Today

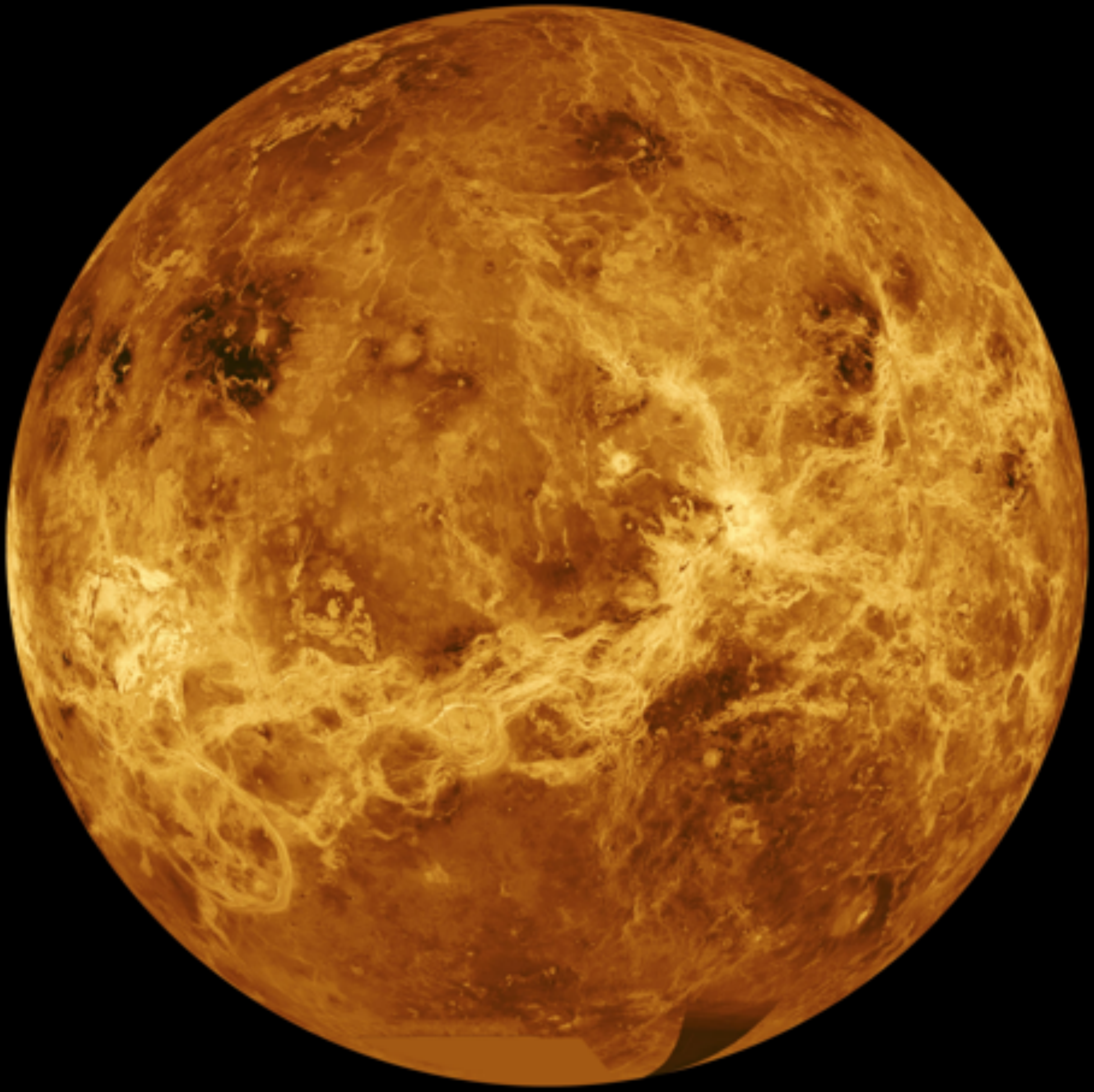
- Terrestrial Planet Geology - Earth
- Terrestrial Planet Atmospheres

