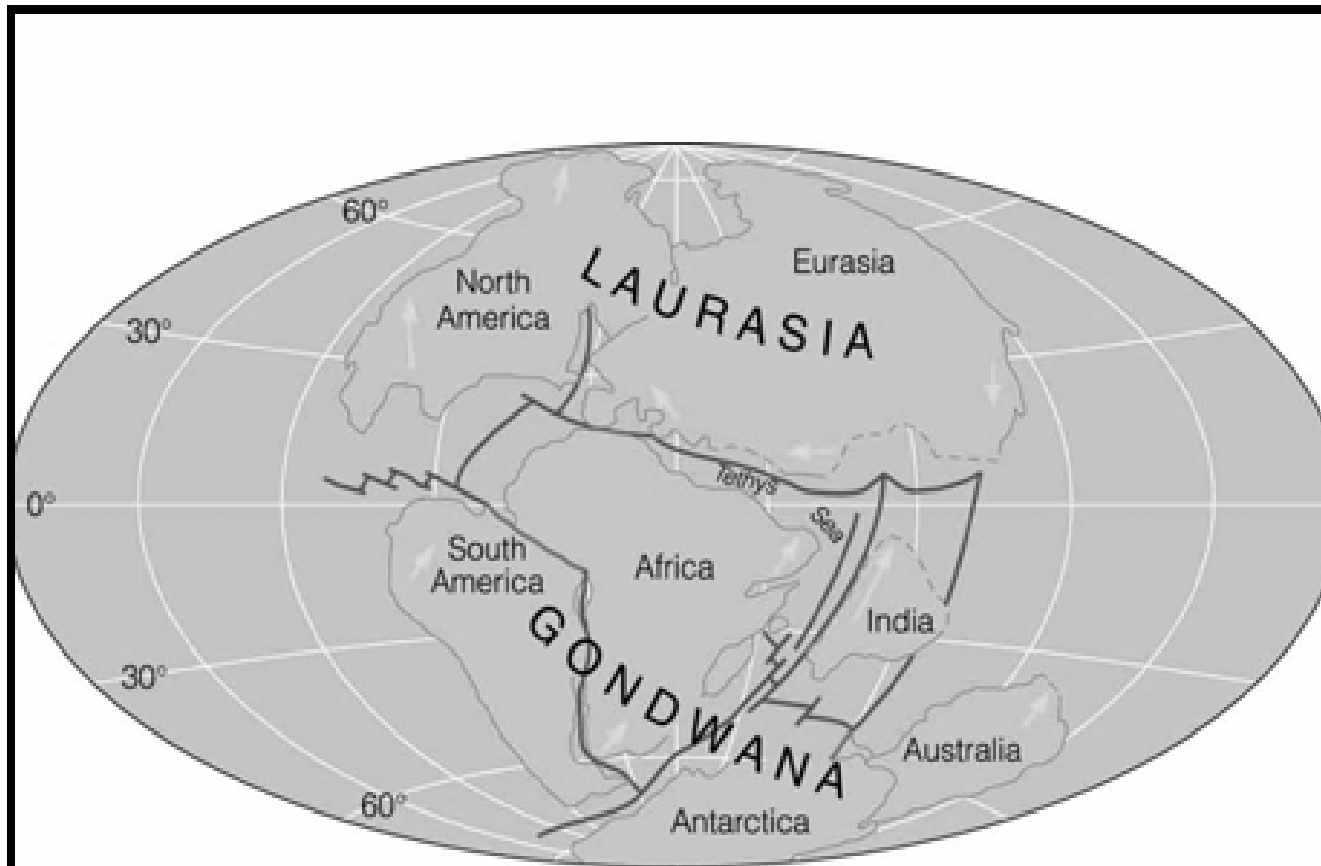


The formation of our world – the Jurassic: 208 to 144 My.

First, the break-up of Pangea; the most recent MegaContinent.



b) Jurassic Period (208–144 MYA)

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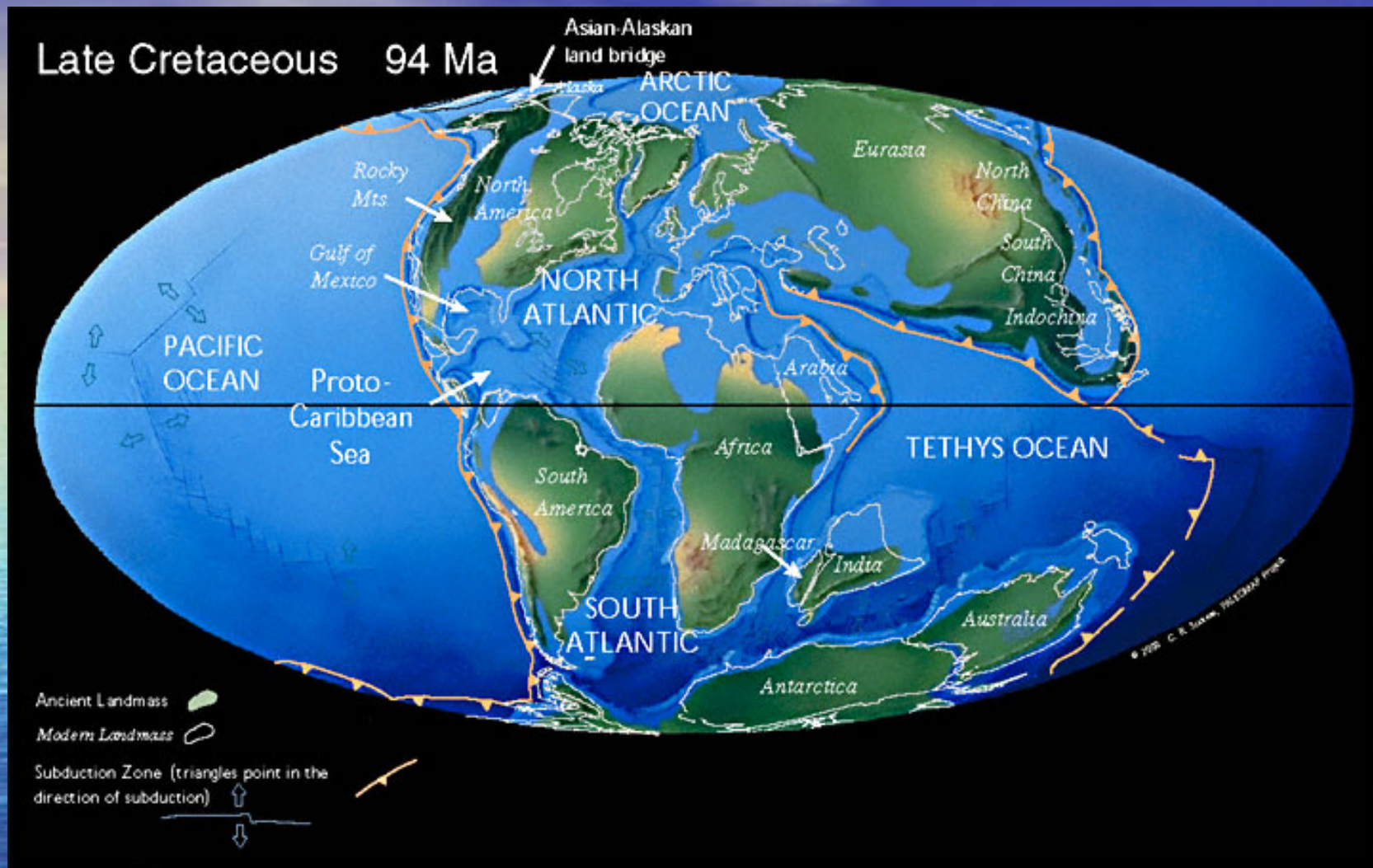
During the Campanian stage of the Late Cretaceous (80 Ma), evidence suggests mean annual temperatures were 10 - 25 degrees K warmer than today.

There is no evidence of significant ice at high latitudes.
No polar ice sheets.

and meridional thermal gradients were very low in the oceans,

and on land. (temperatures were warm, everywhere).

Late Cretaceous atmospheric CO₂ was much higher than today, with levels estimated from 5 to 20 times present day.



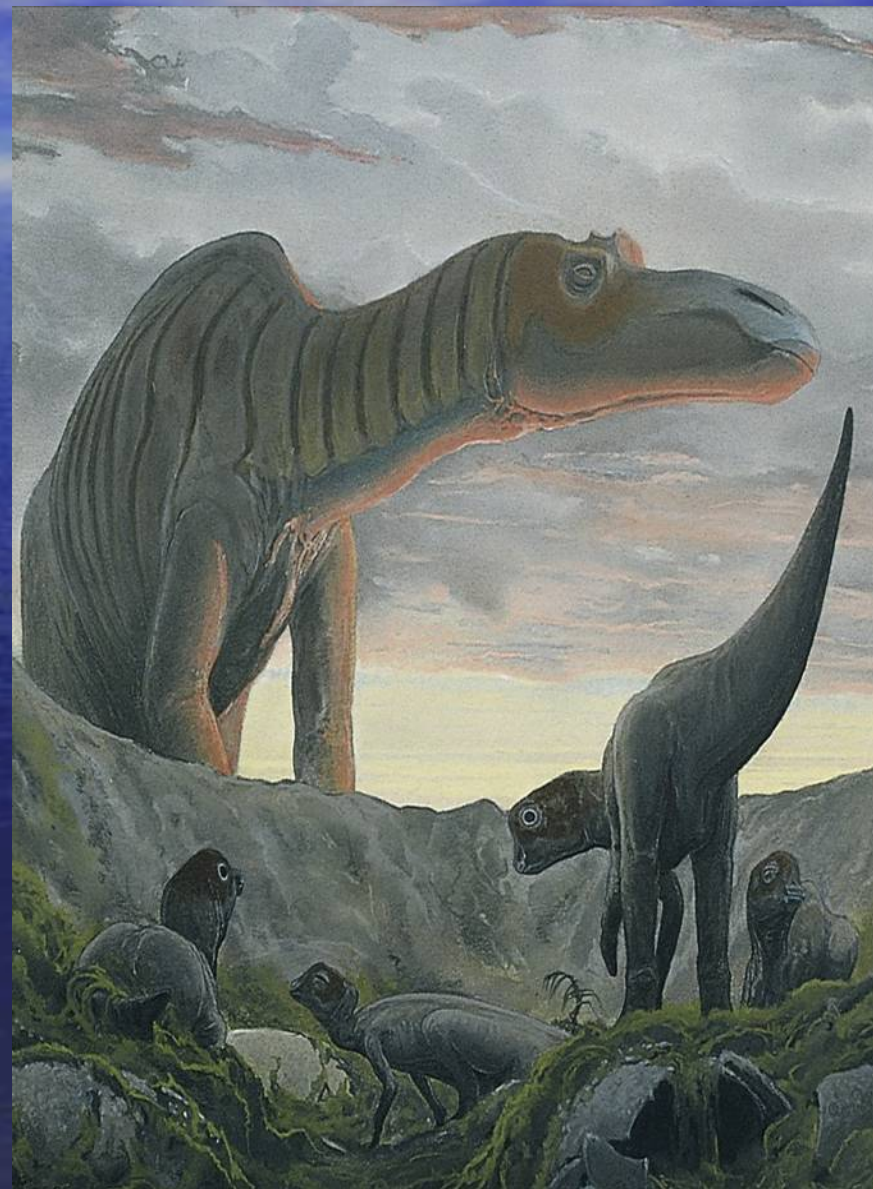
During the Cretaceous the South Atlantic Ocean opened. India separated from Madagascar and raced northward on a collision course with Eurasia.

