Paleoclimatology

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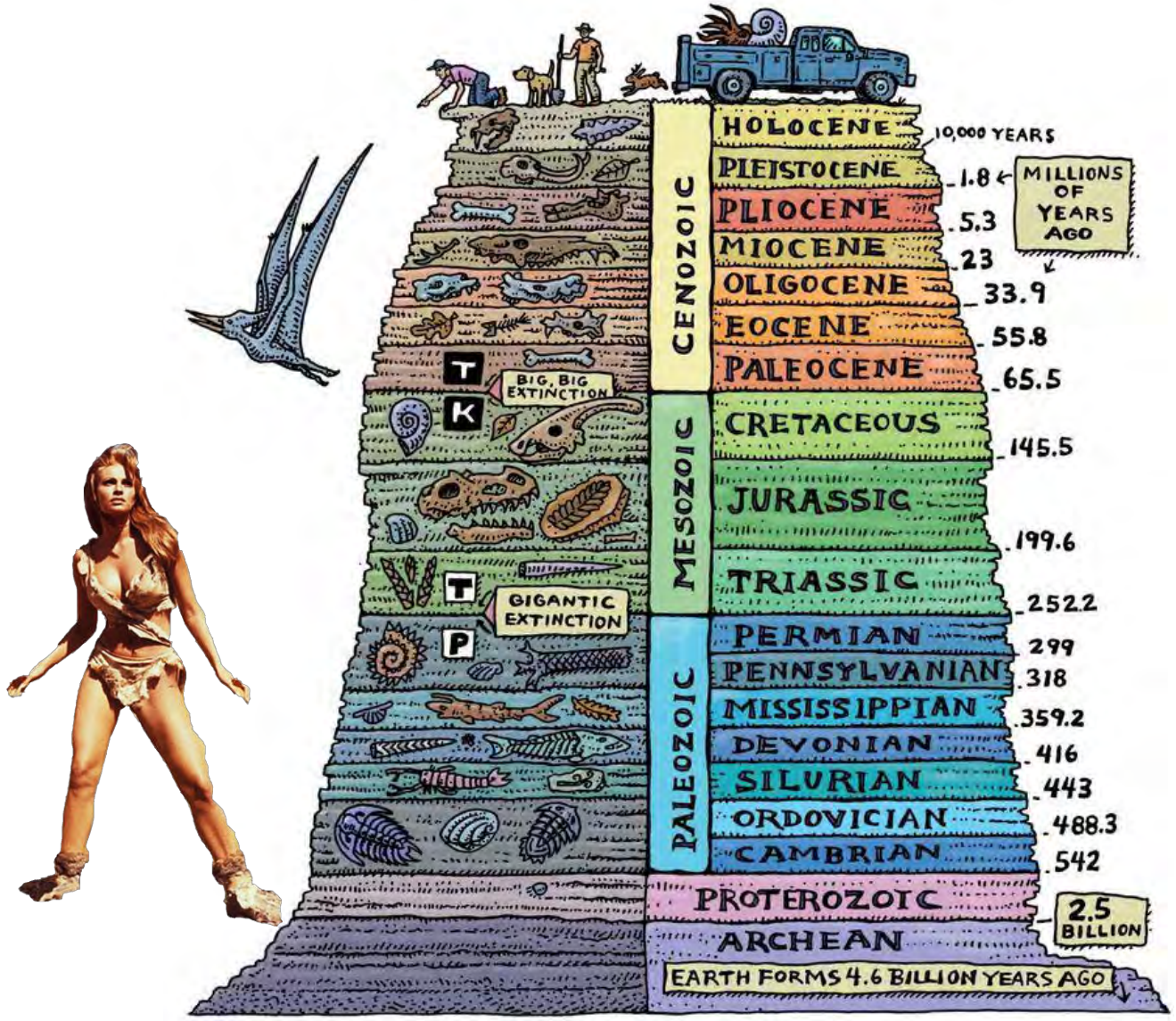
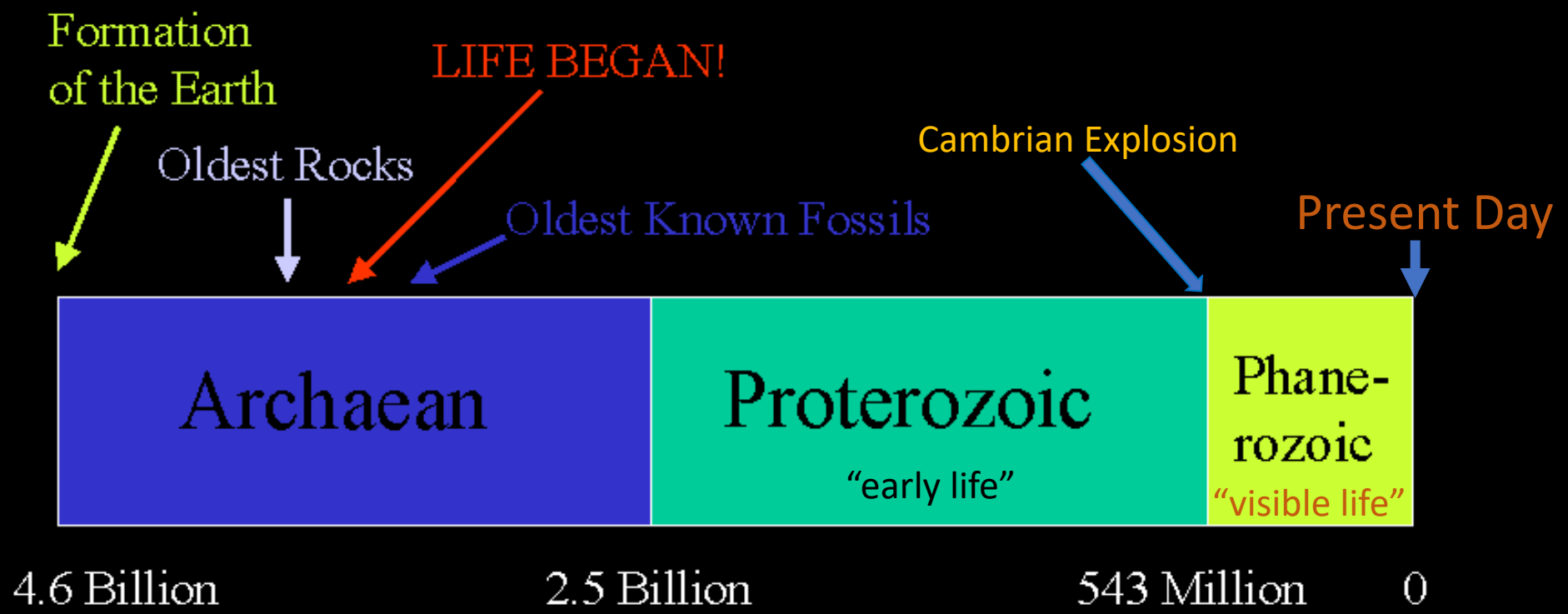
fall 2023

