The Carboniferous Period

359 TO 299 MA

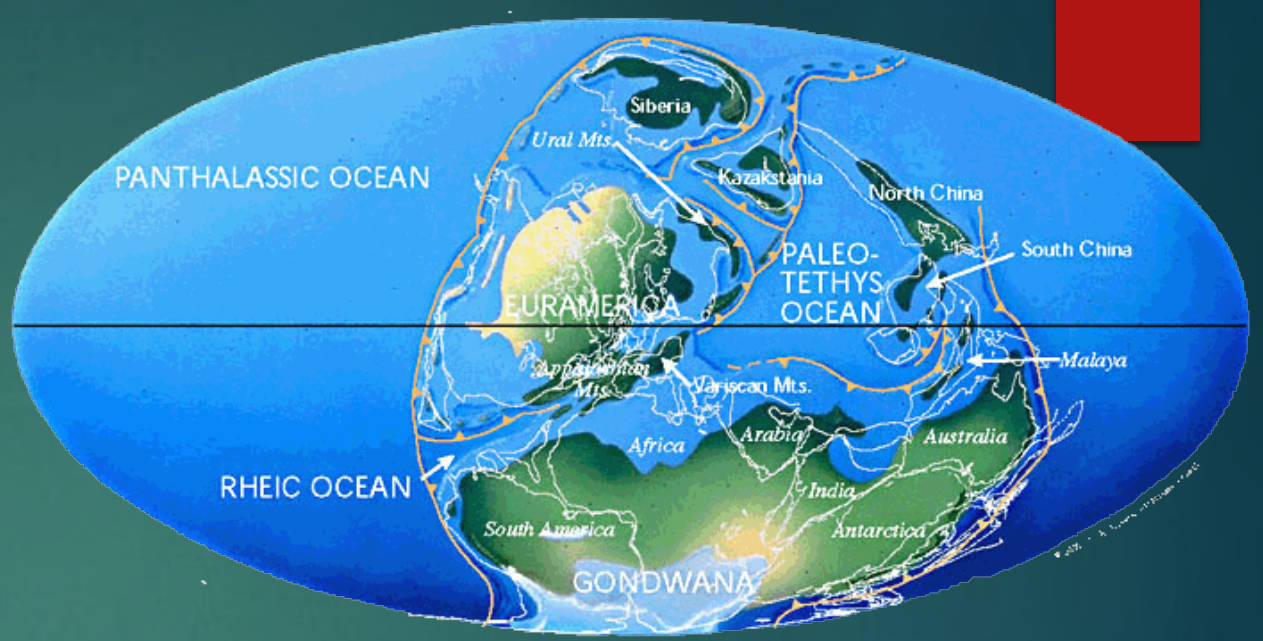
60 MILLION YEARS, THE LONGEST PERIOD OF THE PALEOZOIC ERA

The Carboniferous Period

- From 359 t0 299 MYA
- Usually divided into the Mississippian (359-323 MYA) and Pennsylvanian (323-299 MYA)
- A time of uniquely high oxygen (up to 35%) which led to a great proliferation of all forms, especially arthropods (one dragonfly fossil measured twenty inches in wingspan)
- Forest burial proceeded on a spectacular scale, producing 90% of the coal deposits on earth.

The World of the Carboniferous

- In the Late Carboniferous Laurasia (present-day Europe, Asia, and North America) collided into Gondwana (present-day Africa, South America, Antarctica, Australia, and India) producing the supercontinent Pangea.



Carboniferous Climate

- The single continent formed by the collision of Gondwana with Euramerica (resulting in the supercontinent Pangea) produced huge mountain chains (Appalachians and Variscans). This led to the production of great floodplains and a wet, warm interior climate.
- Newly evolved true trees (with lignin and cellulose for structural integrity).
- However these new trees had very shallow roots and thus toppled easily. Bacteria to digest the lignin had not yet evolved, leading to a massive interment of carbon.
- With the very high oxygen forest fires were frequent and widespread (some argue global) augmenting the burial of carbon.

Carboniferous Climate (cont'd)

- Pangaea stretched from Gondwana in the antarctic to Siberia in the arctic. This led to climate extremes, with glaciation in Gondwana from 330 MYA to around 270 MYA. While technically an ice age, the temperate Carboniferous world was warm and swampy.