Events

- Homework DUE next time

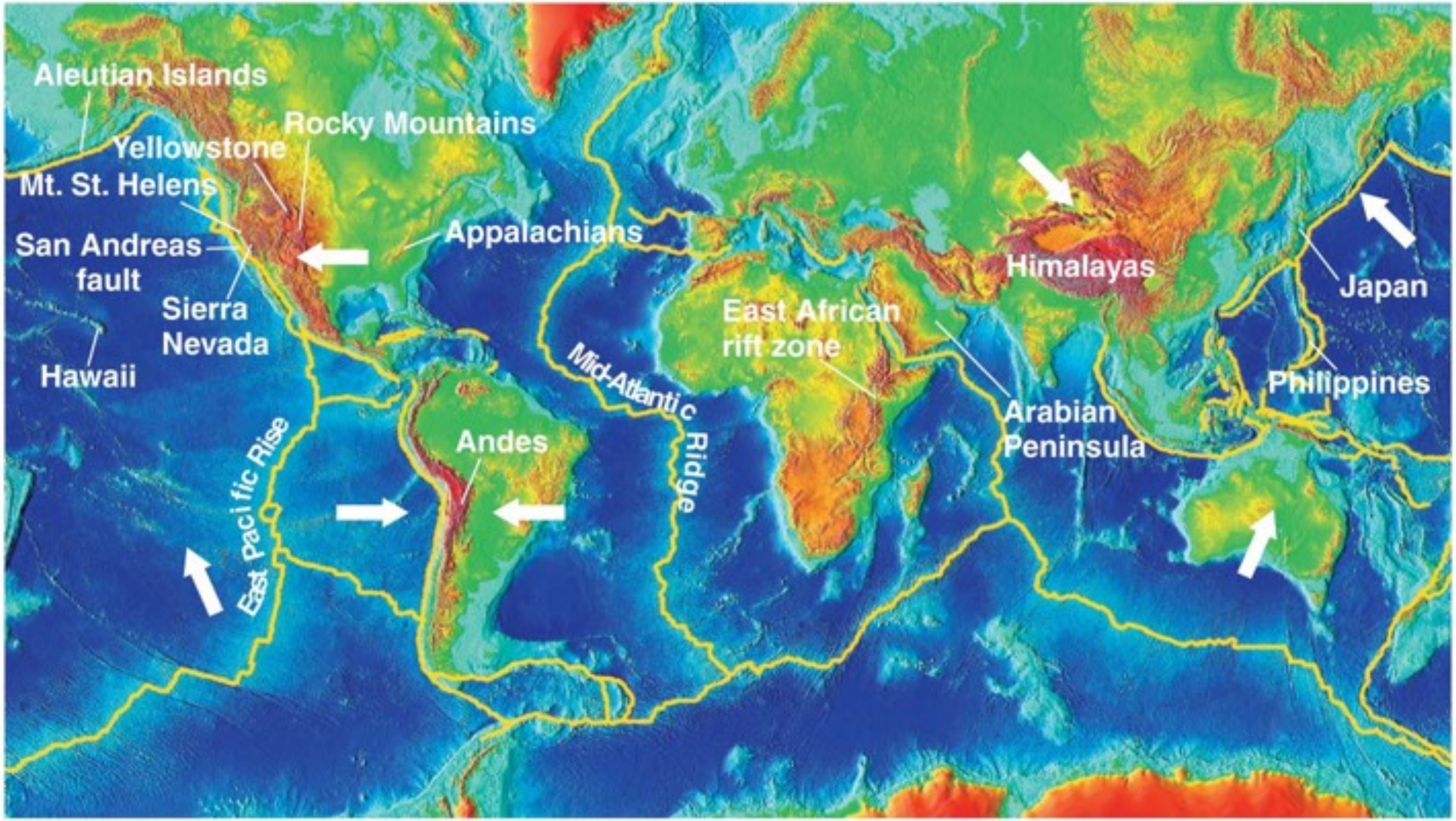
Venus

Surface mapped with radar
by Magellan orbtier



https://www.youtube.com/watch?v=Ub_bBs_oh_c