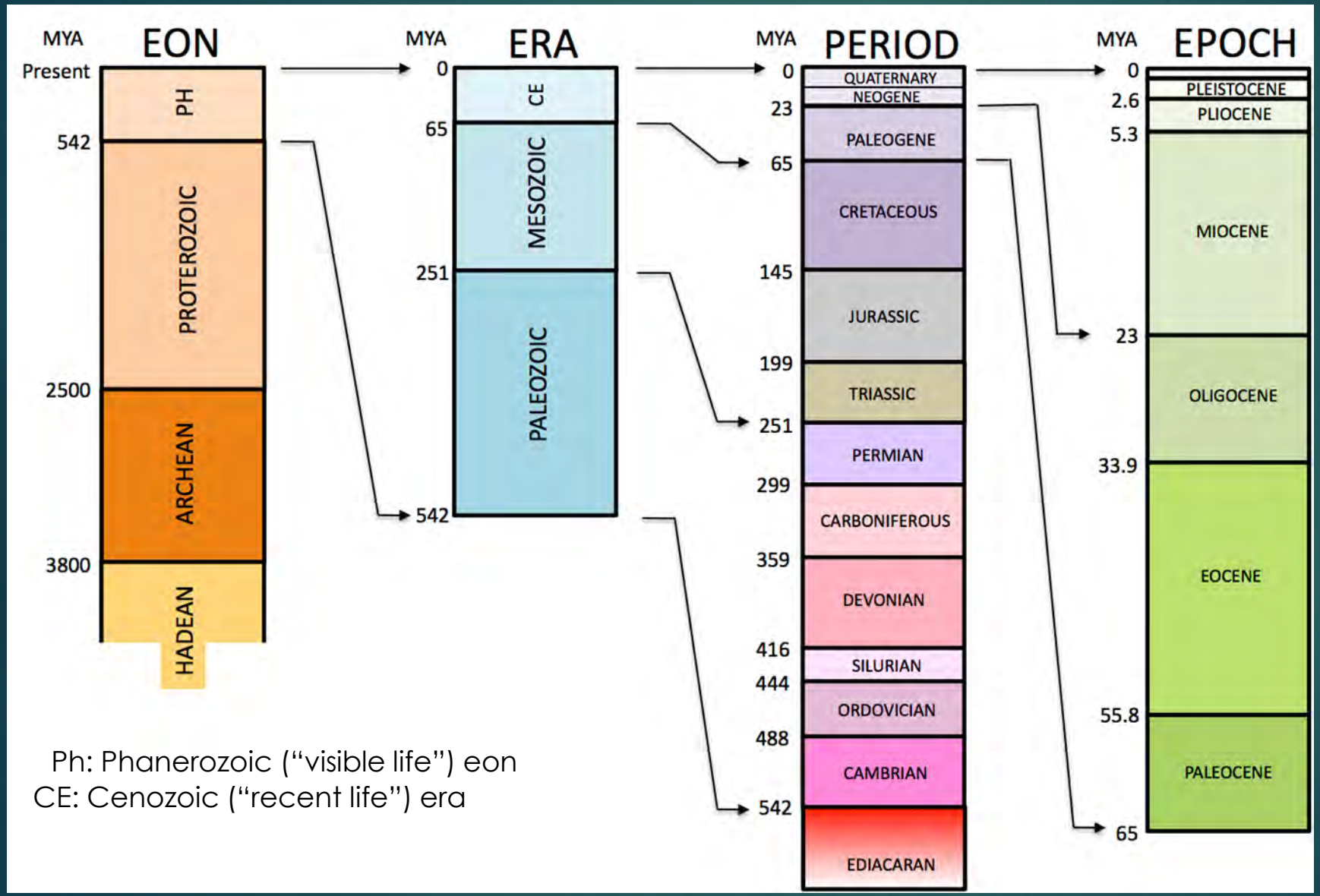
- To begin with, we need some sense of the time over which the earth's climate has changed.



THE EONS


Formation of the Earth
LIFE BEGAN!
Oldest Rocks
Oldest Known Fossils
Cambrian Explosion
Present Day
Archaean
Proterozoic
"early life"
Phane-rozoic
"visible life"
4.6 Billion
2.5 Billion
543 Million
0
Years Ago