North America was still connected to Europe, and that Australia was still joined to Antarctica.

Warm-adapted animals
found at high latitudes.

Dinosaurs, turtles and
crocodiles found pole-wards
of the Arctic and Antarctic
circles.

Coral reefs indicative of
warm tropical waters found
within 40° of equator
(latitude of Chicago).



Paleobotanical Evidence for Warm Climate in the Cretaceous

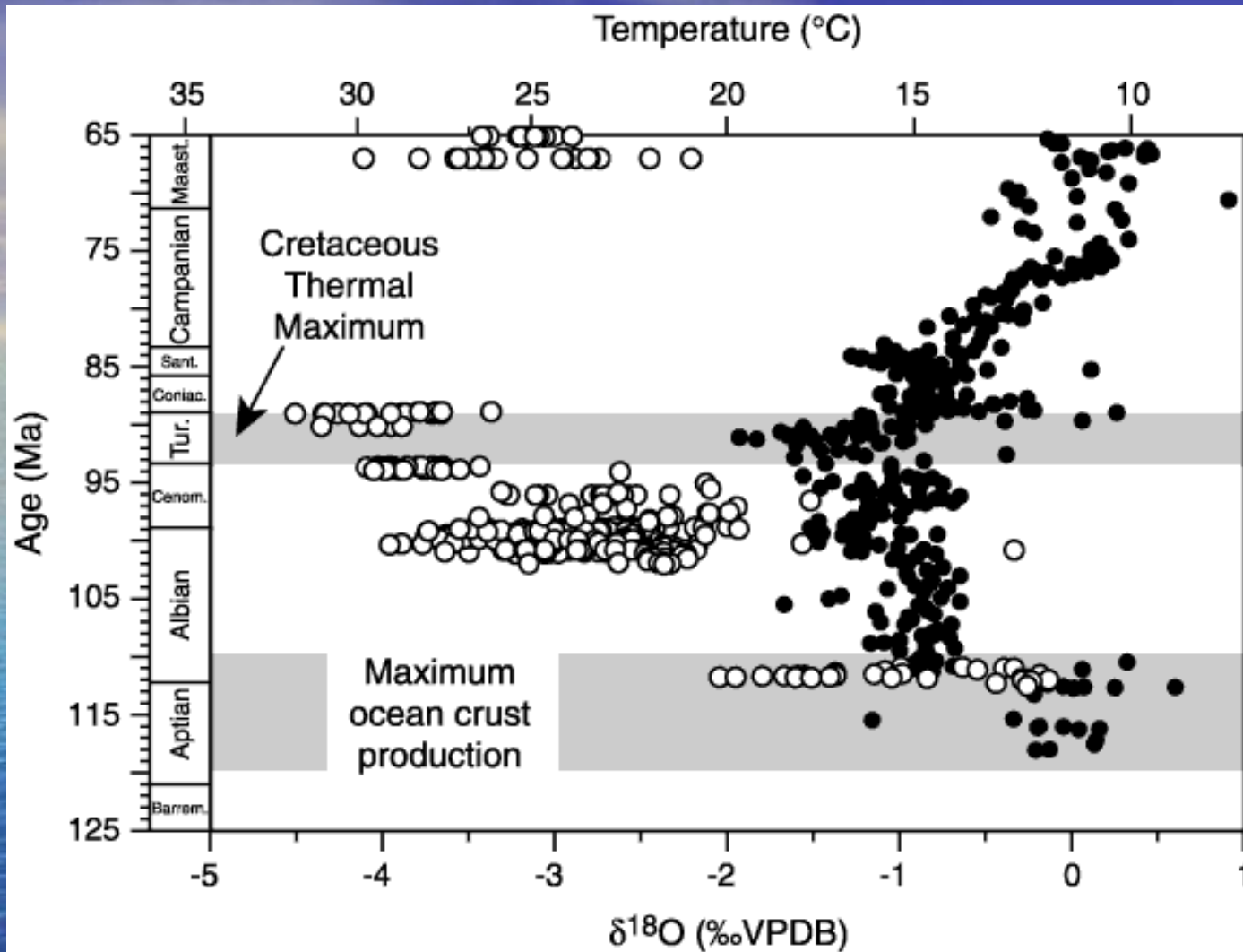
Warm-adapted evergreen vegetation found above Arctic circle.

Leaves of breadfruit tree found north of Arctic Circle.

Today breadfruit trees found only in tropical to subtropical environments.

Equator-to-pole temperature gradient were much different in Cretaceous.





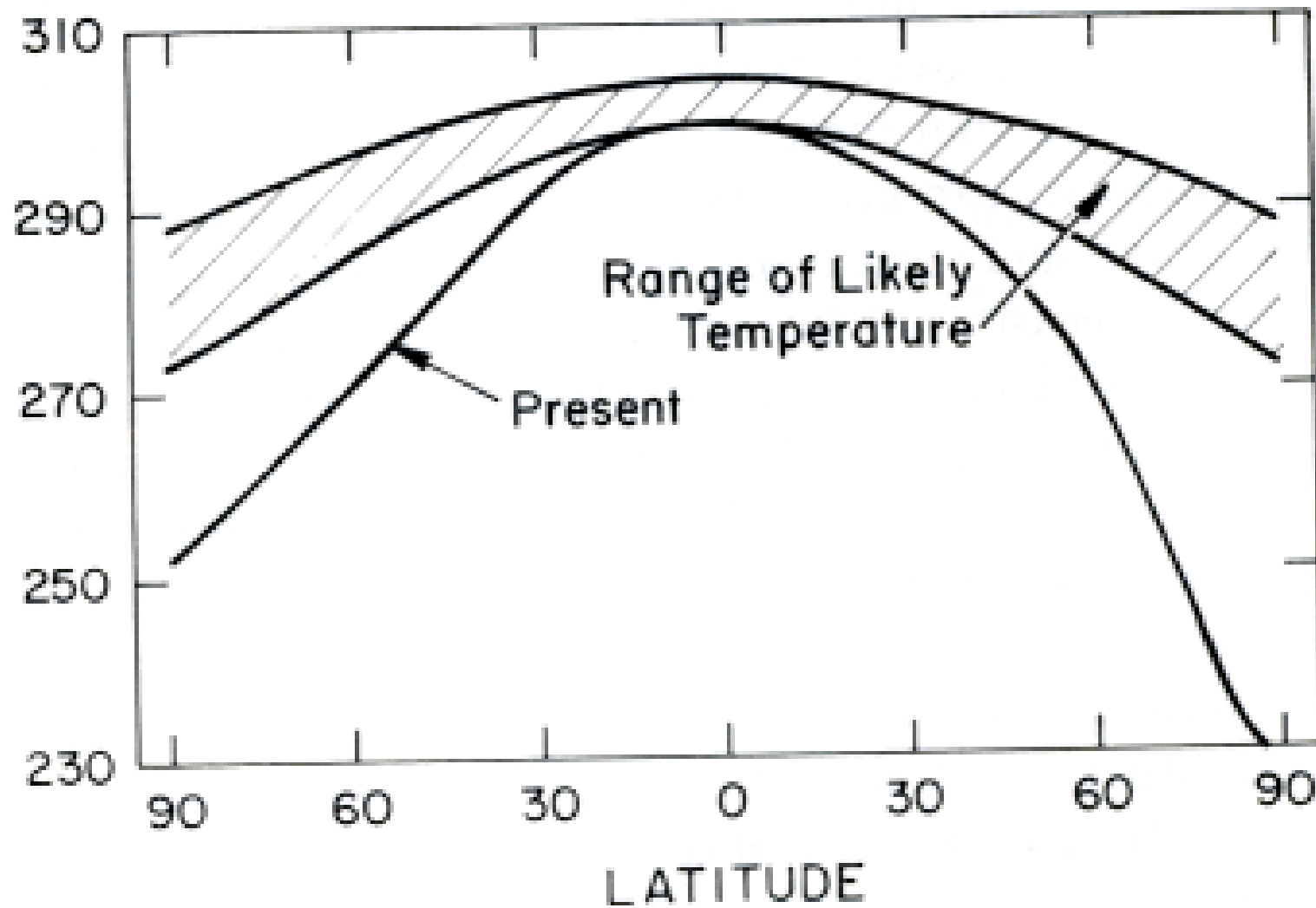
Cretaceous ^{18}O temperature records from Indian (solid) and global (open) carbonates. All temperatures are conservative values and would be 3° – 6°C higher if modern latitudinal trends were applied.

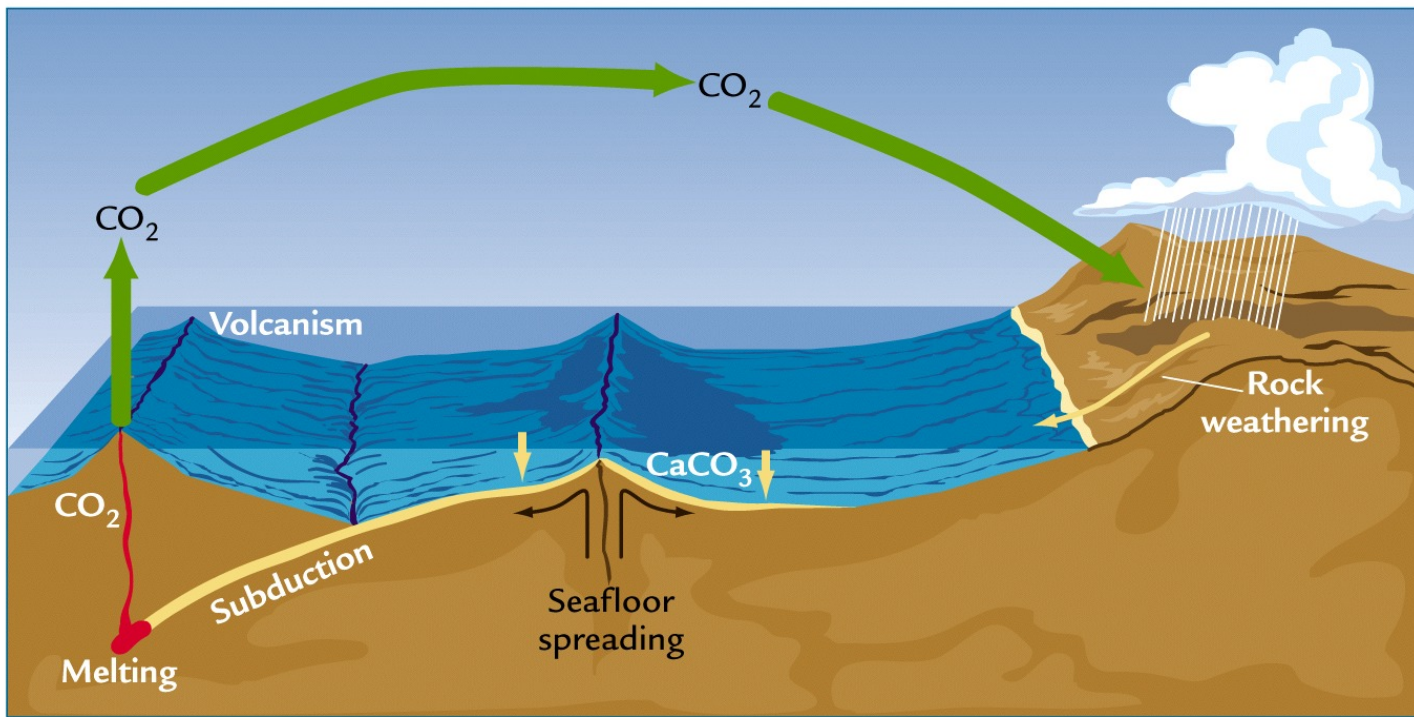
VPDB = Vienna Peedee belemnite.