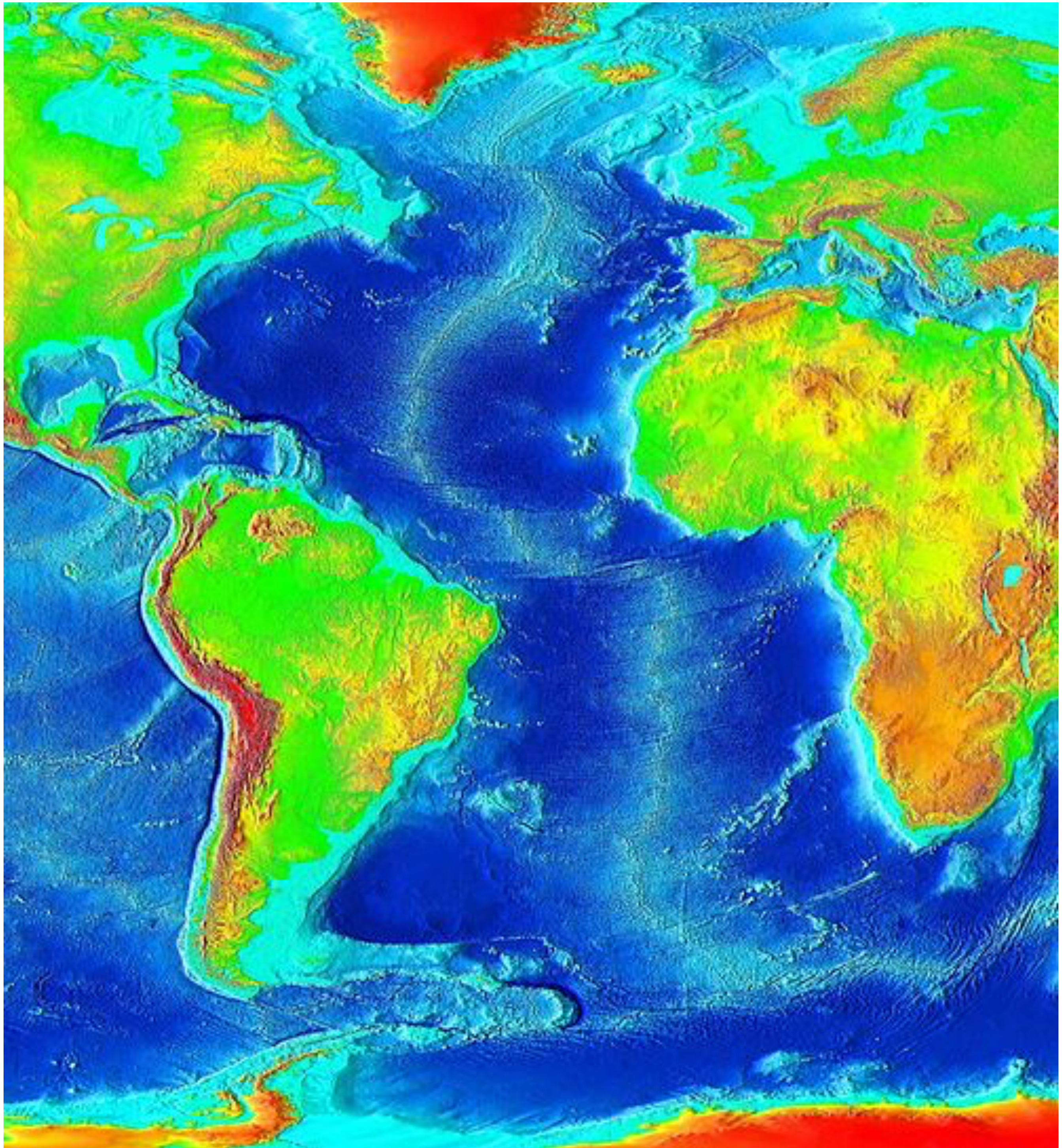
Continental Motion



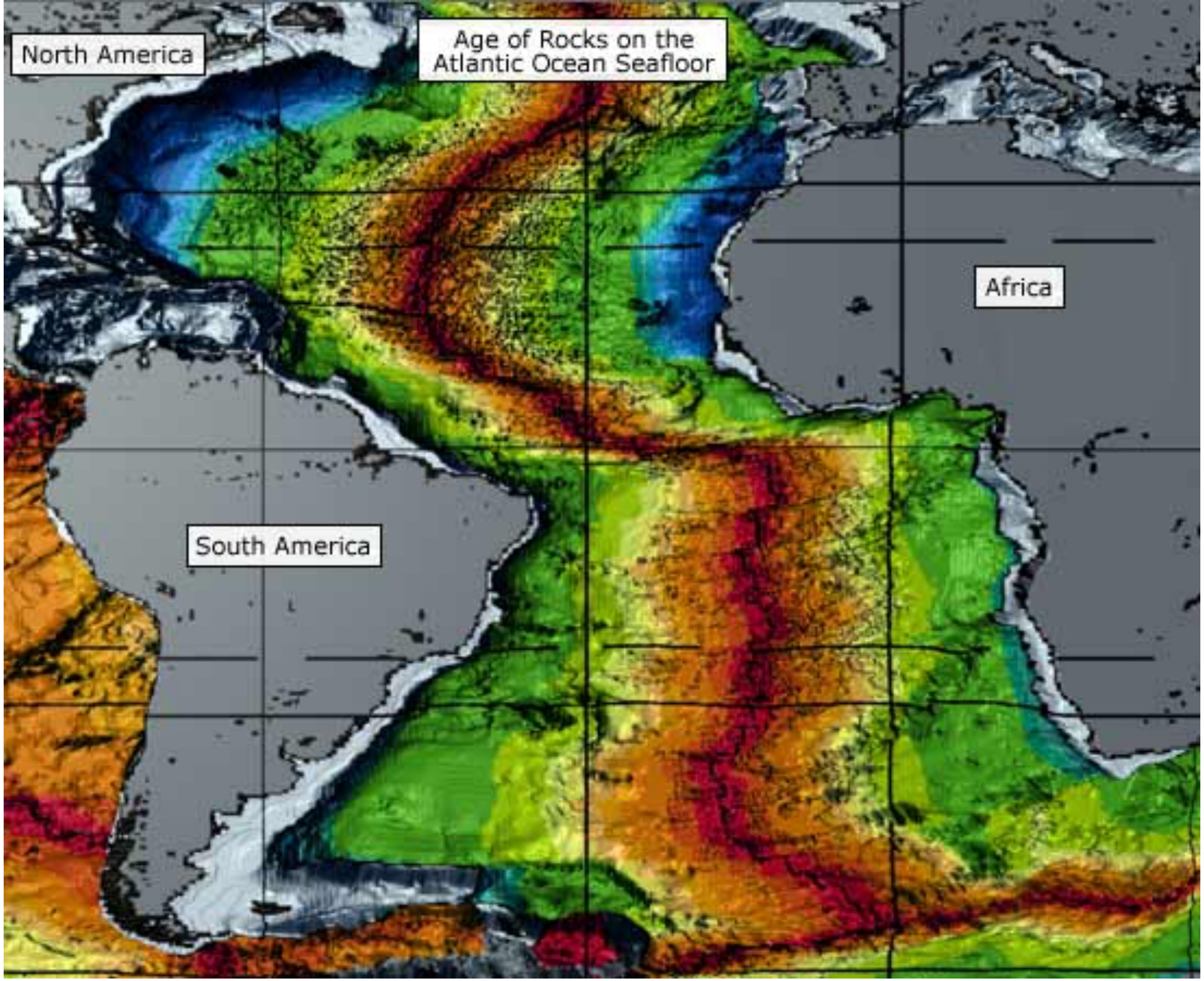
- Motion of the continents can be measured with GPS.