Looking a little closer at the divisions…

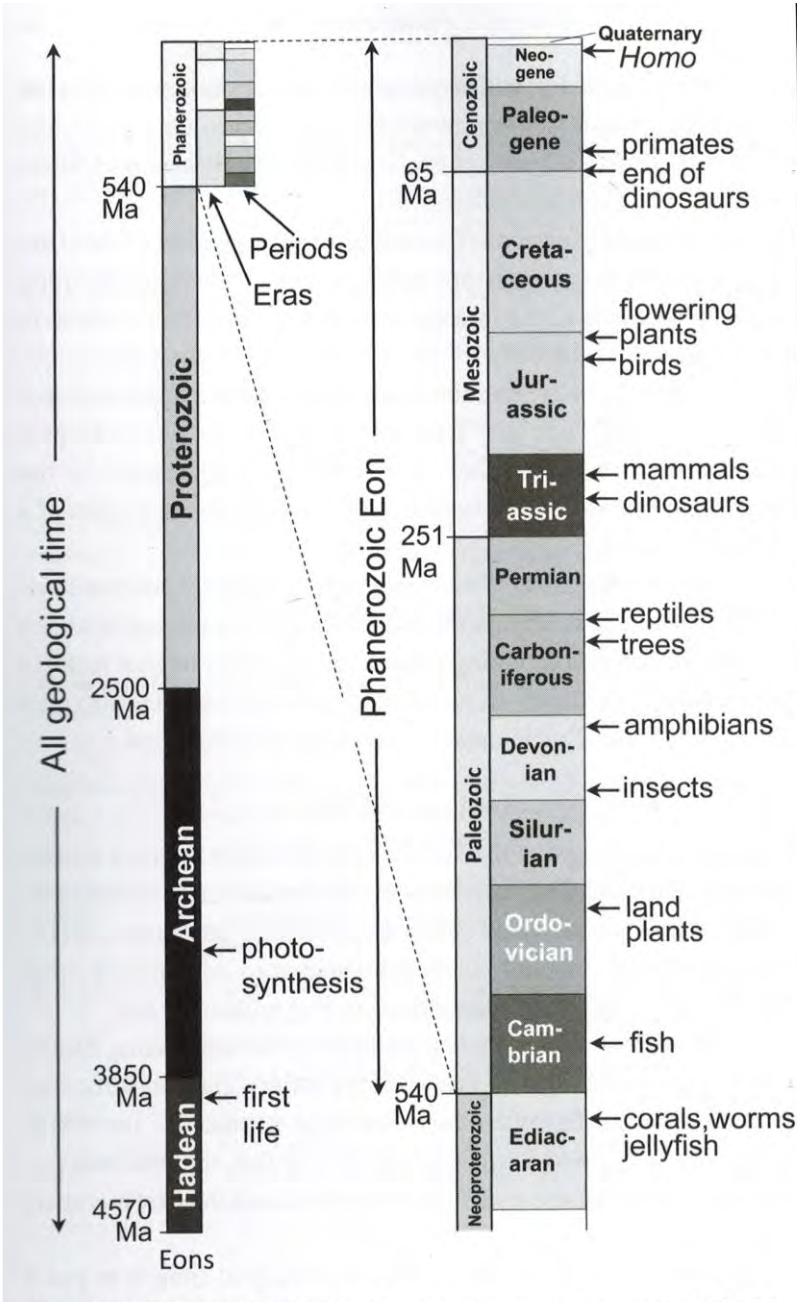


Ph: Phanerozoic ("visible life") eon
CE: Cenozoic ("recent life") era

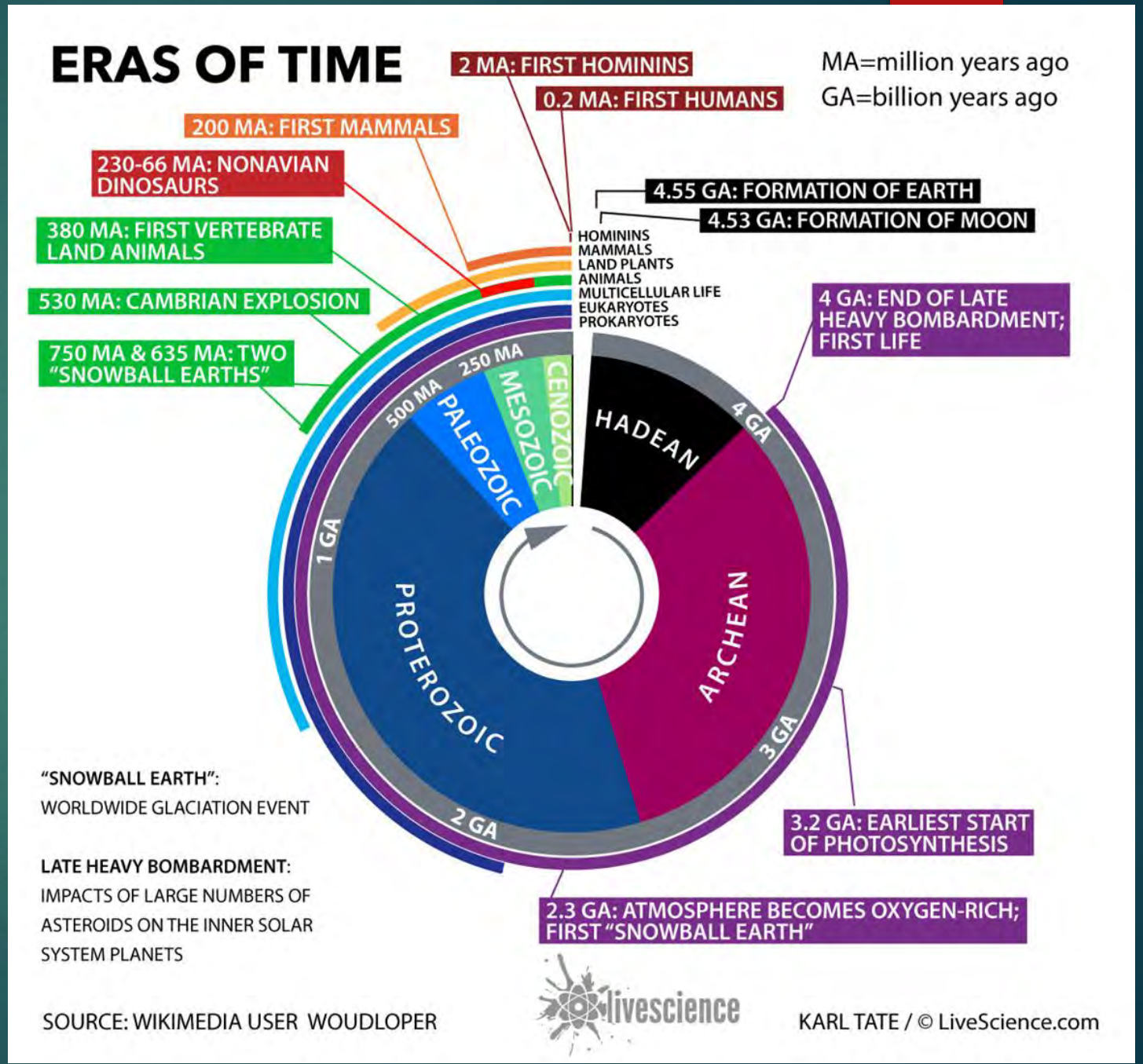
Geological divisions are based on major climate changes.

History of the earth in one year:

Midnight, January 1: Earth forms
Mid-February: life begins as single-celled organisms
November 13: multicellular organisms (worms, jellyfish, corals) appear
November 24: Plants move onto the land
December 3: Vertebrates (amphibians) move onto land
First week of December: reptiles appear
December 13: Dinosaurs and early mammals appear. (Dinosaurs last until Boxing Day, December 26)
December 27: Mammals appear
Humans leave Africa about two minutes to midnight.



And what was going on all that time??