Carboniferous Climate (Cont'd)

- Average global temperatures in the Early Carboniferous Period were high: approximately 20 °C (68 °F). However, cooling during the Middle Carboniferous reduced average global temperatures to about 12 °C (54 °F). Lack of growth rings of fossilized trees suggest a lack of seasons in a tropical climate. Glaciations in Gondwana, triggered by Gondwana's southward movement, continued into the Permian *

*Wikkipeda

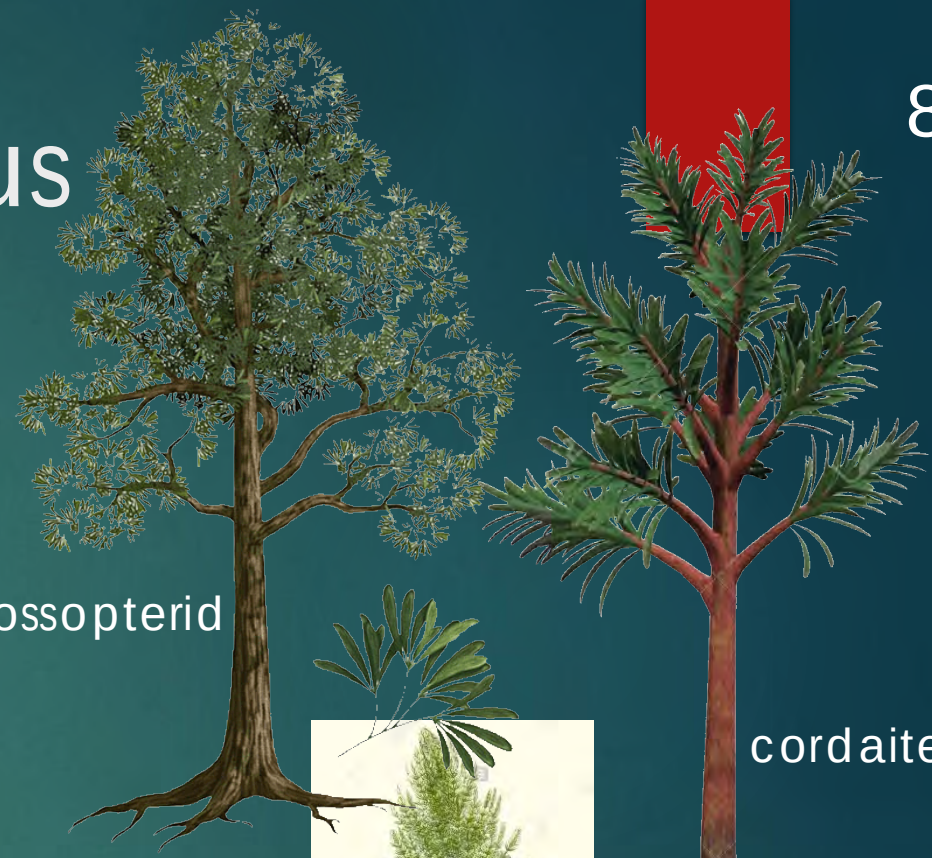
Carbon Dioxide and Oxygen in the Carboniferous

- During the early Carboniferous CO_2 concentration was at or near 1,500 ppm (today it's 407 ppm), keeping the temperature tropical over much of the earth.
- Oxygen levels also rose from around 20% (similar to today) to around 35% or even higher.

Some consequences of this high O_2 concentration were enormous insects and more active animals (potentially driving evolution of reptiles from amphibian stem stock). It probably led to forest fires unlike anything seen today in both extent and ferocity.

Plants of the Carboniferous

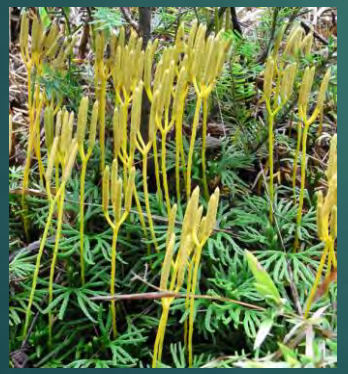
- For the first 10 million years (350-340 MYA) lycophytes and seed ferns dominate coastal swamps; Horsetails lined streams, along with sphenopsids.
- By 320 MYA conifers and glossopterids appear; lianas and epiphytes appear in forests dominated by lycopsids, cordalites and seed plants. Small ferns provide ground cover (no grasses).