Continental Motion

- The idea of continental drift was inspired by the puzzle-like fit of the continents.
- Mantle material erupts where the seafloor spreads.

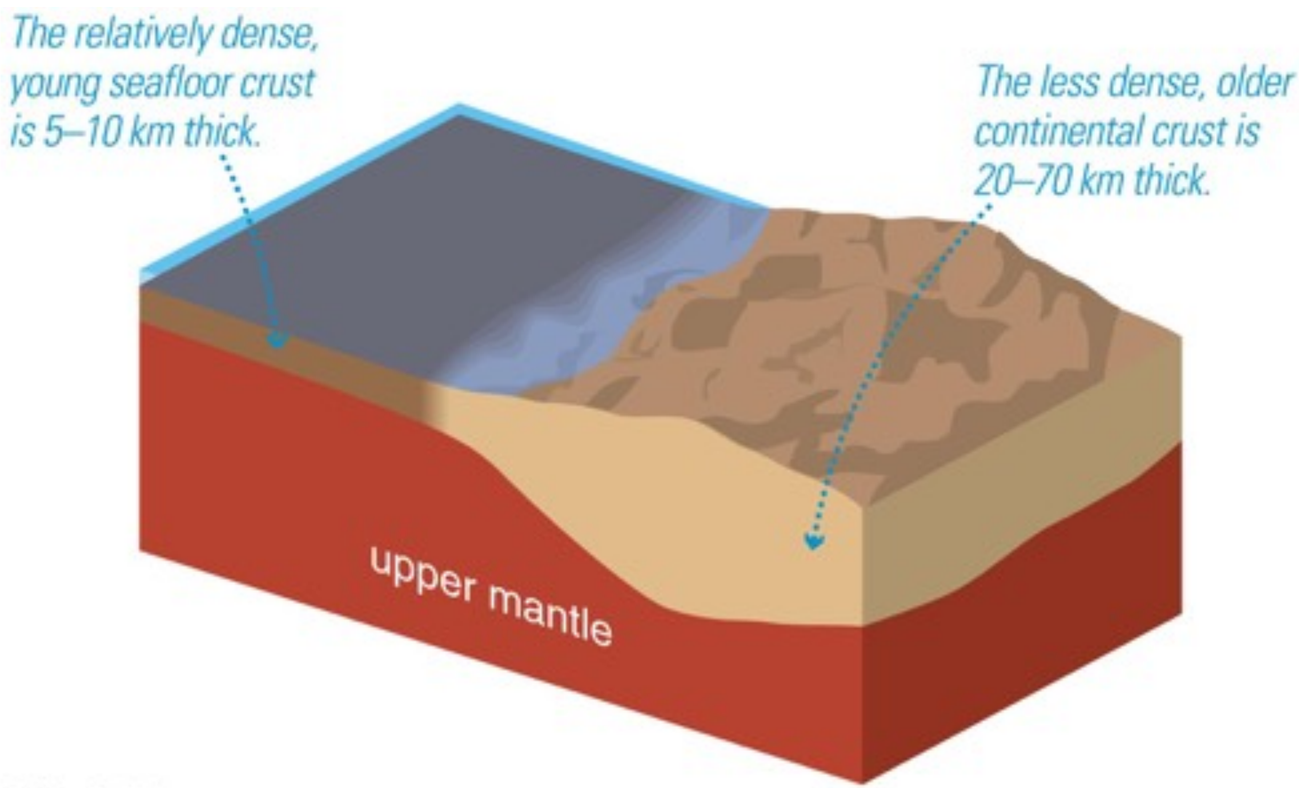


- Mid-Atlantic ridge
- Chain of mountains from whence seafloor spreads
- Age gradient in rocks with the youngest rocks at the center of spreading