MOVIE here

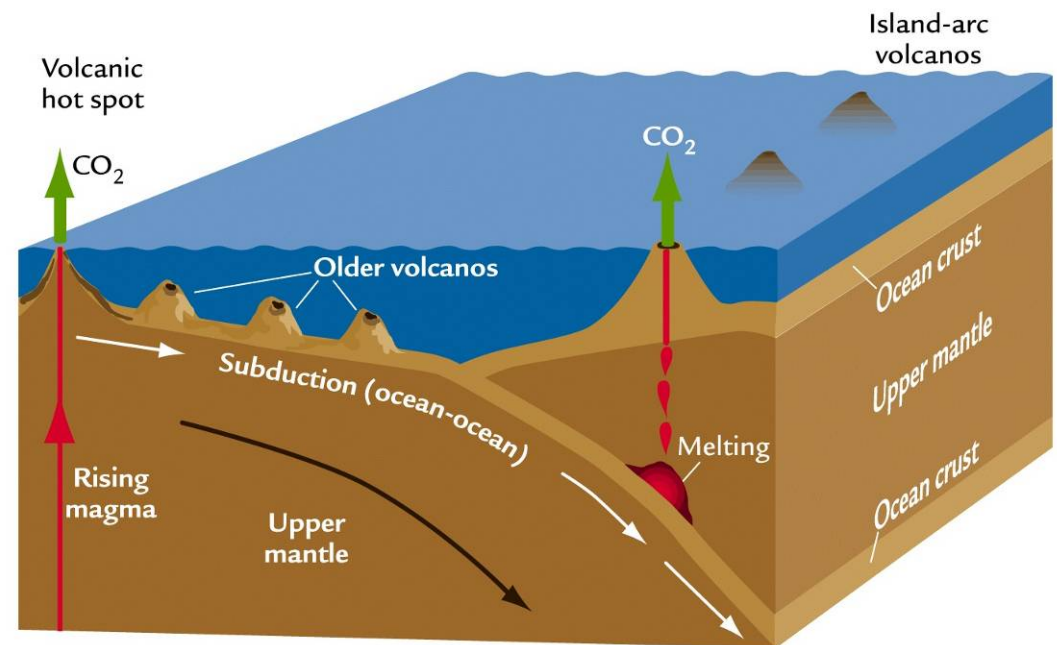
How was this heat distributed North-South over the earth?





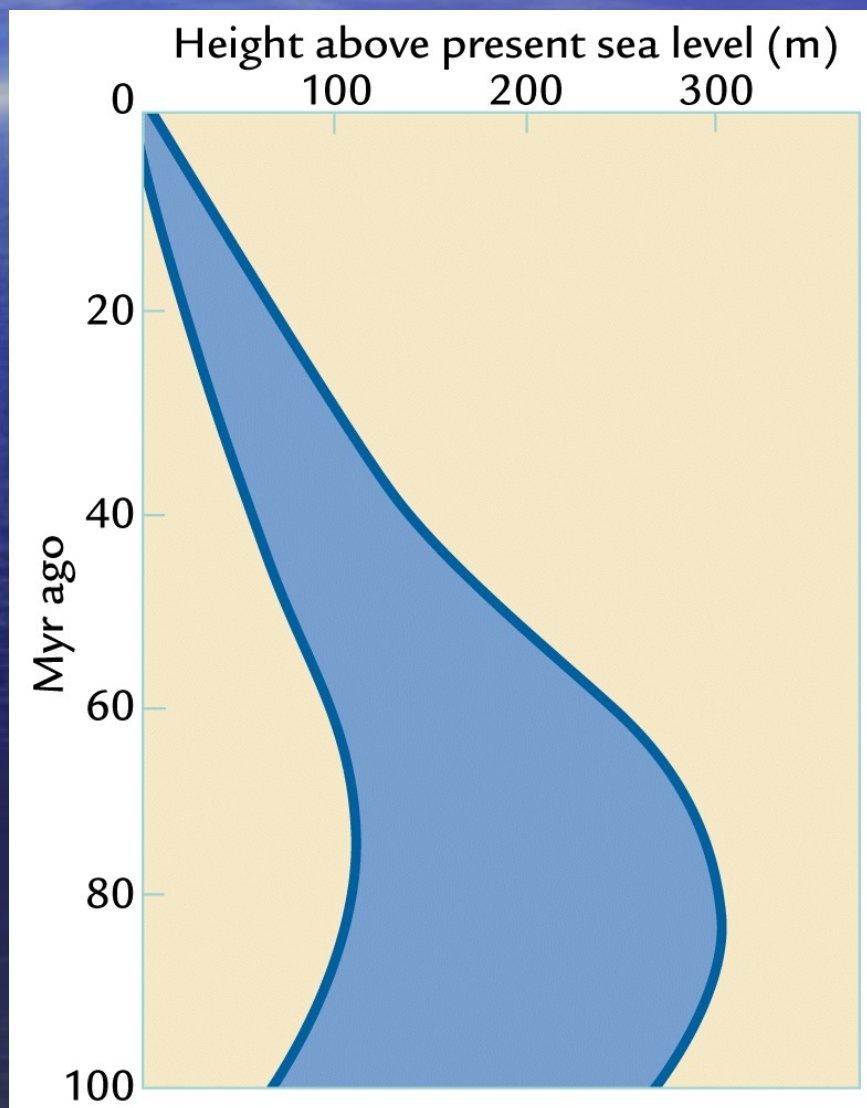
Control of
atmosphere CO₂
by changing sea
floor spreading
rate.

Taking mantle 'hot spots'
to the max – the
Cretaceous Hot House



- No land-based ice.
- Seawater was warm (and expanded in volume).
- Seafloor spreading was fast, and mid-ocean ridges were elevated (along with older ocean crust).
- Large igneous provinces were forming – those that erupted displaced seawater.
- Those LIPS that didn't erupt, still displaced seawater.
- The combination of all of these processes caused a dramatic increase in sea level that flooded the interiors of most continents.

Sea level during the Cretaceous was very high – why?



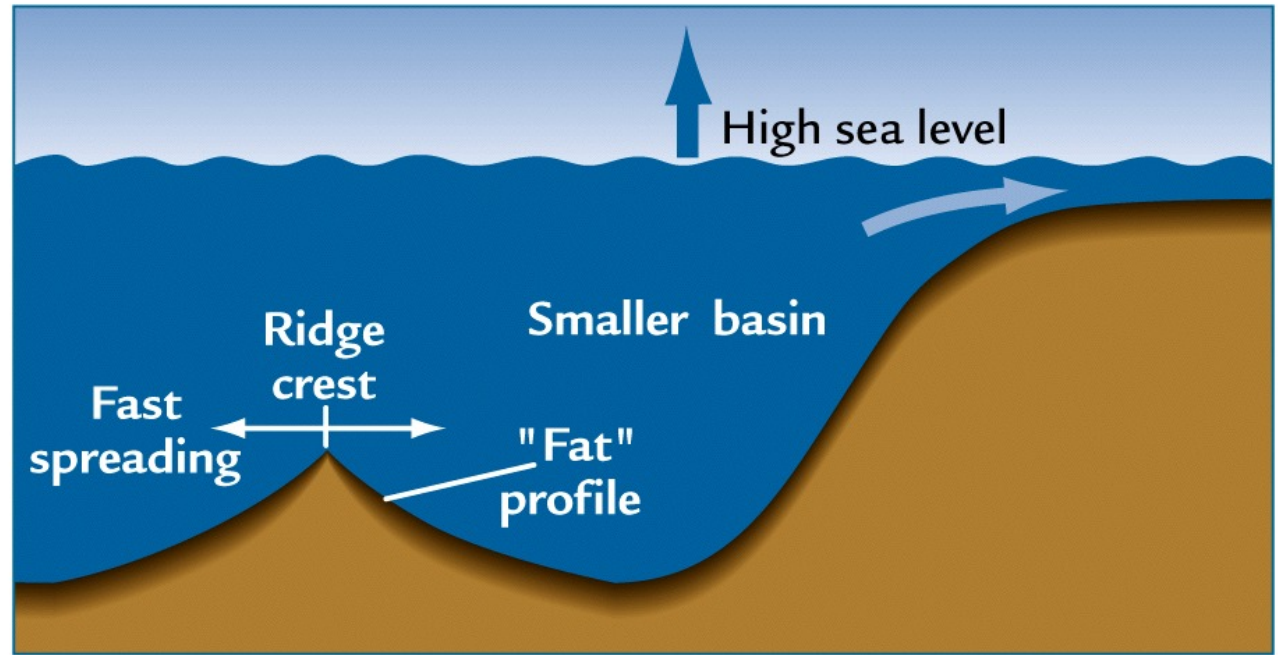
What processes impact sea level?

1. Amount of Ice on continent.
2. Temperature of seawater.
3. Sea floor spreading rates (shape of the ocean basins).
4. Amount of continental margin (either a single Mega-continent - or lots of individual continental fragments).