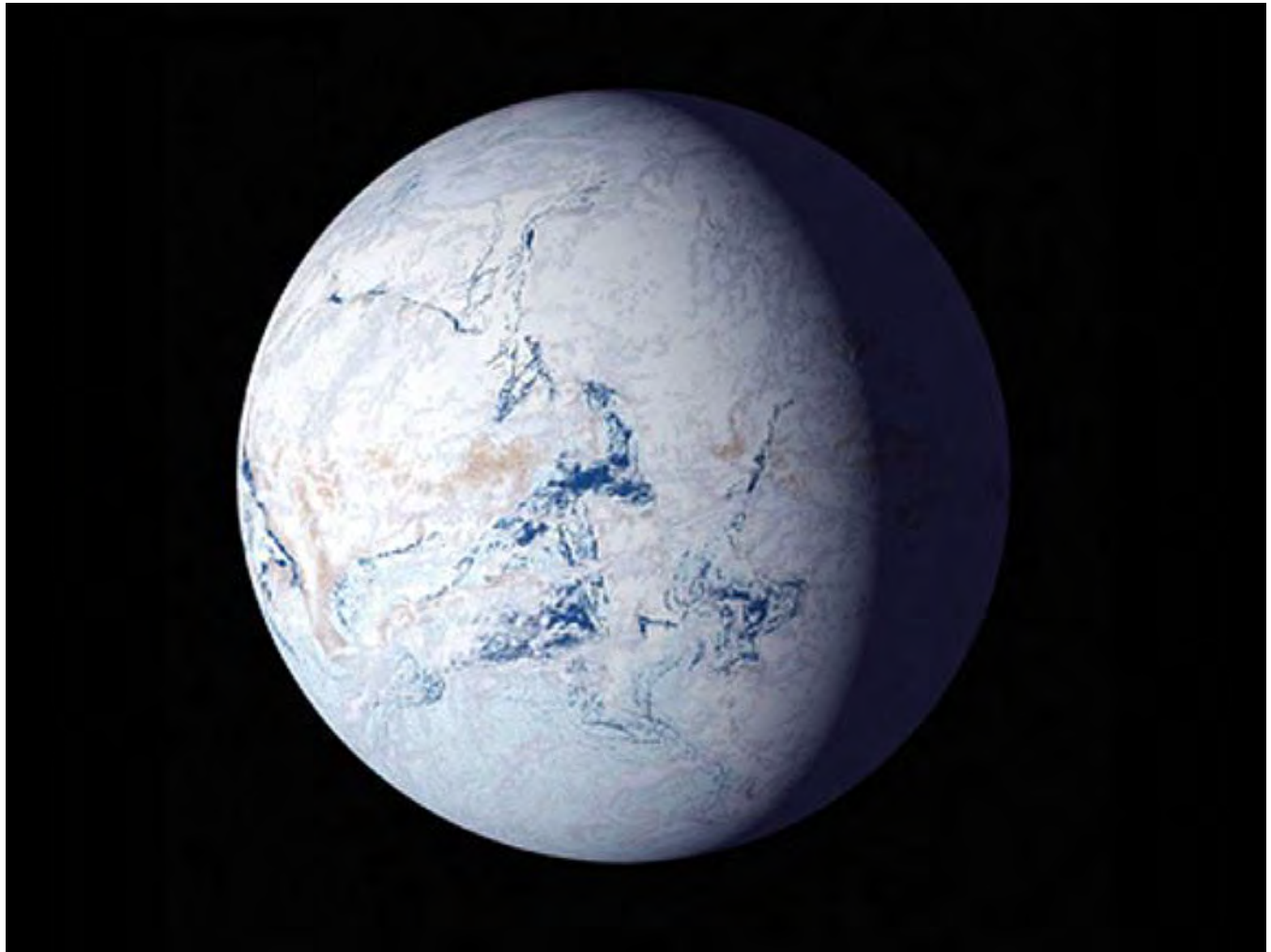


More dramatically, here's our history in ONE DAY!

Snowball Earth

Twice in the 4.5 billion year history of the earth it has been frozen solid from pole to pole. This was in the Cryogenian period from 720 to 630Ma*

The Sturtian glaciations (ca. 715–680 Ma) and Marinoan glaciations (ca. 650–635 Ma) were the most extensive ice times known to have existed on Earth. They extended to the equatorial zone



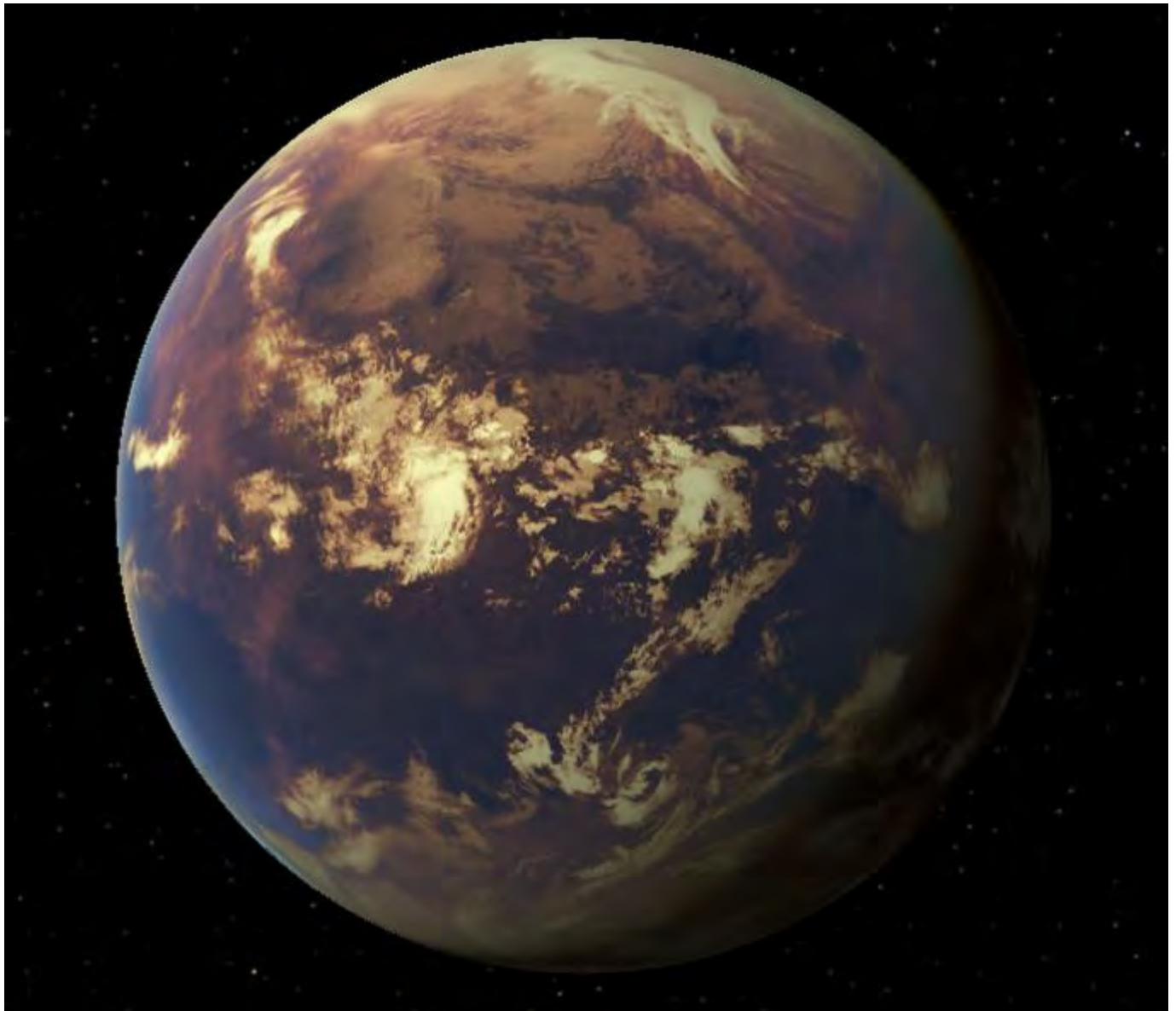
*Ma: “Mega-annum”: Millions of years ago.
Ga: “Giga-annum”: Billions of years ago.
Note that the “ago” is implied and not stated.

Hothouse (“Greenhouse”) Earth

At least twice in the Earth’s history there was no ice *anywhere*, including at the poles.

One occurred 90-120Ma.

A second occurred 55Ma (the PETM, or Paleocene-Eocene Thermal Maximum, one of the greatest extinction events in history.)



What drives the changes in the earth's climate?