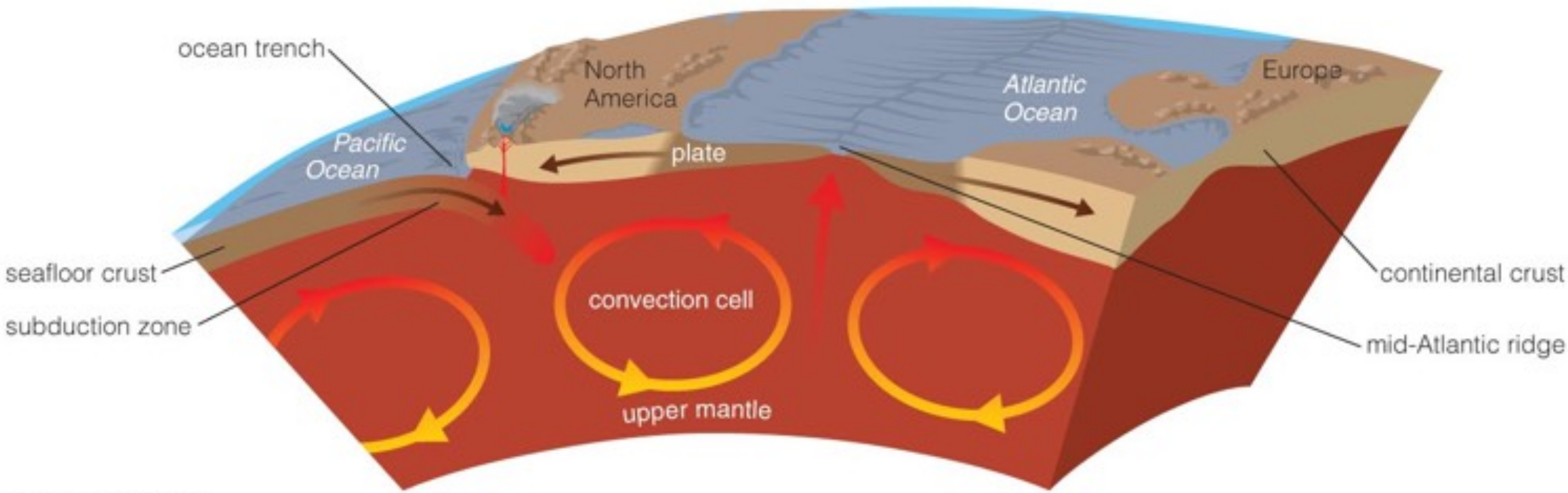
Younger rocks colored red

Seafloor Crust



- Thin seafloor crust differs from thick continental crust.
- Dating of the seafloor shows that it is usually quite young.

Seafloor Recycling



- Seafloor is recycled through a process known as subduction.