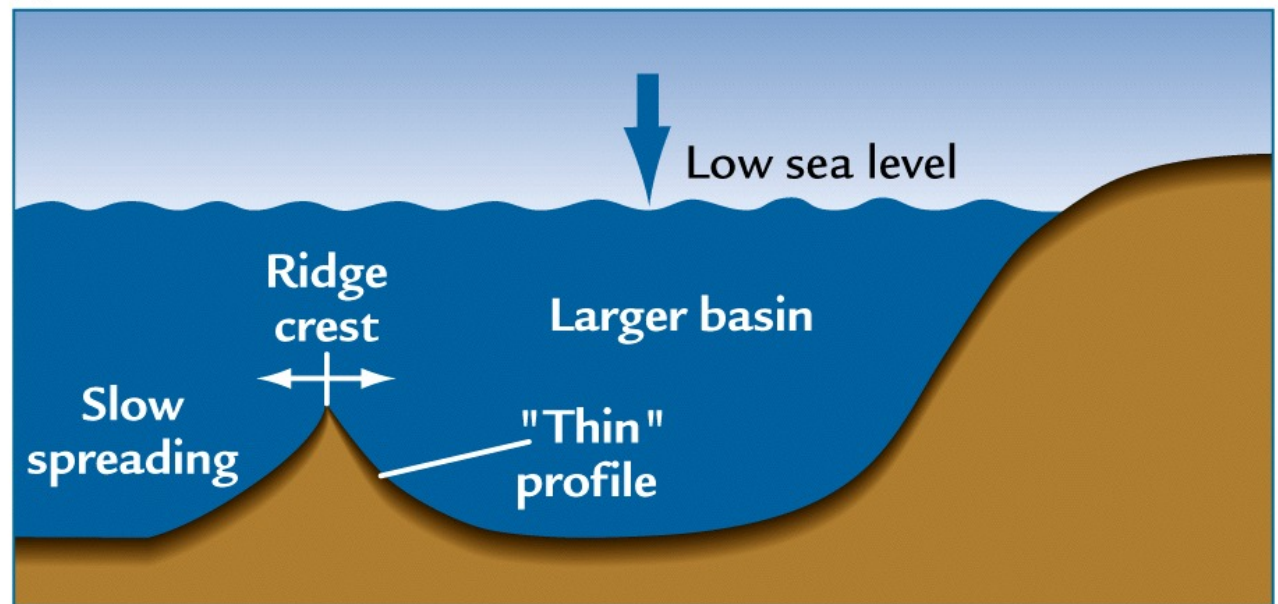
The change in sea floor spreading rate can also have a dramatic change on sea level.

Faster sea floor spreading produces a hotter crust, and a more elevated mid ocean ridge – which continues elevated even on the ridge flanks.

Slower sea floor spreading produces less elevated crust, and a lower sea level.



A

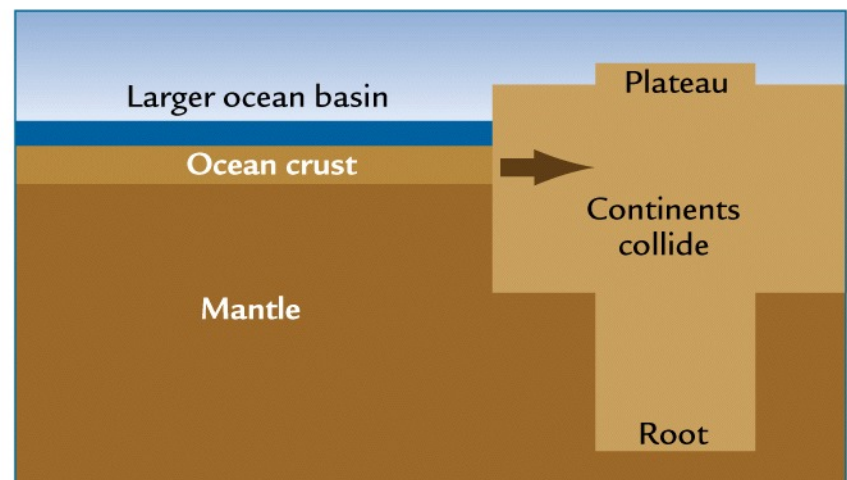
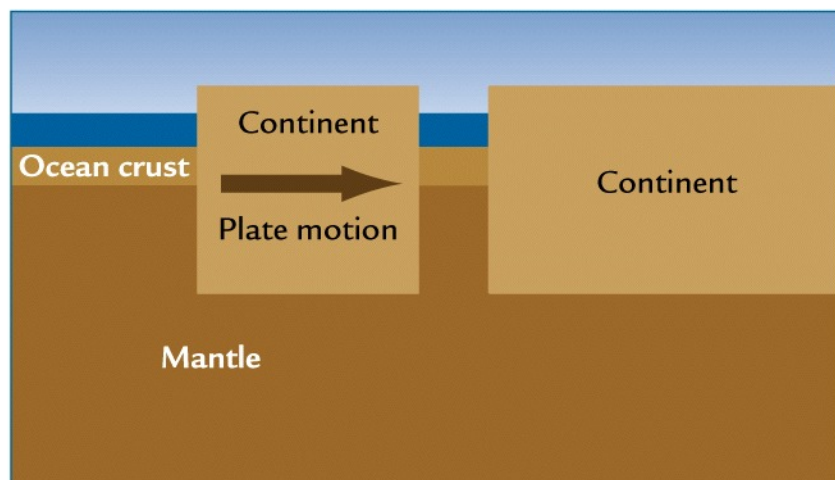


B

Continental margins have a lot of volume, and displace substantial amounts of seawater.

If you have a lot of continental fragments, each will have its own margin, and sea level will be 'high'. If you only have one mega-continent, you will have less total margin area, and sea level will be 'low'.

Does this apply to the Cretaceous?



Oceanic plateaus (Large Igneous Provinces – made of basalt) can be BIG (the size of Western U.S.). These can displace a LOT of seawater.

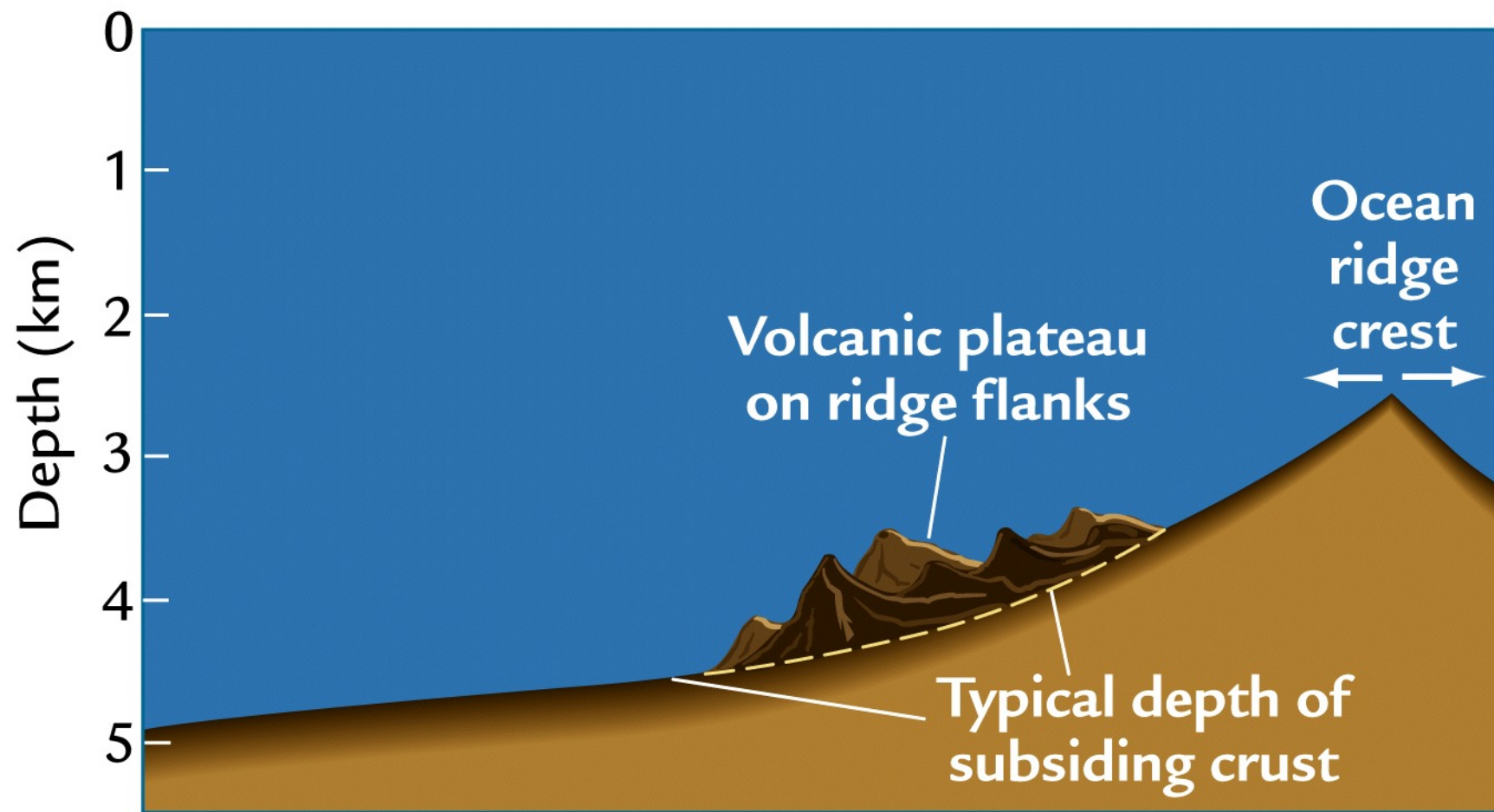


TABLE 6-1 Factors Contributing to Sea Level Fall
in the Last 80 Million Years

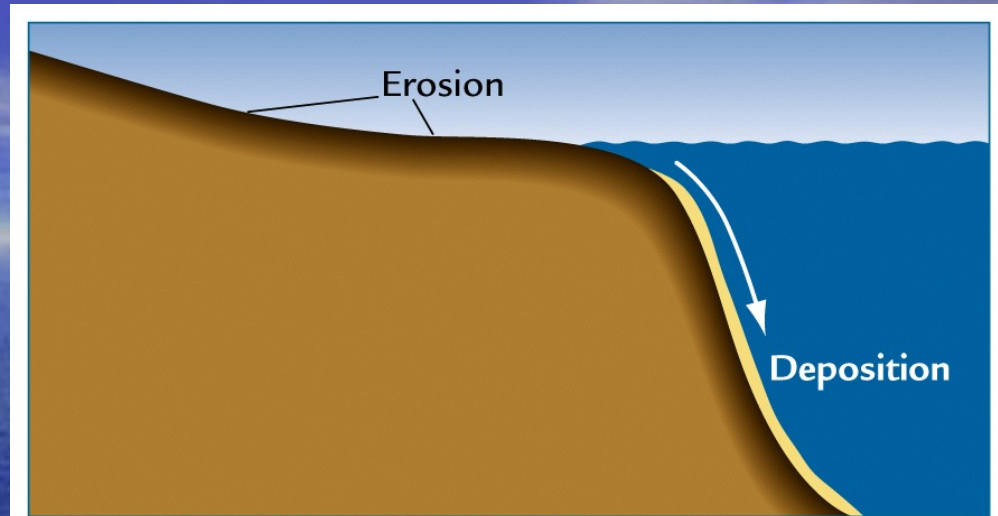
Cause of sea level change	Estimated change (meters)
Decrease in ocean ridge volume	−200 to −300
Collision of India and Asia	−40
Decrease in volcanic plateau volume	−10 to −40
Water stored in ice sheets	−50
Thermal contraction of seawater	−7
All factors	−300 to −440

Continental shelves (where most biological productivity presently occurs) have a big impact on climate.