Albedo

Continental Drift

Milankovitch Cycles

Greenhouse gasses

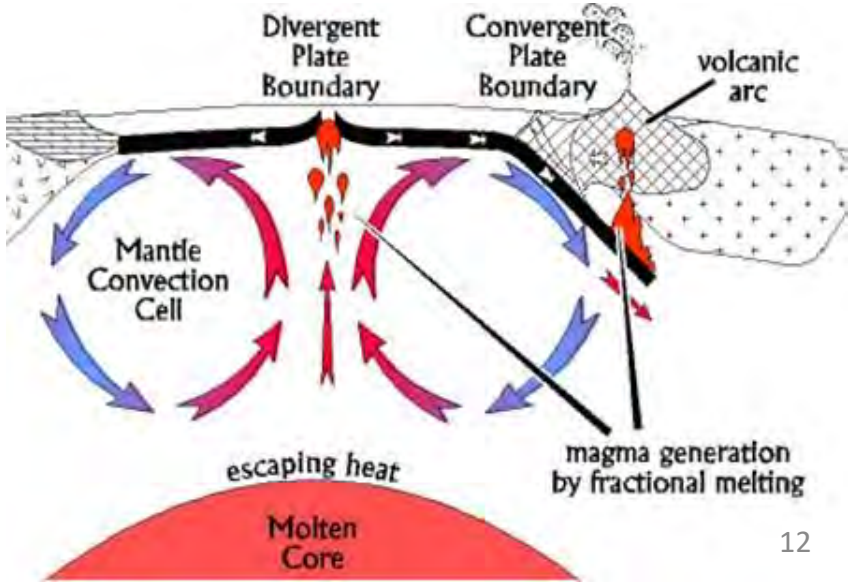
Albedo

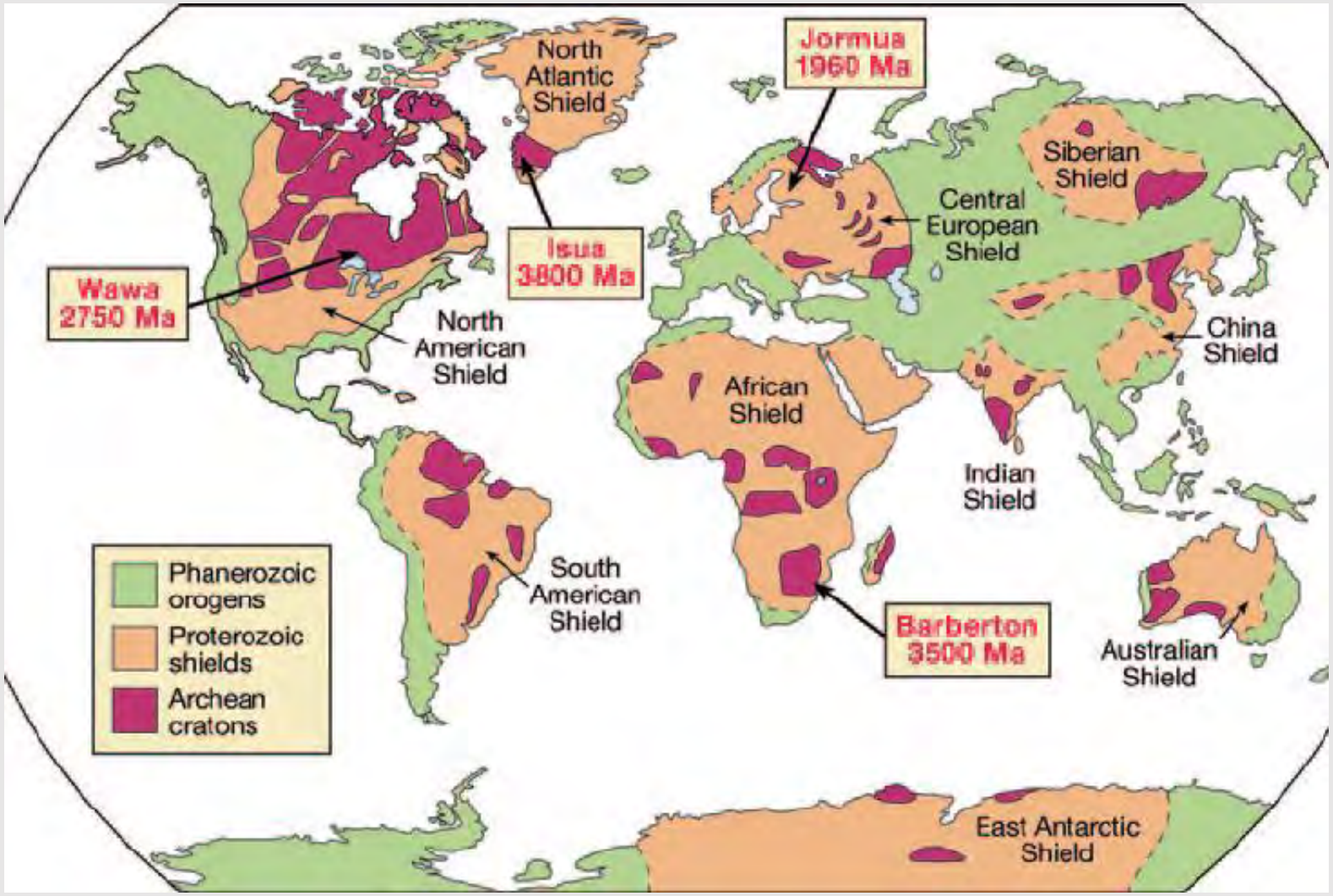
Albedo refers to the percent of light that is reflected from a surface. It ranges from 0 to 100% The lower the albedo, the more energy the surface absorbs, leading to heating. Albedo is wavelength sensitive, but here we use an average albedo for visible light.
Examples:

- Typical rock and sand surfaces: 30% (i.e., they absorb 70% of the radiation.)
- Forests: 10 to 15%
- Water: 3 to 10% depending on the angle of the sun overhead (3% when the sun is directly overhead.)
- Snow: New-fallen, 90%; Melting, 40%; Dirty, 20%. Antarctic average is 80%
- Clouds: 75 to 80%
- Asphalt: 5% (try walking in bare feet on this in the summer!)