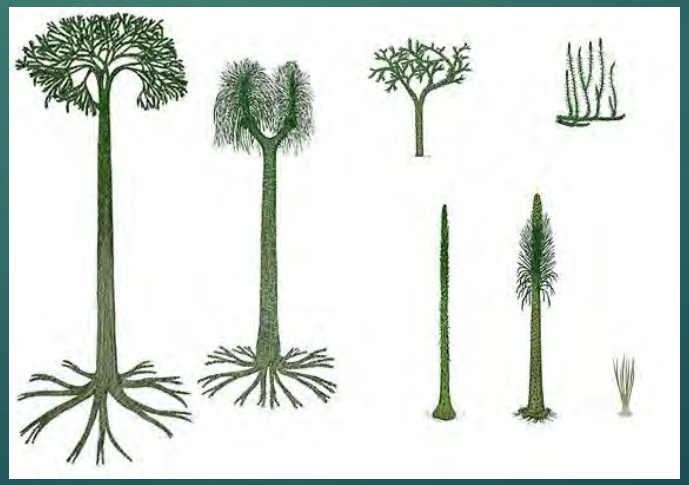
glossopterid

cordaite

Carboniferous lycophyte



Modern lycophyte



lycopsids

Carboniferous horsetail

Animals of the Carboniferous

EarlyTetrapods Explore Mississippian Riverbanks
Acanthostega (foreground) and Ichthyostegans

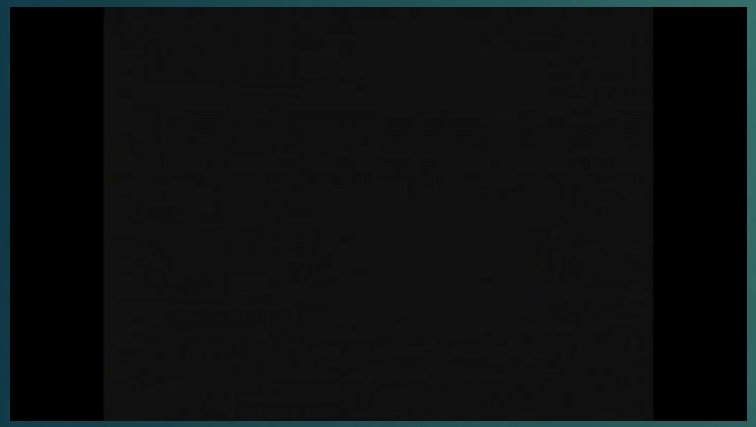
Lots of Oxygen leads to *BIG* insects!