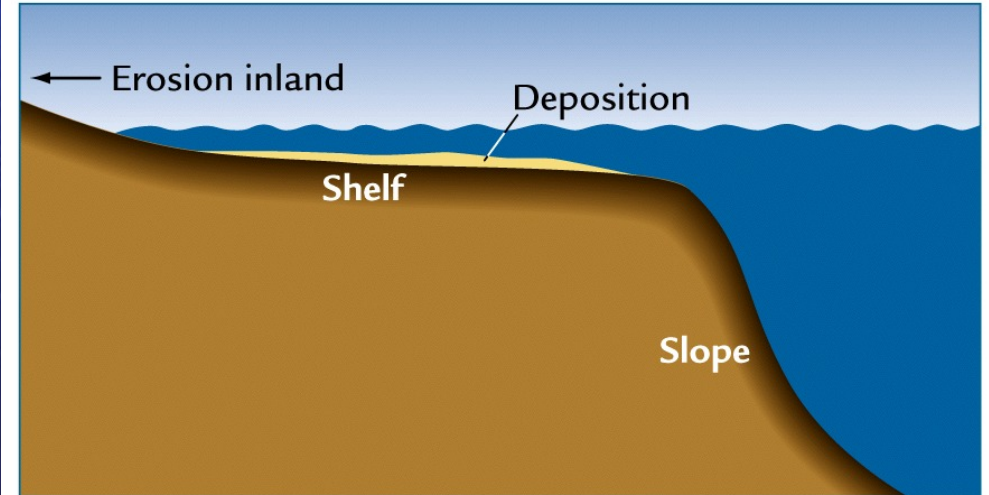
When sea level is LOW, most sediment deposition (and nutrient flux) is in the deep ocean basins, and biological productivity is also LOW.

When sea level is high, this increases biological productivity.

The amount of exposed continental shelf at high/low sea levels also impacts the albedo (land is reflective; sea water absorbs incoming sunlight).



A Low sea level



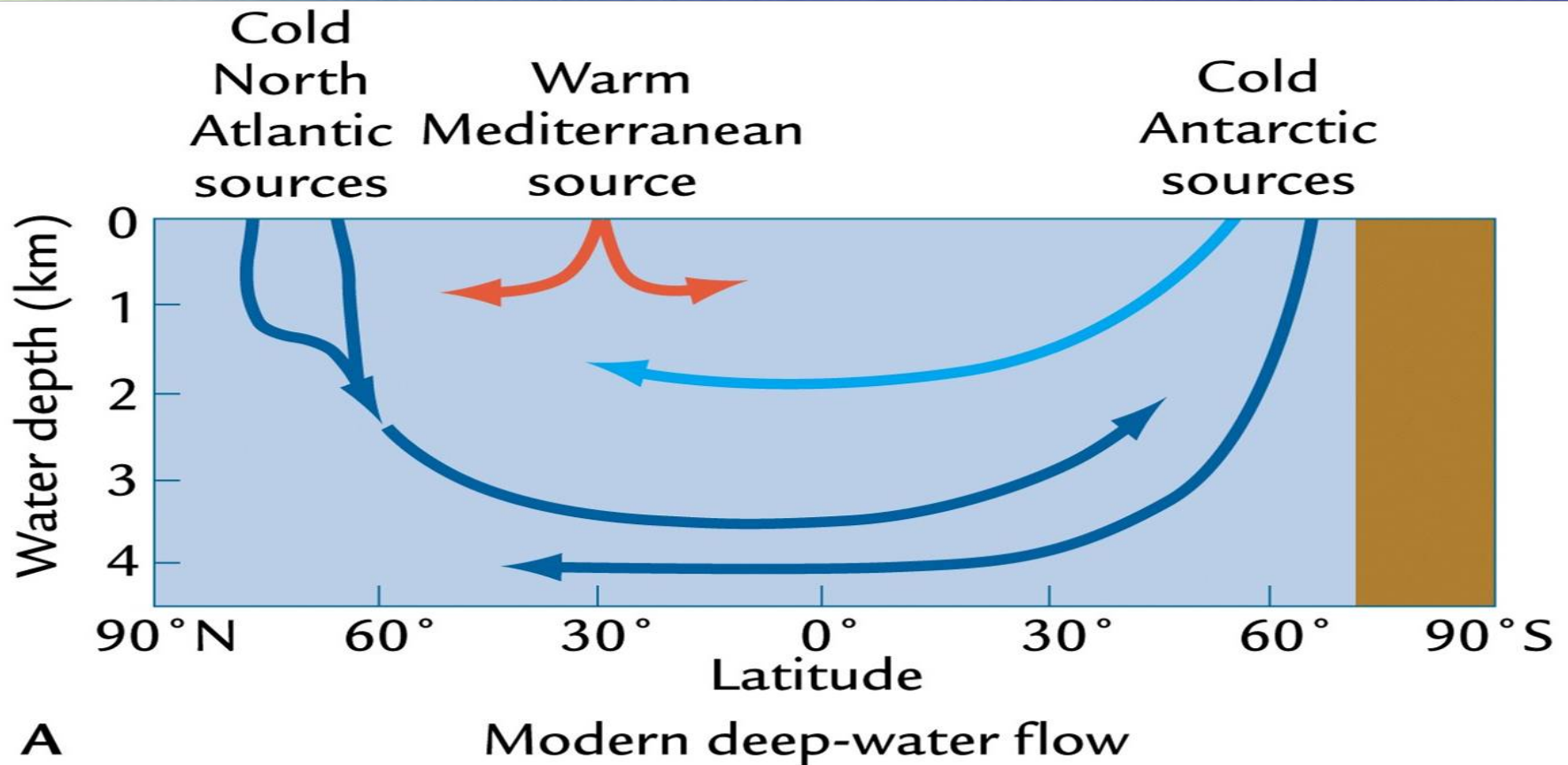
B High sea level

- Equatorial temperatures were only a few °C warmer than present day temperatures.
- But polar temperatures were 20°-30°C warmer!
- Cretaceous was an ice-free world.
- Present day polar Temperatures are very cold.
- Understanding Cretaceous climate requires understanding the unusual equator-to-pole temperature gradient.

What would this have implied for ocean circulation?
For ocean stratification?

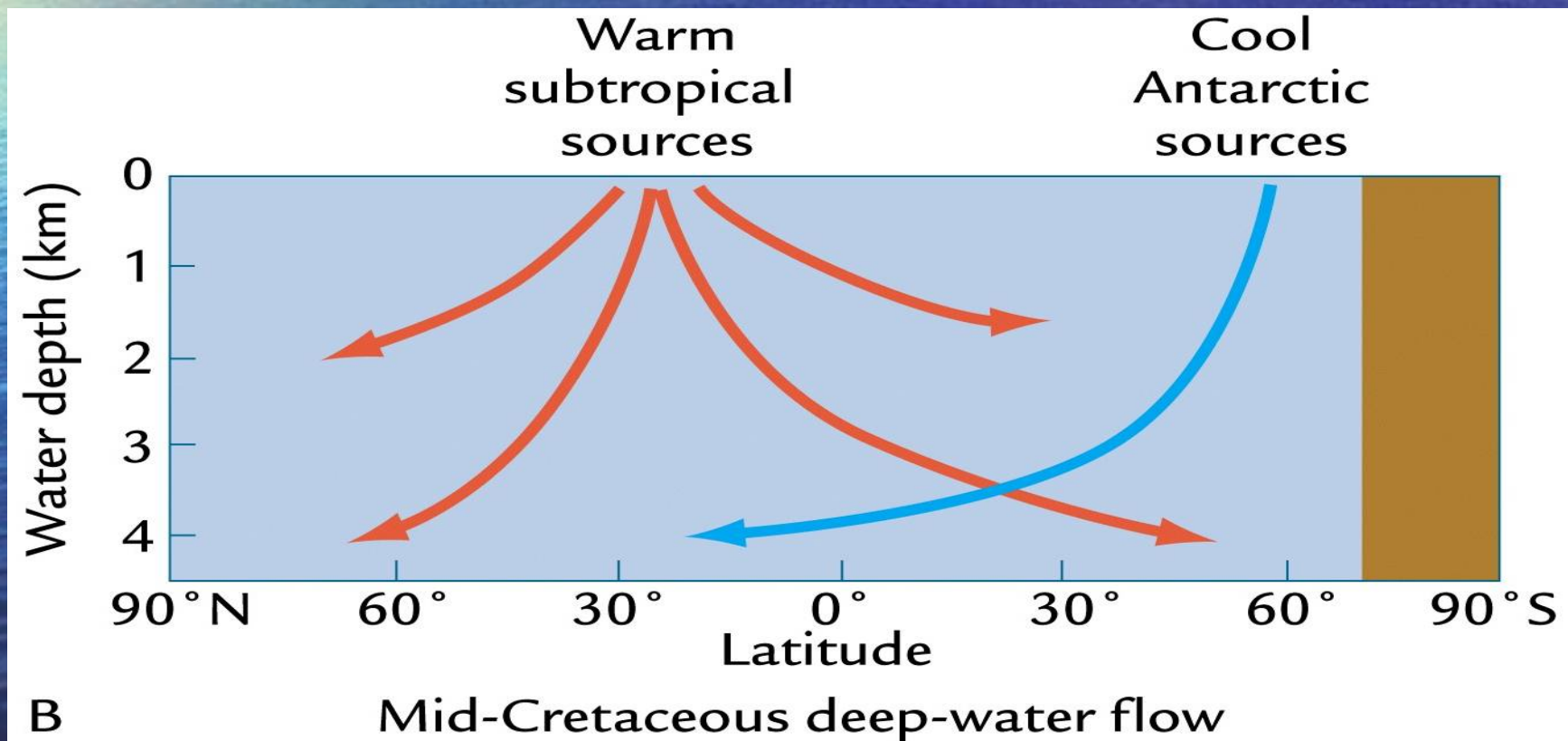
Heat transfer through deep ocean today;

Formation of cold dense water in polar regions with some warm saline water from Mediterranean