Continental Drift

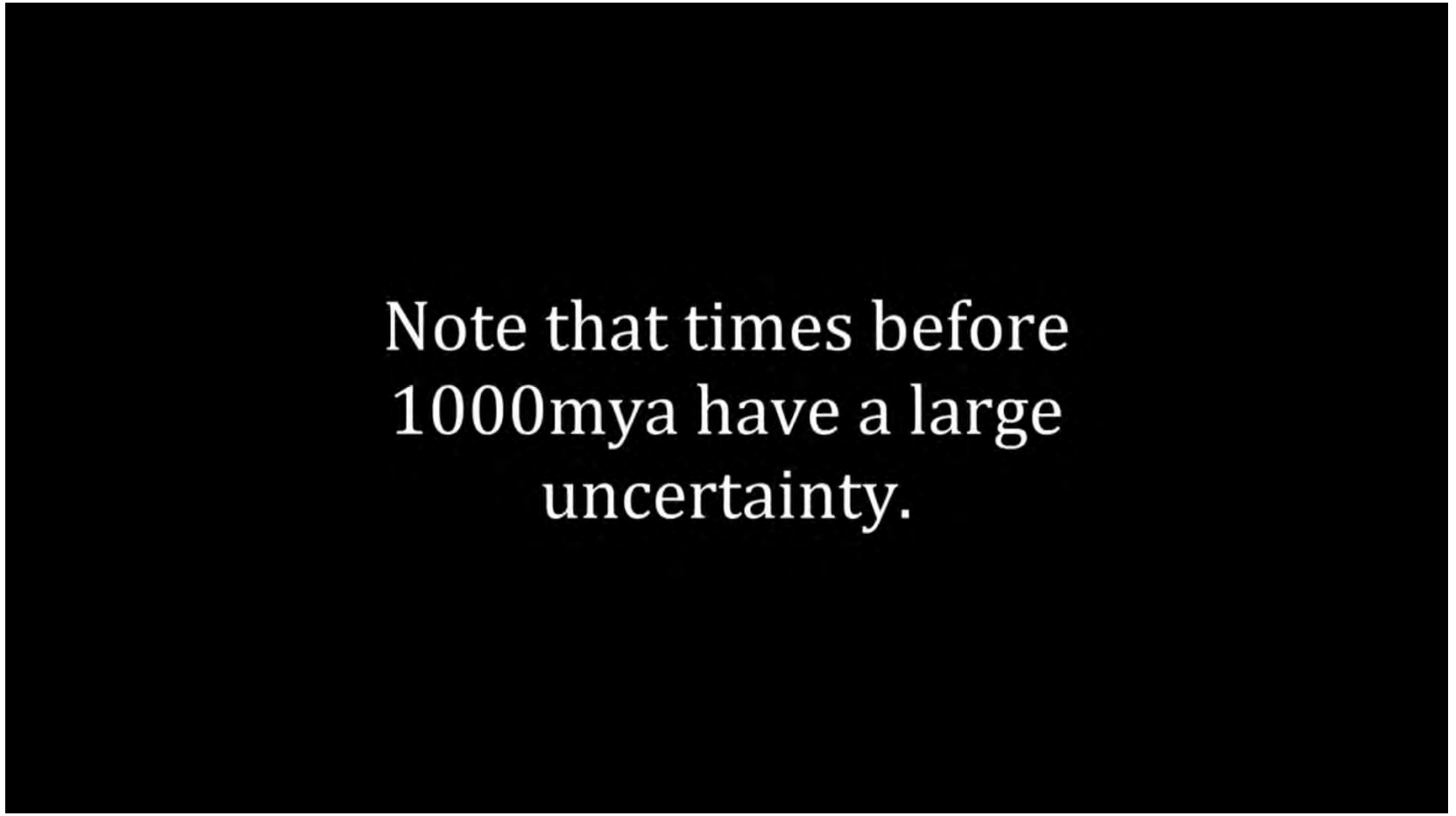
- At the outset the Earth's crust was, like that of most planets, basalt (the stuff of black lava).
- As the basalt crust cooled and hardened it trapped the Earth's inner heat, allowing it to raise and melt the lower levels.
- This lower-level magma combined with silicon as well as water, sodium, potassium and other elements to form a lighter rock, granite.
- The newly-formed lighter granite rose to the surface and began to float on the basalt, forming "islands" of granite called "cratons". Driven by convection cells in the Earth's mantle these floating islands drifted, colliding, forming continents.





Some three dozen or so cratons survive today, among the oldest rocks in the world.

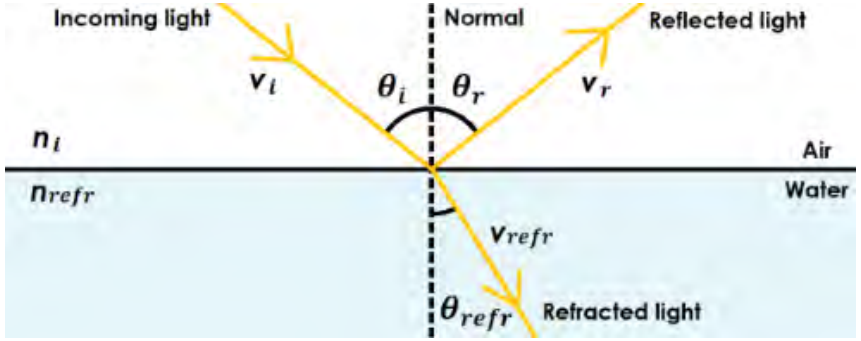
Continental Drift Begins



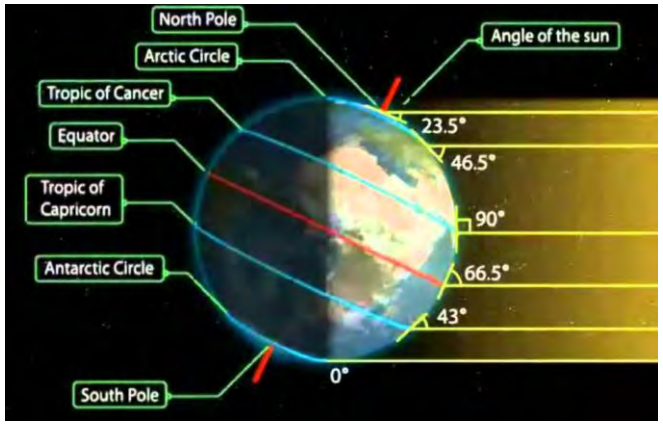
Continental Drift has many times altered the climate and biology of the Earth.

Albedo: Continental Drift, Latitude and Paleoclimatology

Albedo of water varies with angle of incidence,



- Albedo of water thus depends on latitude:
  - At low latitudes (equator) the sun is high year-round. Albedo is low.
  - At high altitudes (poles) the sun is below the horizon for much of the year and the angle of incidence is high. Albedo is high.



