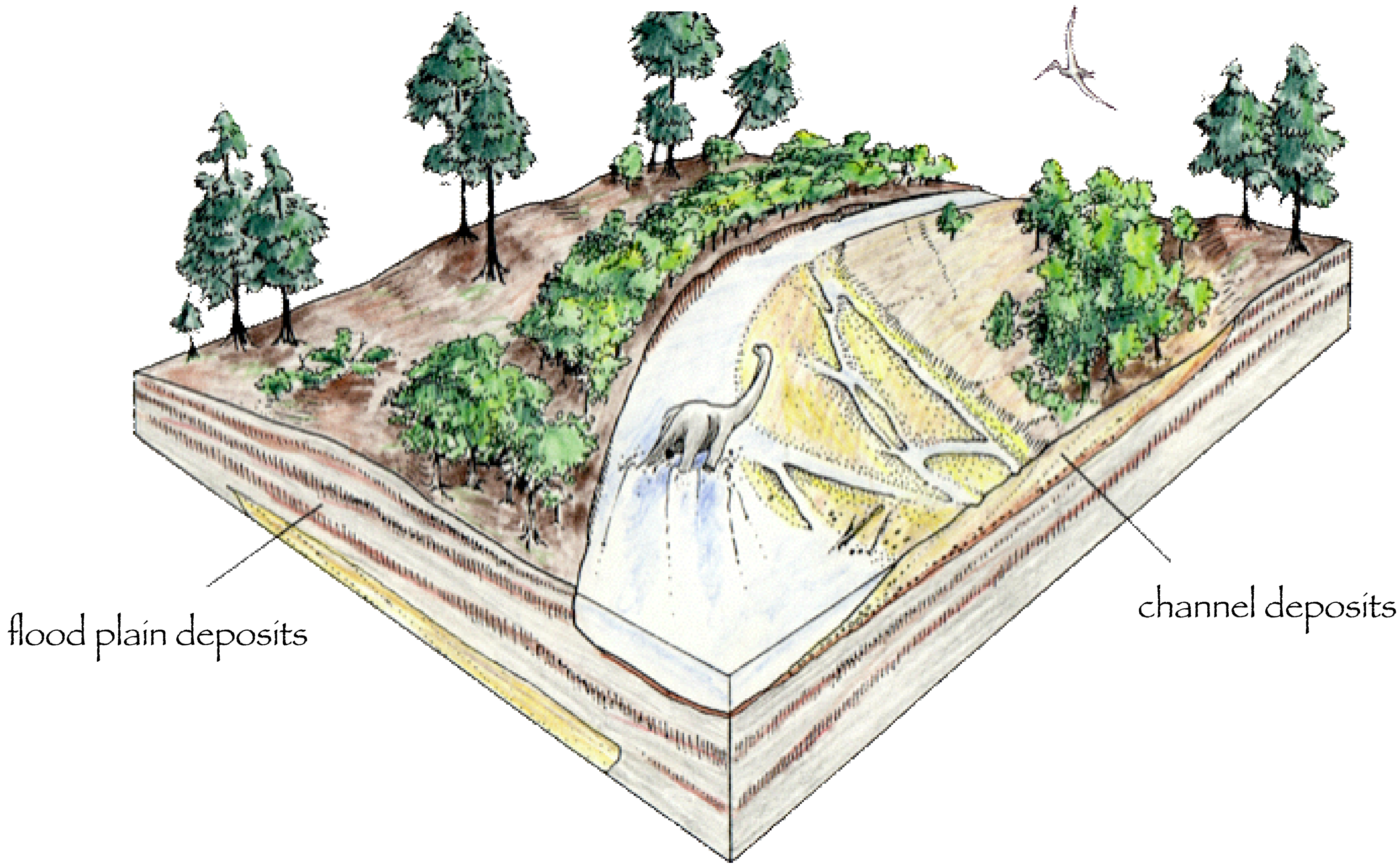
During Aguja time...





Big Bend National Park/Rosillos Ranch
Southern Canoe Valley
Upper Cretaceous Rocks
Aguja and Javelina Formations

During Javelina time...



Well drained - far inland uplands environment


Latest Cretaceous
Javelina Formation paleosols
Rhizocretion