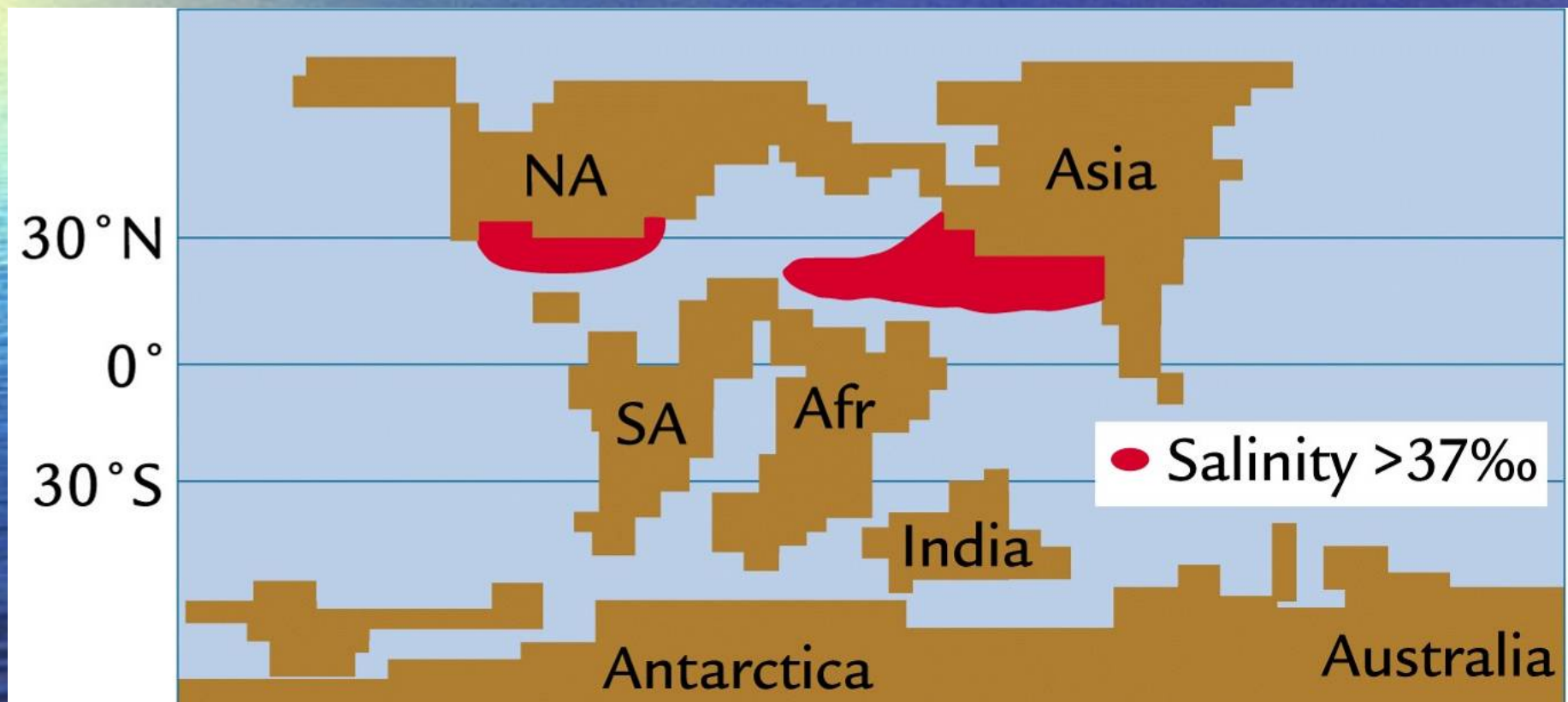


Deep ocean 100 My ago was filled with warm saline bottom water;

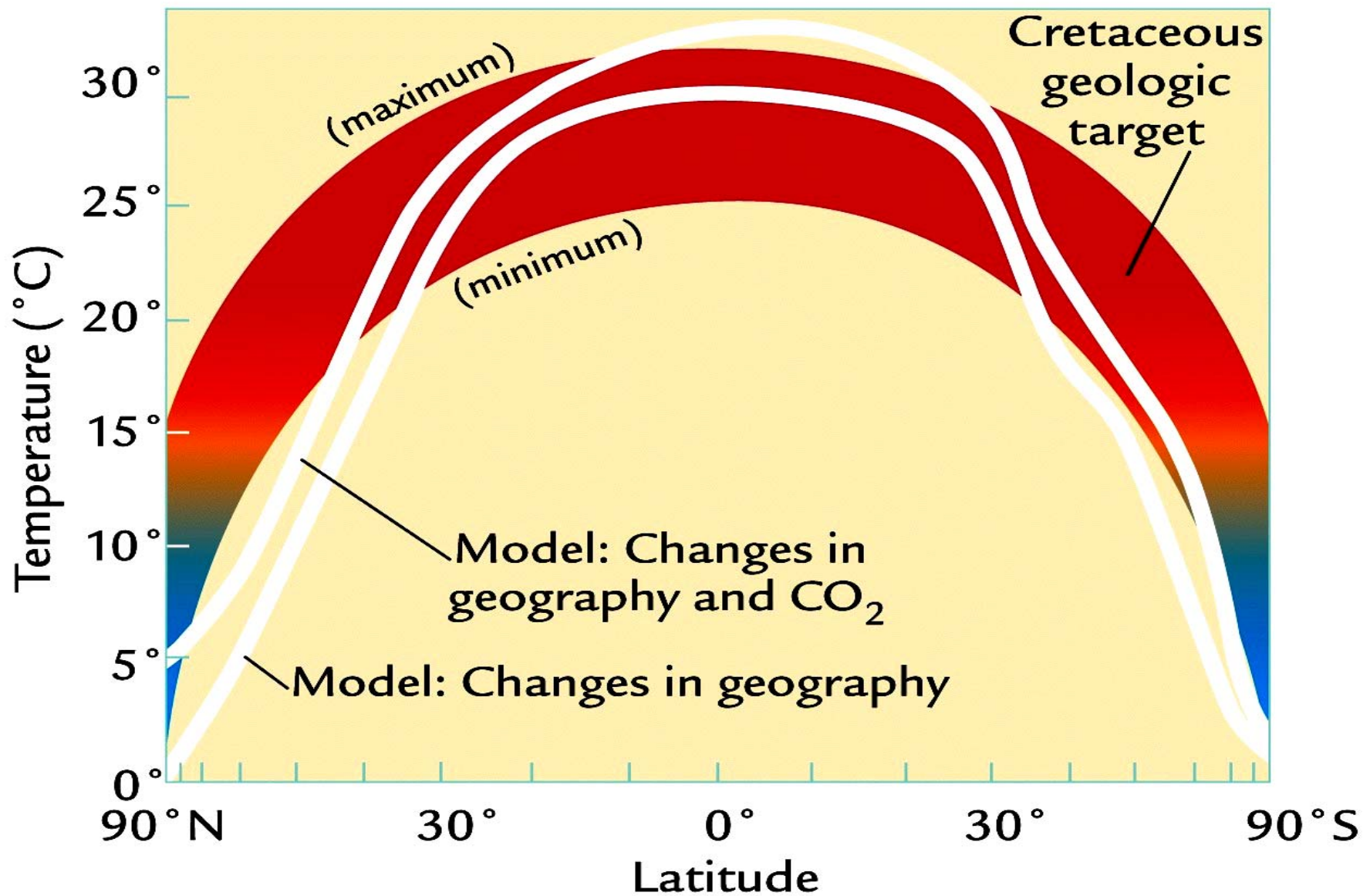
Cretaceous bottom water formed in tropics or subtropics and flowed pole-ward transferring heat

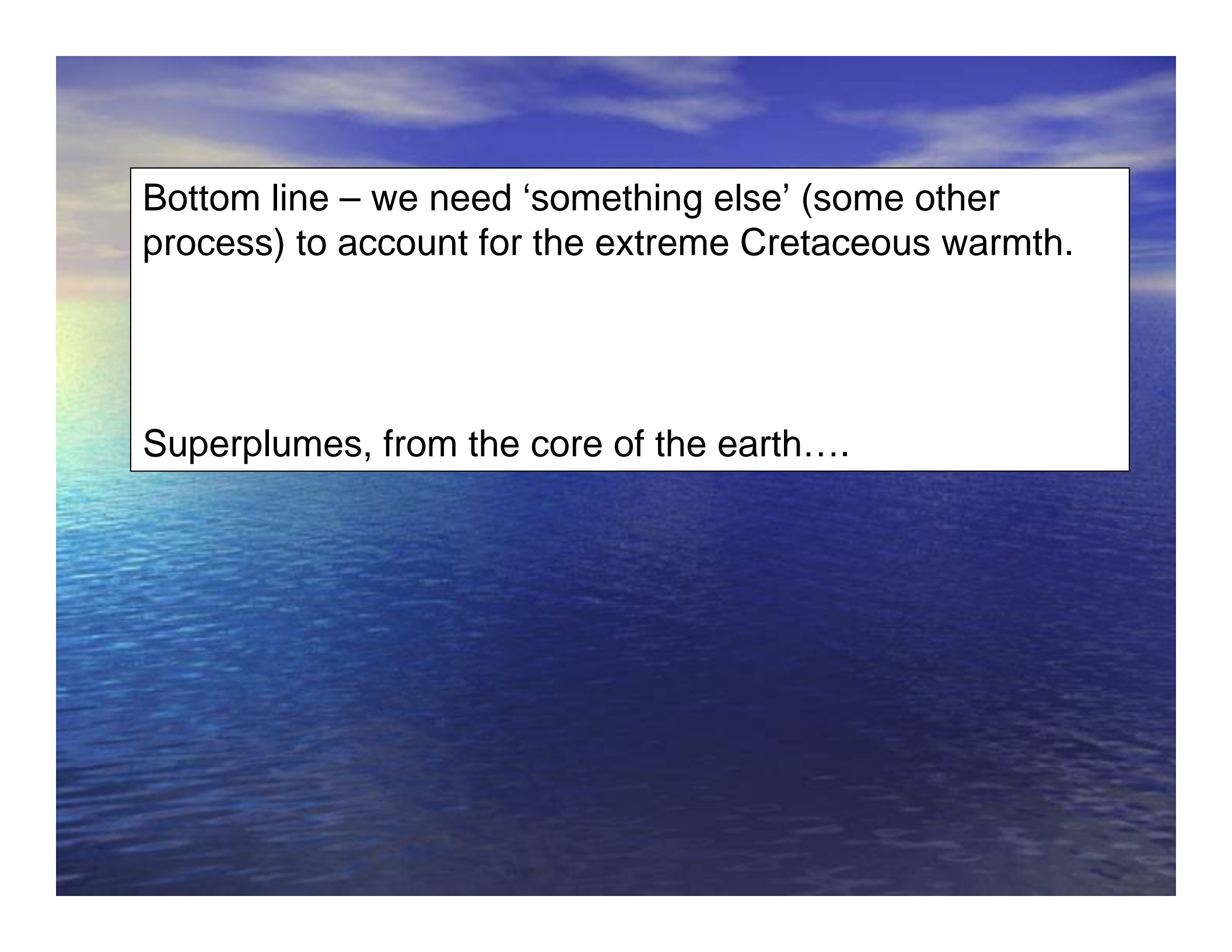


Warm saline water could have formed in Northern hemisphere when salinity exceeded 37%.



Attempts to model Cretaceous climate only partly successful.