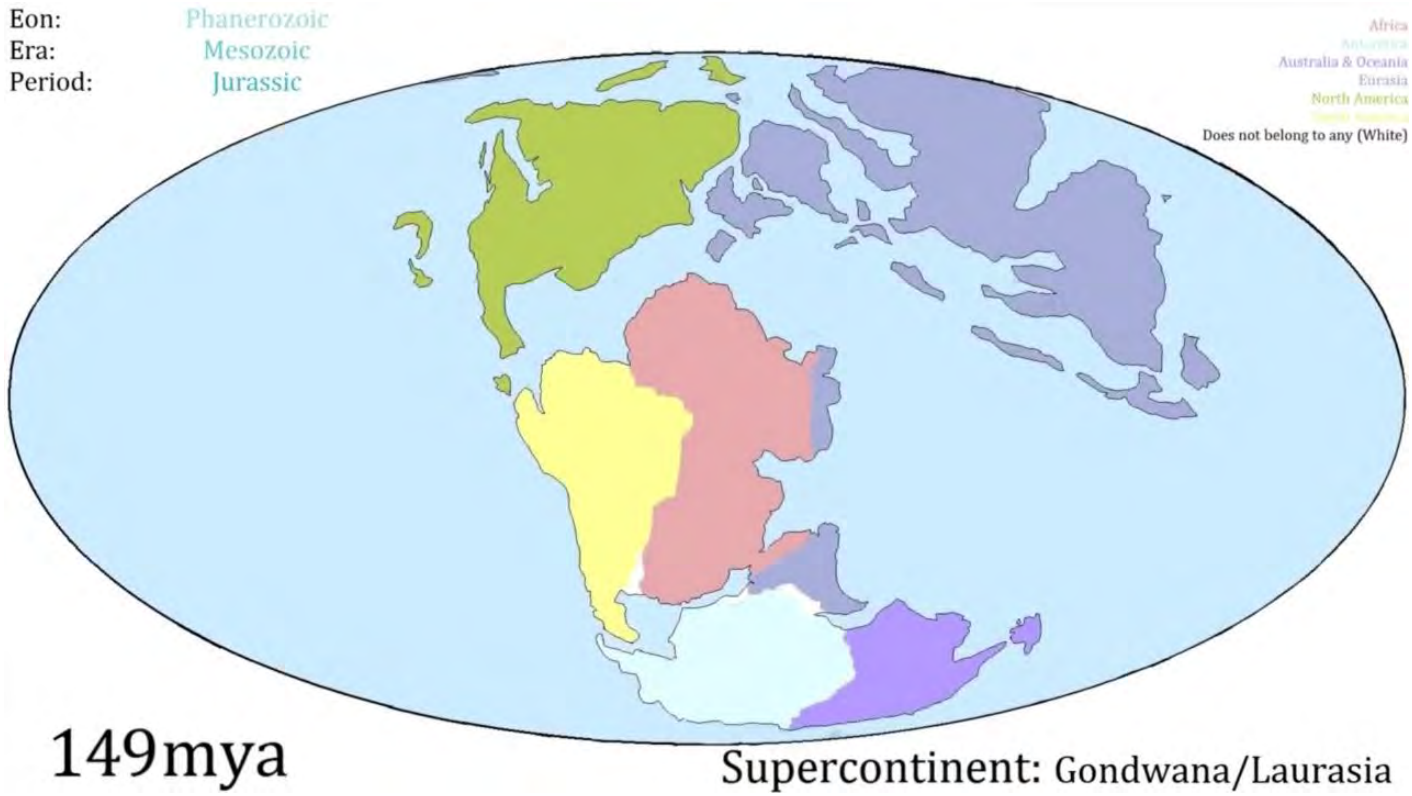
Continental Drift alters the distribution of land and open ocean globally.

When there is more open ocean at the equator, more solar energy will be absorbed.

N.B.: Insolation at the surface is also inversely proportional to the distance sunlight travels through the atmosphere.

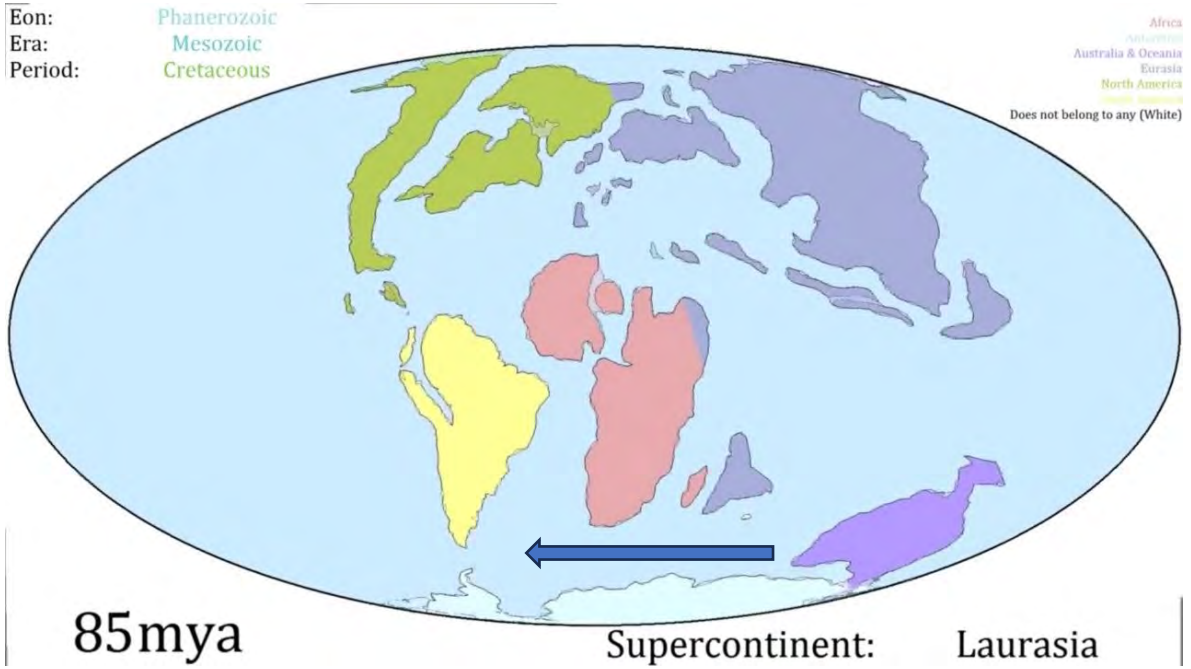
Continental Drift, Ocean Currents and Paleoclimatology