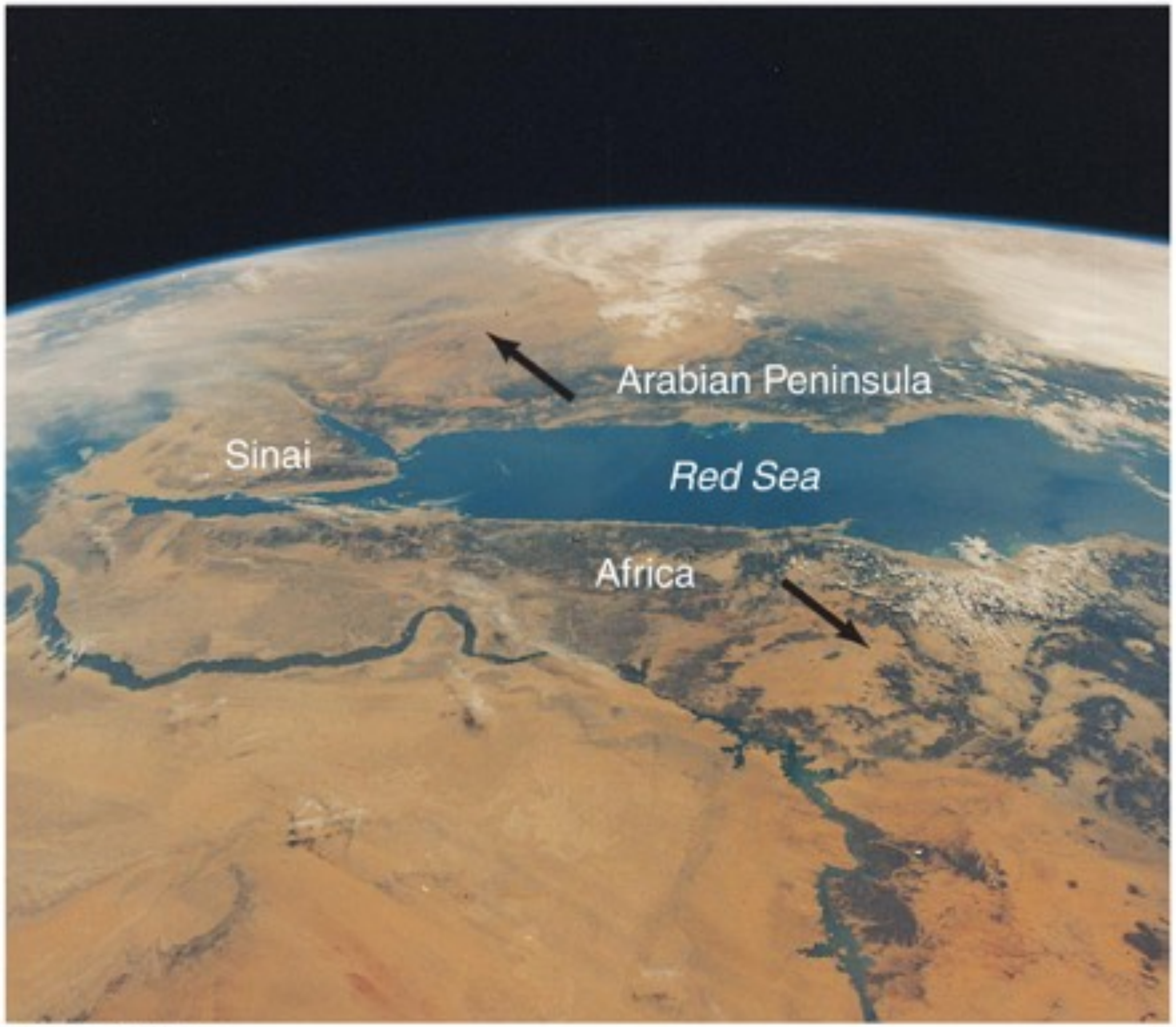
Surface Features

- Major geological features of North America record the history of plate tectonics.

Surface Features

- The Himalayas formed from a collision between plates.

Surface Features



- The Red Sea is formed where plates are pulling apart.

Rifts, Faults, Earthquakes

- The San Andreas fault in California is a plate boundary.
- Motion of plates can cause earthquakes.