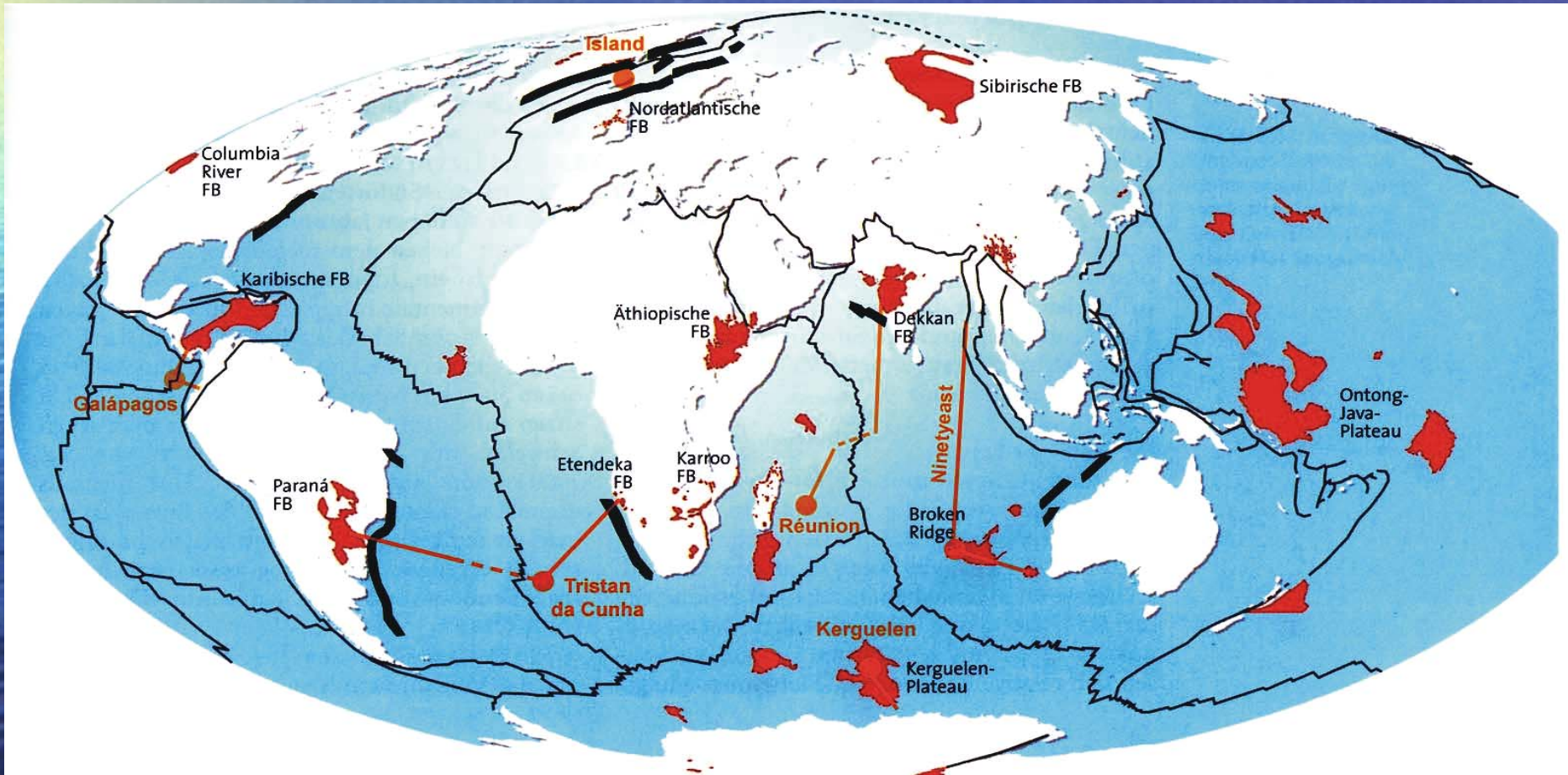
Bottom line – we need ‘something else’ (some other process) to account for the extreme Cretaceous warmth.

Superplumes, from the core of the earth....

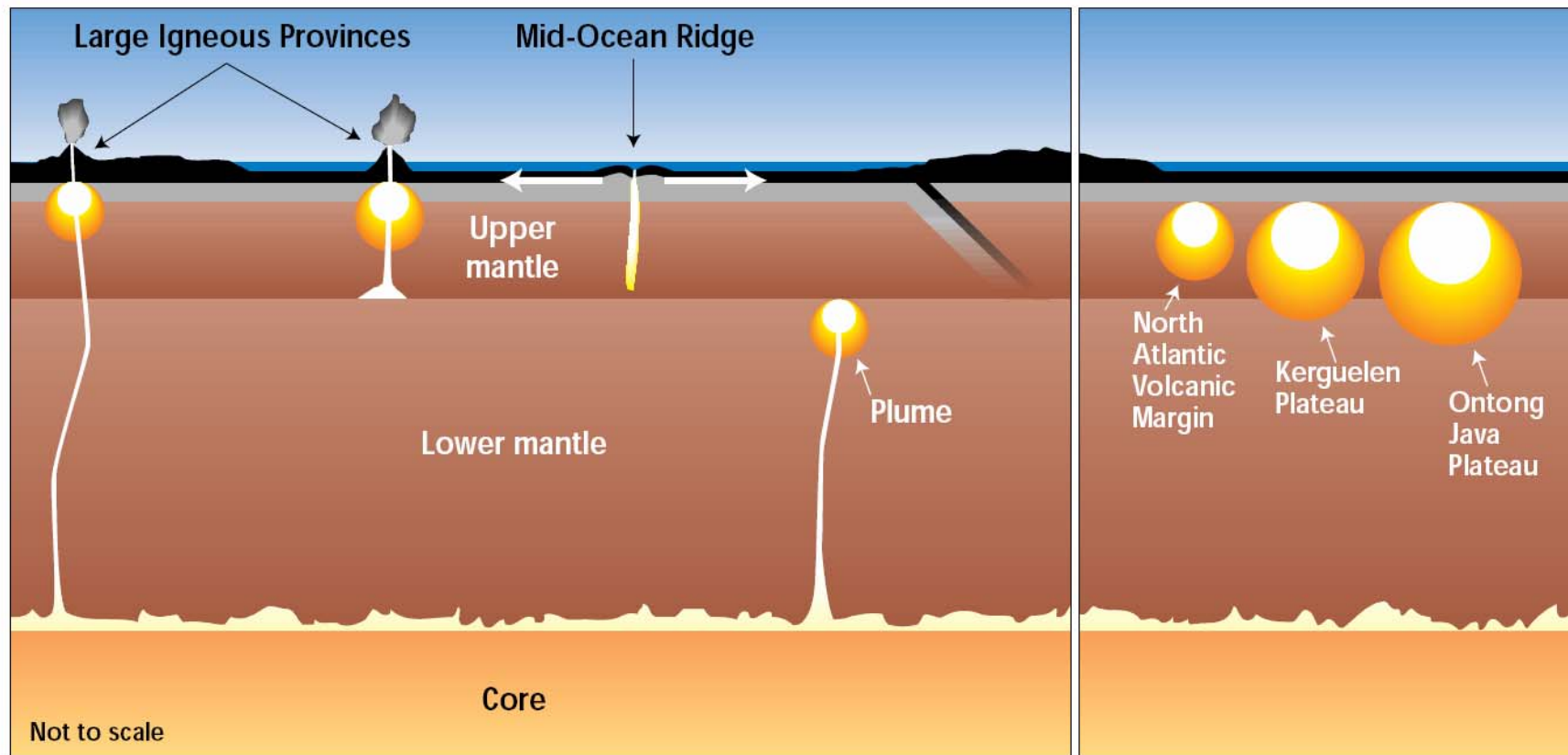
Location of Large Igneous Provinces:

Most (but not all) are 'Cretaceous' in age.

'Rolling Thunder' – age progression from East (Parana) to West (Ontong-Java, then Kerguelen, then Deccan).



(Coffin und Eldholm 1994, Schmincke 1999)



Rising plumes of hot material migrate through Earth's mantle; where the head of the plume reaches the surface, a large igneous province forms (left). Plumes probably originate at the boundary layers between the core and mantle at 2900 km below Earth's surface, and between the upper and lower mantle. The parent plumes of the most voluminous igneous provinces were so huge that they must have originated at least in part in the lower mantle, most likely at the core-mantle boundary. The spheres on the right depict the minimum (white) and maximum (orange) inferred diameters of the plumes associated with five large igneous provinces.