- Antarctica:
  - Prior to 85Ma, South America was connected to Antarctica



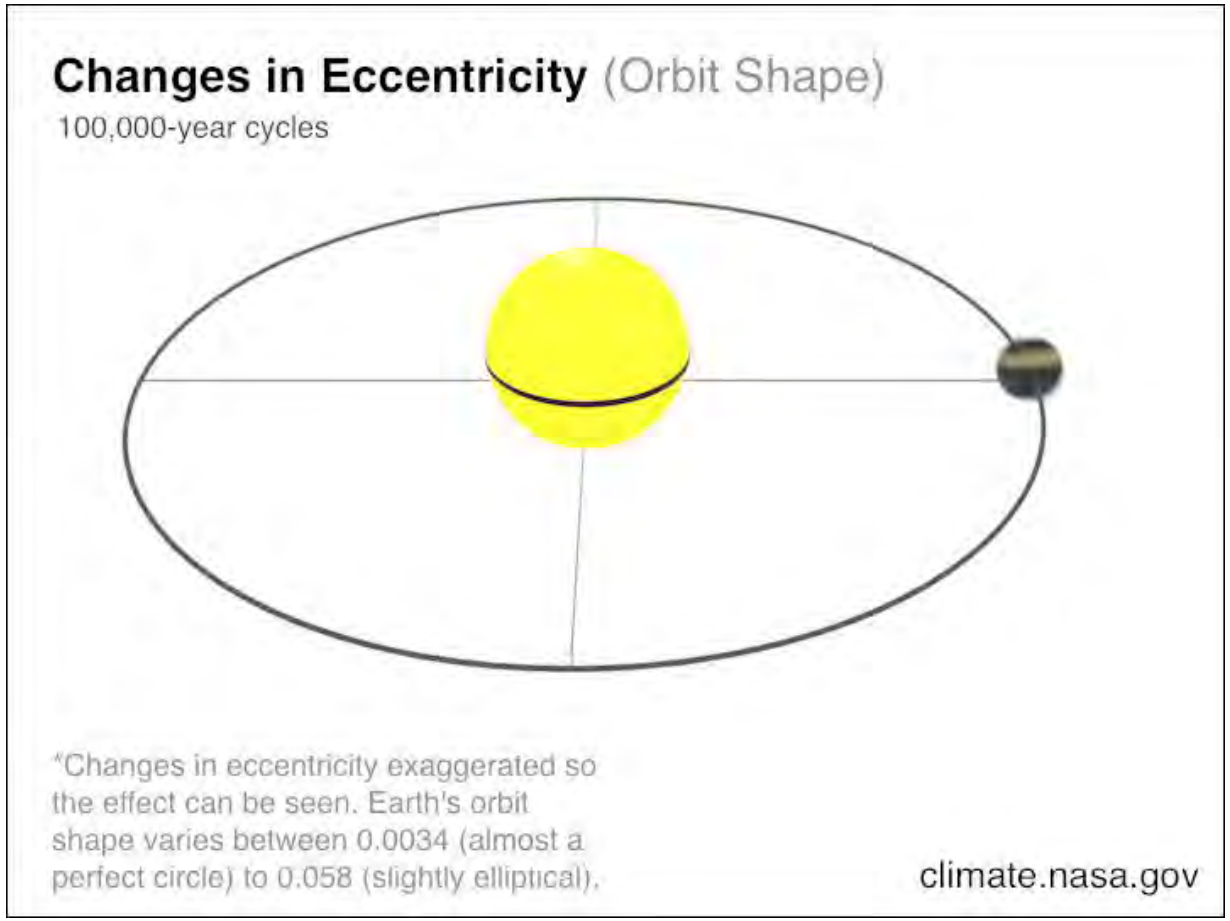
Continental Drift, Ocean Currents and Paleoclimatology

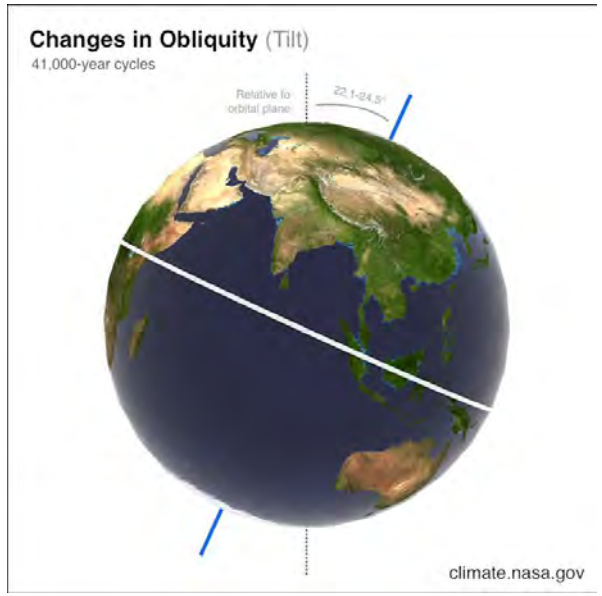
Around 85Ma, the Drake Passage opened up.
This allowed the development of the Antarctic Circumpolar Current (ACC)
The ACC isolated Antarctica from the warmer currents of the Southern Pacific, Atlantic and Indian Oceans.
Glaciers soon covered Antarctica, burying what had once been a temperate climate environment. There were global implications as well.



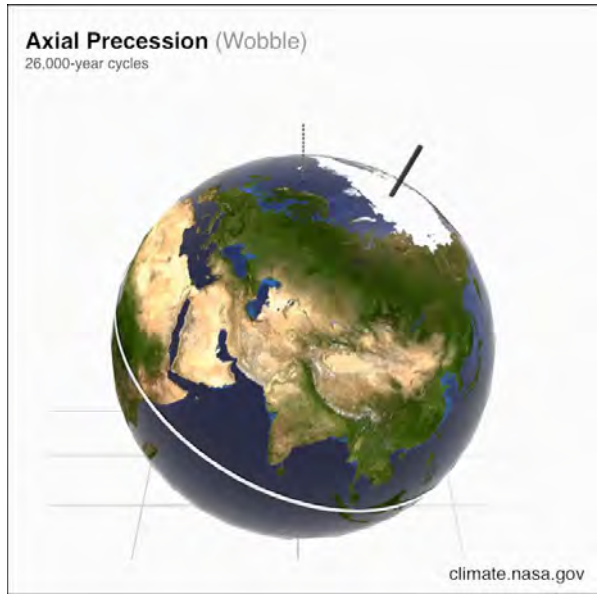
What might the future hold?

Milancović Cycles



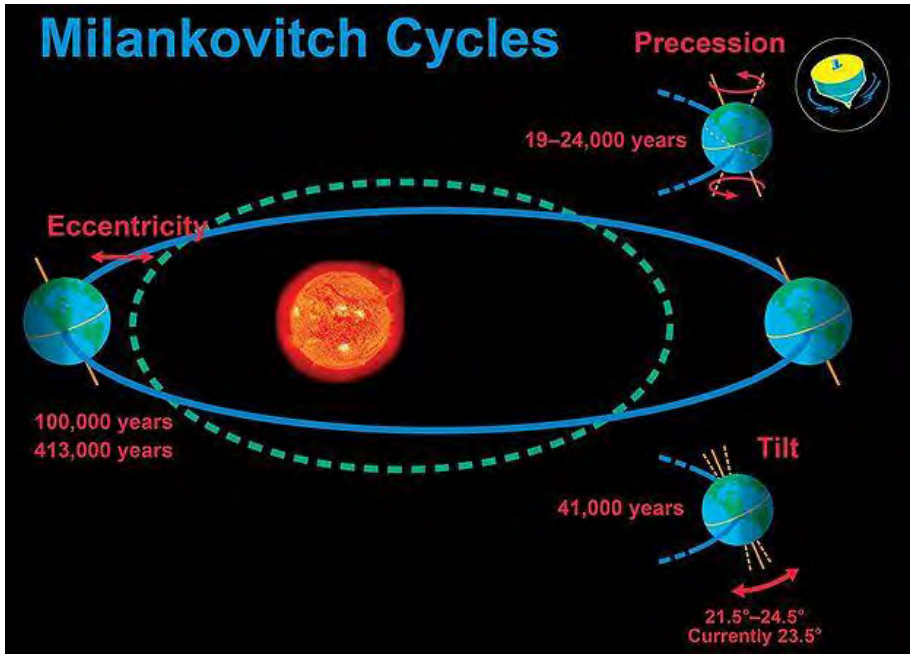


41,000 years



26,000 years

Milancović Cycles



Eccentricity (*ca* 100,000-year cycle) influences overall insolation. Determines how close the earth will be to the sun during the northern hemisphere winter.
Precession (26,000-year cycle) and ***Obliquity*** (41,000-year cycle) both influence the extremes of summer and winter in the northern and southern hemispheres.