Ring of Fire

- Boundaries of plates traced by Earthquakes and Volcanos

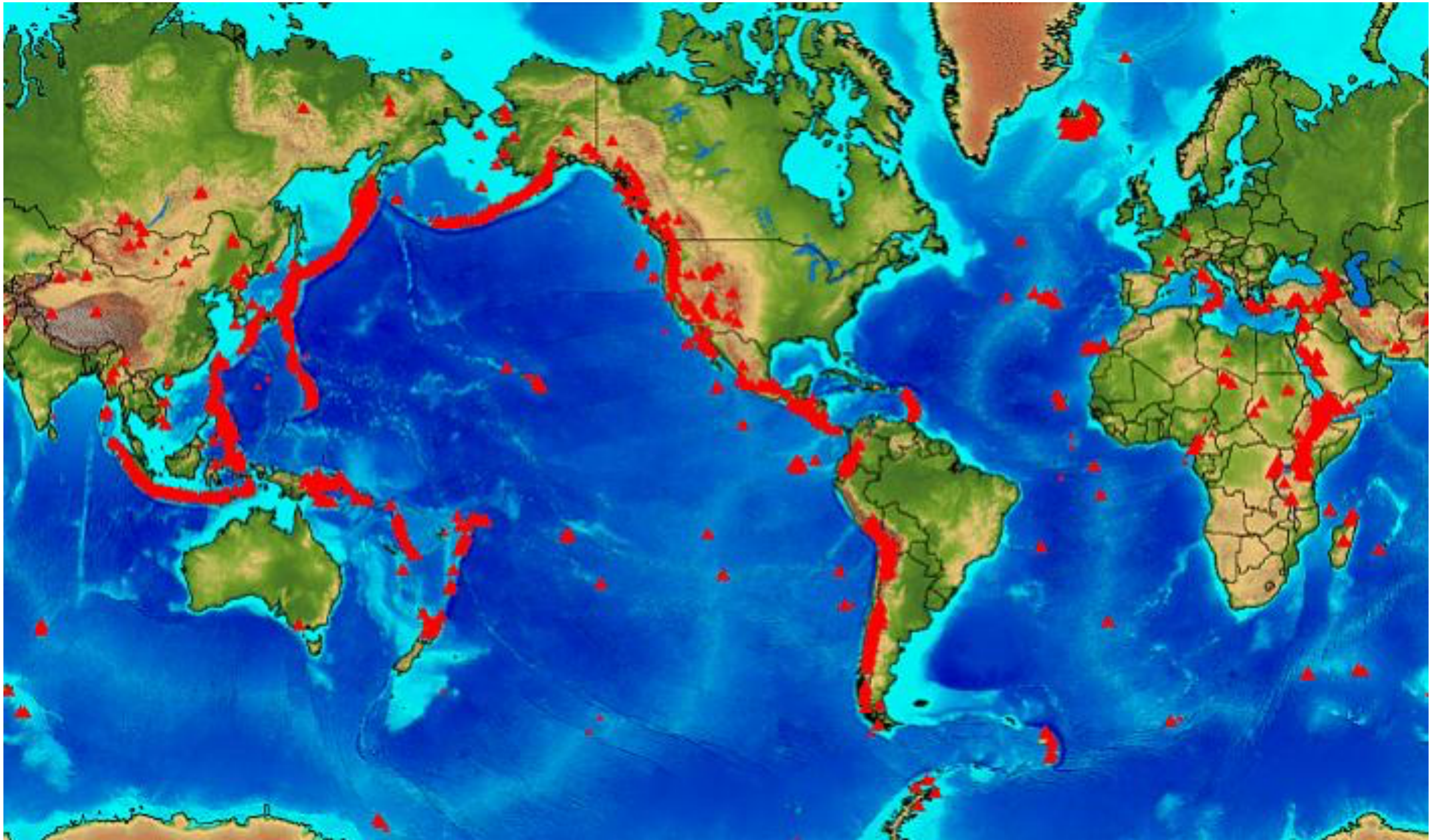
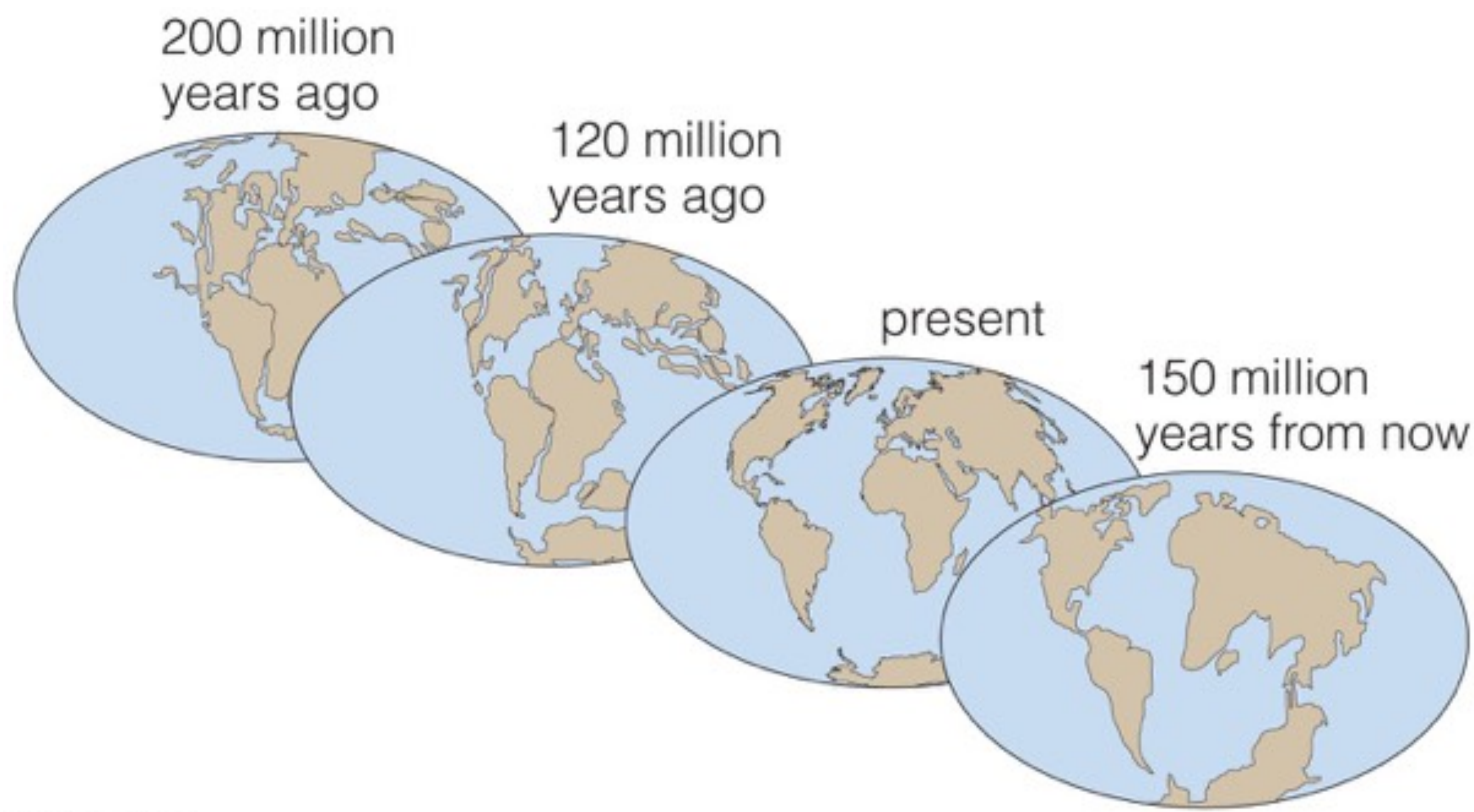