David Attenborough: Giant Millipede of Carboniferous

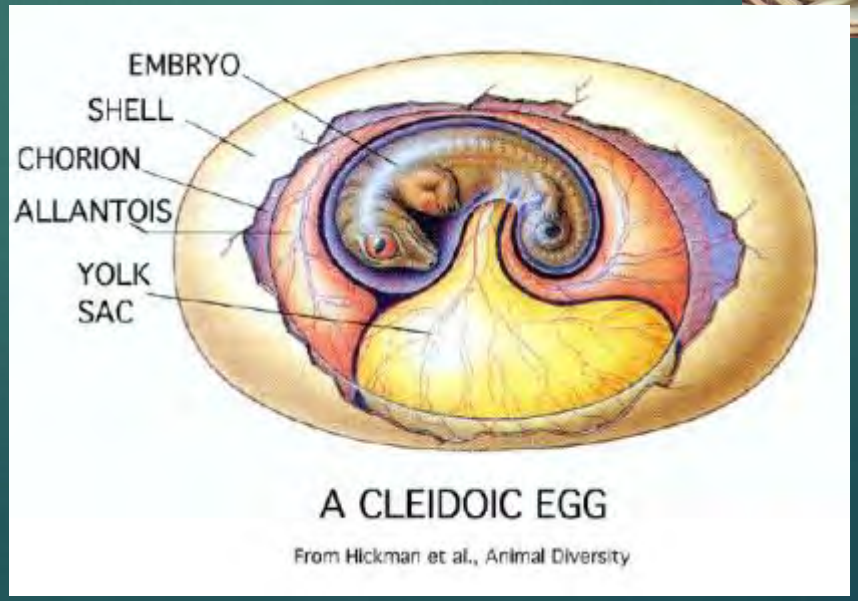
Meganeura

Rise of the Reptiles: Cleidoic Egg

A major adaptation for terrestrial living, the cleidoic egg arose in the Carboniferous. It enabled reptiles to become completely independent of water for reproduction.



Amphibian (frog) development



Coal Formation in the Carboniferous

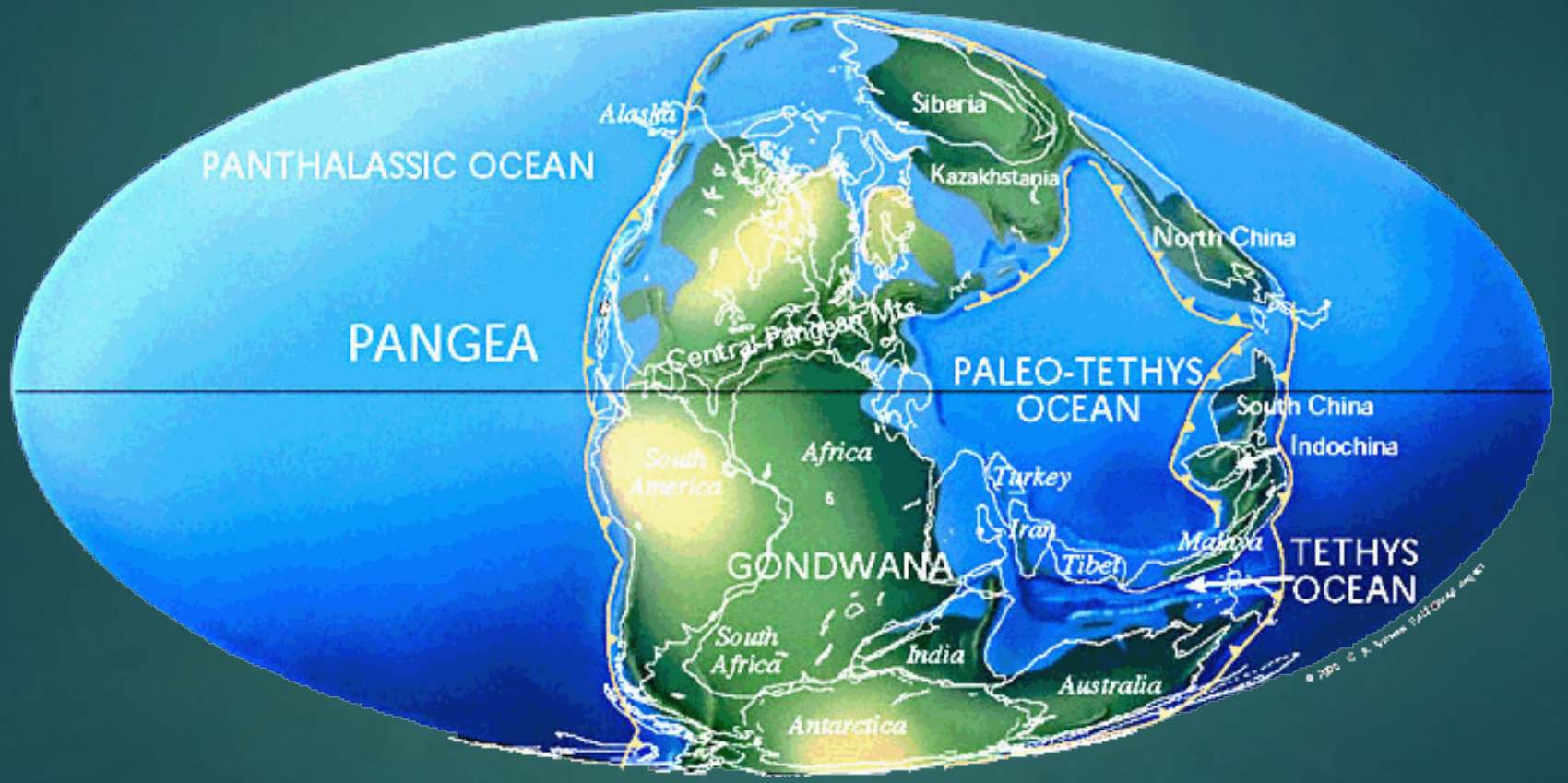
- 90 percent of the earth's coal was produced in the Carboniferous.
- The prevalent theory is that while plants had developed lignin to strengthen stems and trunks, no fungus or bacteria had evolved to digest the lignin leading to vast deposits of un-broken-down plant matter which eventually became coal.
- A 2018 paper* disputes this, presenting a number of countering facts and proposing that instead the rapid burial of plant matter was due to orogenic factors such as ground subsidence.