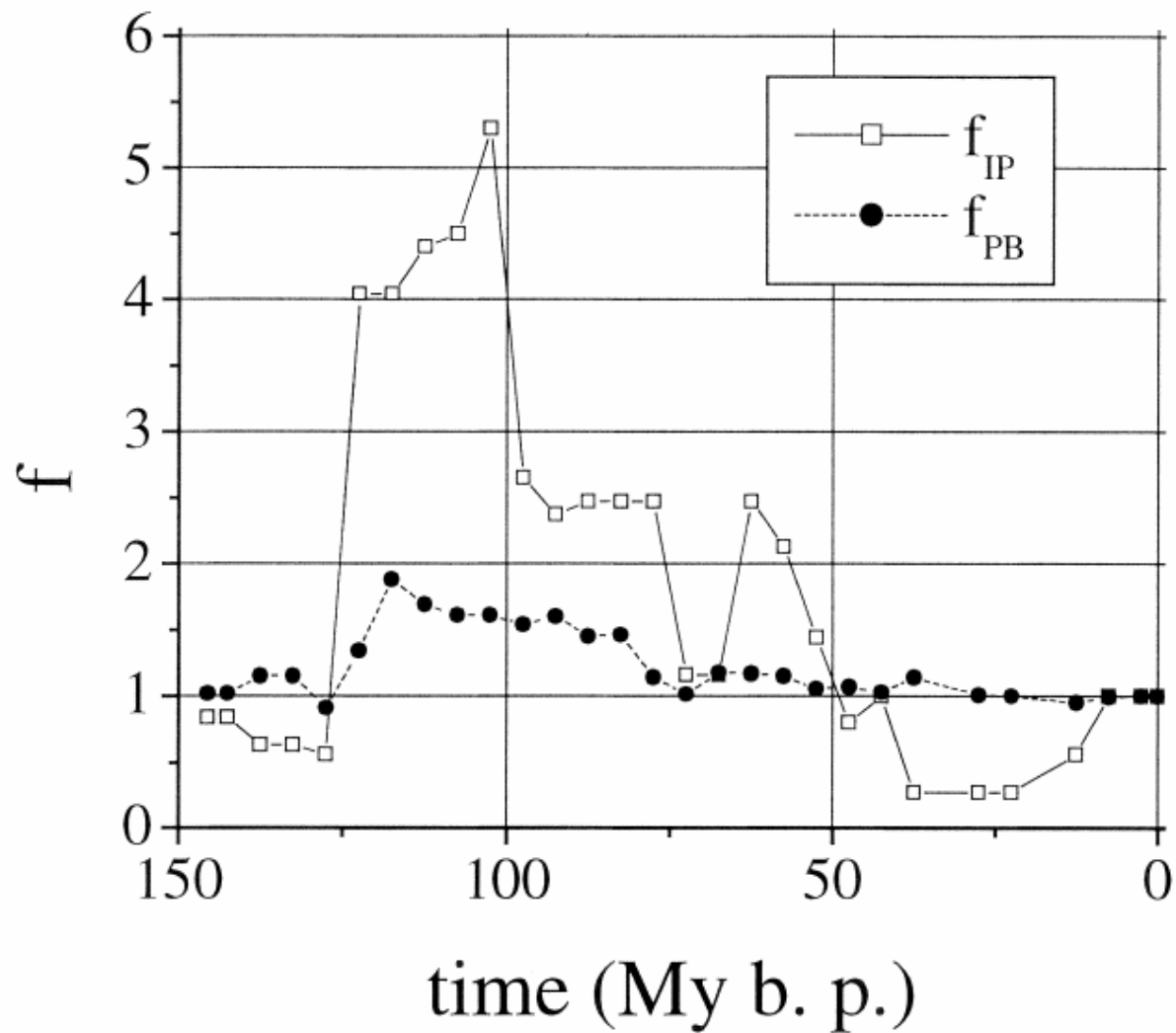
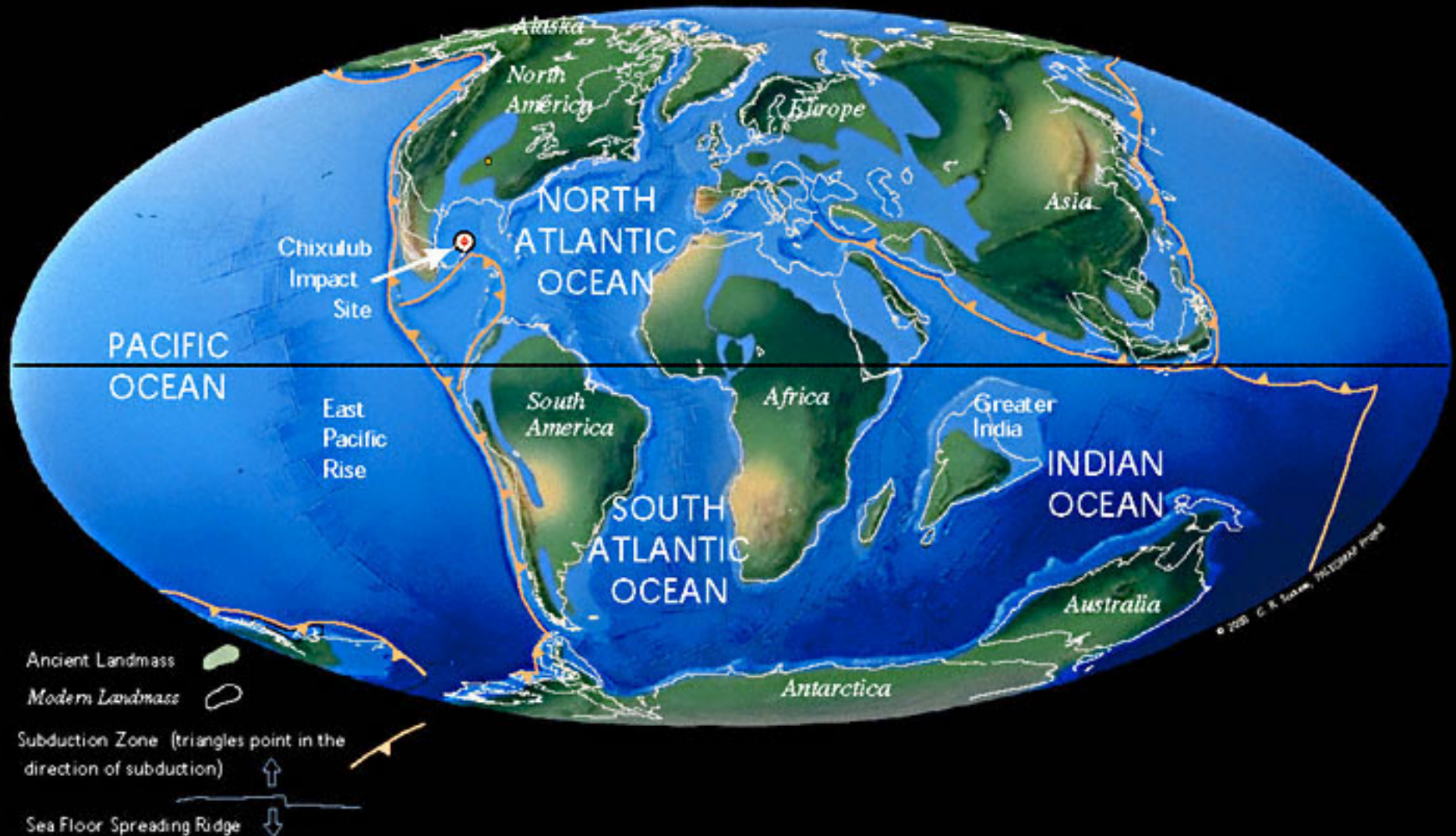


Fig. 2. Changes in spreading/subduction rates (f_{PB}) and in the activity of intraplate volcanism (f_{IP}) through time (Larson; 1991a; b). All data were normalized to the present values to calculate the non-dimensional variables f_{PB} and f_{IP} .

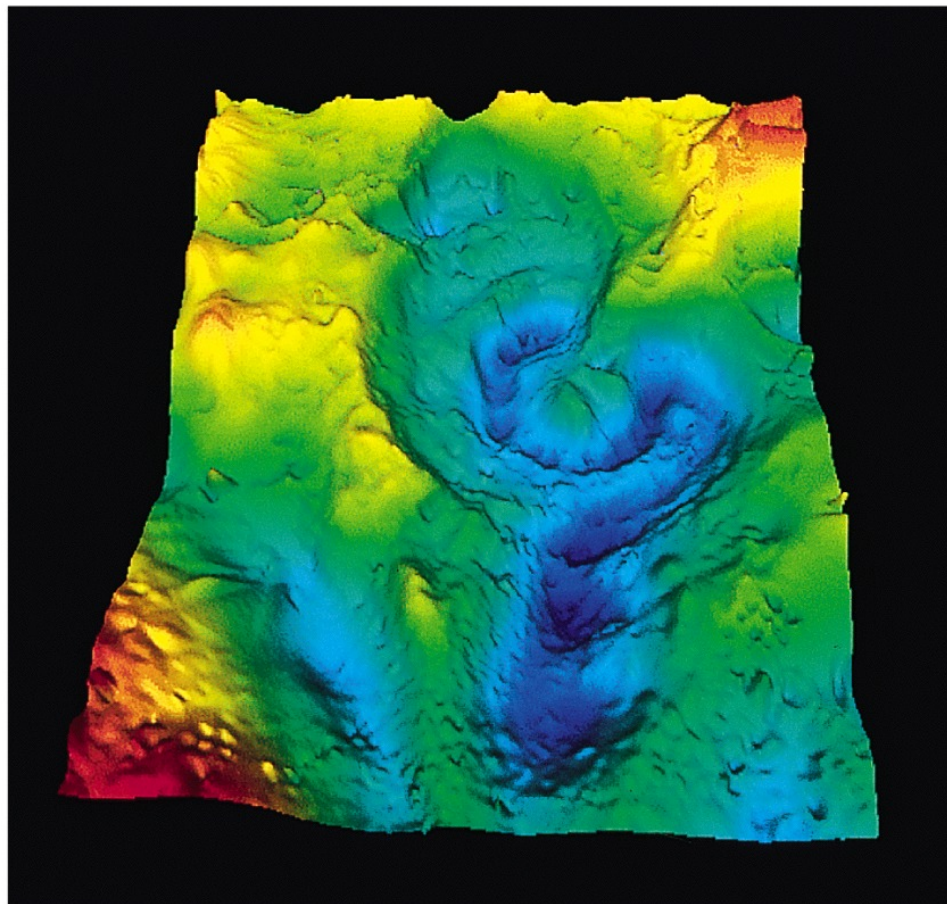
End of an Era – the end-Cretaceous ‘event’

K/T Boundary 66 Ma



RECORDS OF THE APOCALYPSE: ODP DRILLS THE K/T BOUNDARY

Richard D. Norris, Woods Hole Oceanographic Institution
and the ODP Leg 171B Scientific Party



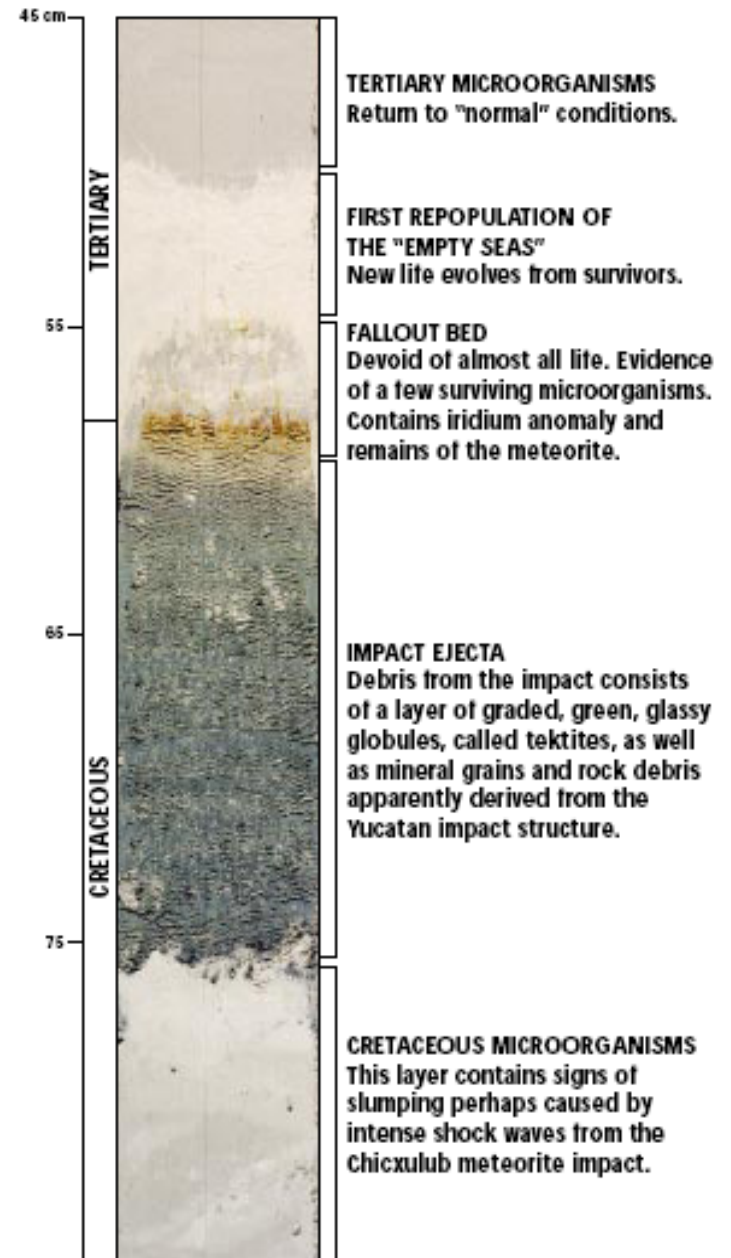
Highest
gravity

Average
gravity

Lowest
gravity

Cretaceous/Tertiary Boundary meteorite impact

ODP Leg 171B, Site 1049, Core 1049A, Section 17X-2



Asteroid impacts can have apocalyptic consequences, but – the impact is not usually long-term. Except in the Eocene.....

Time after asteroid impact	Minutes or less	Days to years	Decades to centuries
Effects on the environment	Shock waves Water & rock vaporized Tidal waves Firestorms	Soot & dust in stratosphere Acidification of lakes and ocean	Higher levels of CO₂ in the atmosphere
Climatic effects	Warming	Cooling	Warming