*Nelsen, M.P., DiMichele, W.A., Peters, S.E. and Boyce, C.K. 2016. Delayed fungal evolution did not cause the Paleozoic peak in coal production. Proceedings of the National Academy of Sciences, USA 113: 2442-2447.

The Permian Period

- Named for the Perm region of Russia, because its limits were found in strata in the Ural Mountains.
- Last period of the Paleozoic era, beginning of the Neoproterozoic era.
- Lasted 47 million years, from the end of the Carboniferous 299 MYA to the beginning of the Triassic, 252 MYA.
- Dominated by the giant supercontinent Pangea.
- Saw several glacial periods, beginning at the end of the Carboniferous with much of the southern hemisphere covered in ice.
- By the late Permian the ice had disappeared, leaving a temperate climate, but rather dry.
- Saw the diversification of the early amniotes into the ancestral groups of the mammals, turtles, lepidosaurs, and archosaurs.
- Ended in the Permian-Triassic Extinction, the largest mass extinction in Earth's history, in which nearly 96% of marine species and 70% of terrestrial species died out. It is the only extinction that affected insects. It marked the end for the trilobites, a run of some 300 million years.

The World of the Late Permian



The Permian Sea, 270 Million years ago

The world at the time was dominated by two continents known as Pangaea and Siberia, surrounded by a global ocean called Panthalassa. The Carboniferous rainforest collapse left behind vast regions of desert within the continental interior. Amniotes, who could better cope with these drier conditions, rose to dominance in place of their amphibian ancestors*.

*AMNH exhibit text

Mammals of the Permian

Cotylorhryncus

Moschops

Dicynodont

Gorgonopsid

Dimetrodon

Dinocephalian

The Granddaddy of Them All: The End-Permian Extinction

250 MILLION YEARS AGO

96% OF ALL SPECIES DIED.

The Permian Extinction: Multiple Causes

- Magma from a massive volcanic eruption poured for thousands of years onto the surface in what is now called the Siberian Traps. From the amount of magma released (2 million square miles of it, in places two and a half *miles* deep) it has been calculated that enough CO_2 was released to raise the global temperature by 5°C.
- That same magma ignited vast underground deposits of coal and shale oil left from the Carboniferous, releasing millions of tons of CO_2 and other gasses, including methane, halogenated butane, methyl bromide and methyl chloride, in an unimaginable explosion.
- Hydrogen sulfide levels increased dramatically over a few hundred years. A mass release of H_2S would react with and destroy atmospheric O_2 and ozone in the upper atmosphere allowing ultraviolet radiation to kill off species that had survived the toxic gas.
- CO_2 released by vulcanism could raise ocean temperatures releasing frozen methane (clathrate) reservoirs, expelling enough methane into the atmosphere to raise world temperatures an additional 5°C.
- The CO_2 would also acidify the oceans which, among other effects, would prevent shell production.
- More likely, the Permian–Triassic extinction event was caused by a combination of some or all of the above and other factors; for example, the formation of Pangaea decreased the number of coastal habitats and may have contributed to the extinction of many clades.

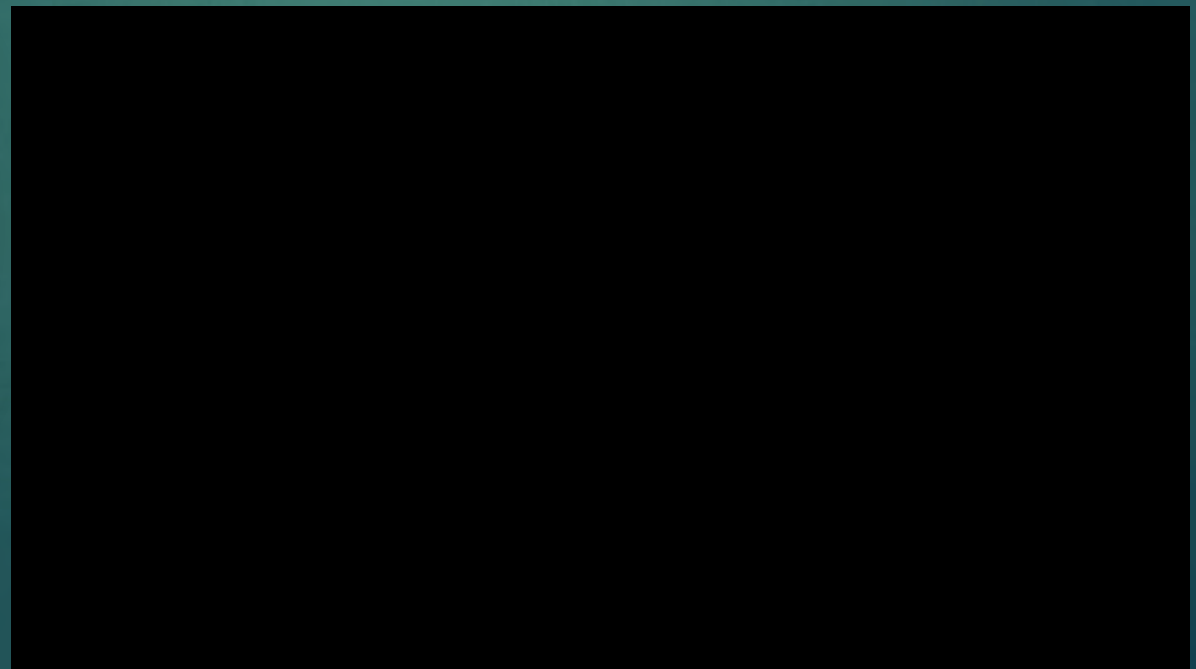
CO_2 and the End-Permian Extinction

- Modern estimates place the concentration of CO_2 at the end-Permian around 8,000 ppm, although some estimates are as high as 30,000 ppm. The Siberian Traps alone might have released from 10,000 to as much as 40,000 gigatons (thousand million tons) of CO_2 into the atmosphere.
- This resulted in catastrophic global warming and acidic seas.
  - For comparison, today we humans release about 40 gigatons of CO_2 per year, and currently the concentration is 417.9* ppm.
  - Burning all known reserves of oil, gas and coal would inject about 5,000 gigatons of CO2 into the atmosphere.

*on April 28th it was 419.75 ppm)

And let's not forget the hypercanes.

- The National Center for Atmospheric Research (NCAR) has developed weather models based on the end-Permian conditions.
- They propose that in addition to all the other effects there were "hypercanes": continent-wide hurricanes packing 500 mile-an-hour winds, loaded with poisonous hydrogen sulfide picked up from the ocean, along with carbon dioxide.



What could the world be like during the End-Permian Extinction

- Here's a reading from Peter Brannen's book, "The Ends of the World"

What ended the End-Permian Extinction?

- It took about ten million years for the Earth's biota to recover from the Hell of the end-Permian world.
- Most of the recovery was due to the absorption of the CO_2 out of the atmosphere, returning it (and the global temperature) to 'sane' levels.
  - Factors at work were weathering and sequestration of CO_2 by coral-reef building and shell-building animals.
  - Plant life was not much help, most of it, including trees, having been killed off in the extinction.
  - Weathering was helped by the high CO_2 which produced acid rain but hindered by the fact that most of the Earth's landmass was concentrated in Pangaea, leading to dry interior.