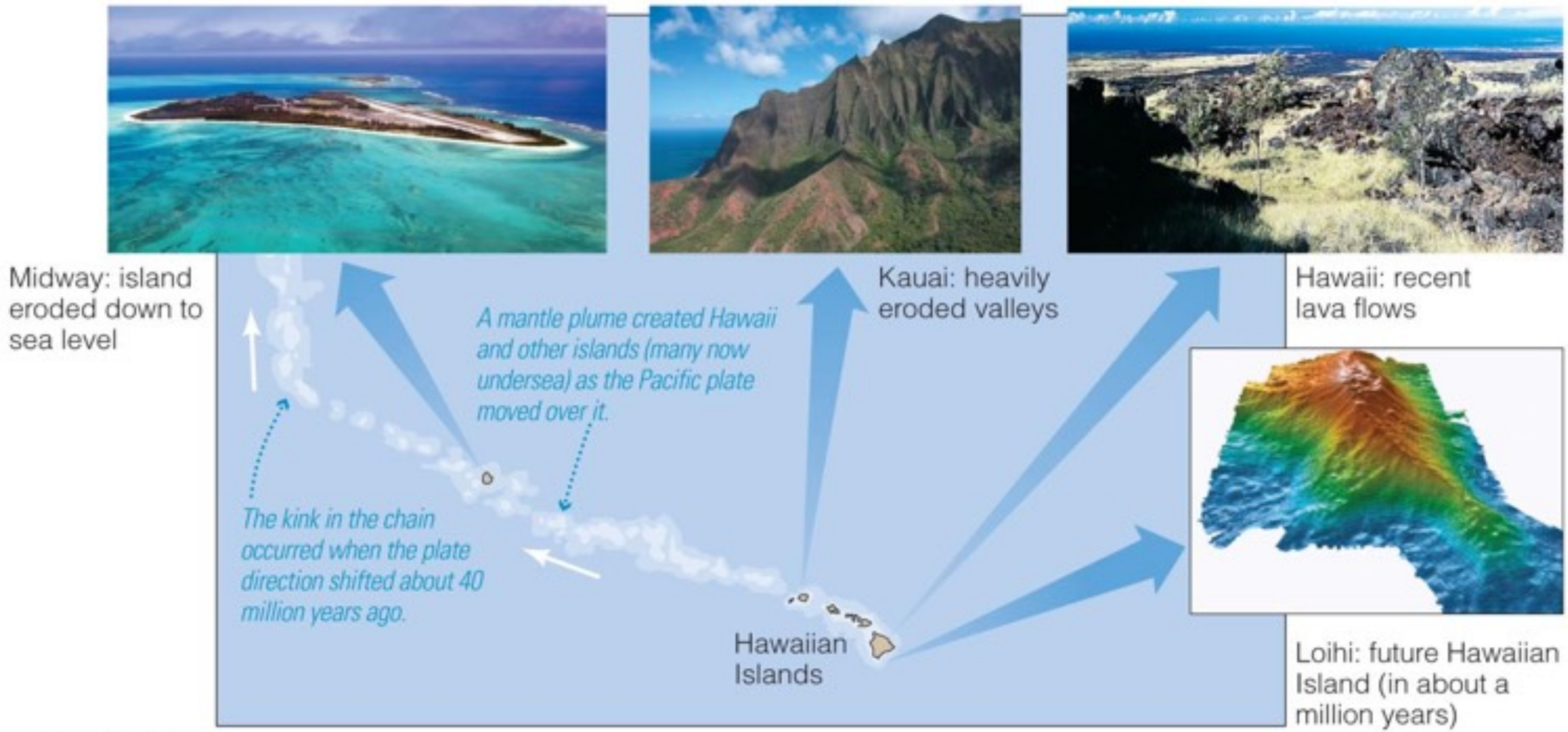
Plate Motions

- Measurements of plate motions tell us past and future layout of the continents.



https://www.youtube.com/watch?v=cQVoSyVu9rk

Hot Spots



- The Hawaiian islands have formed where a plate is moving over a volcanic hot spot.

Hot Spots

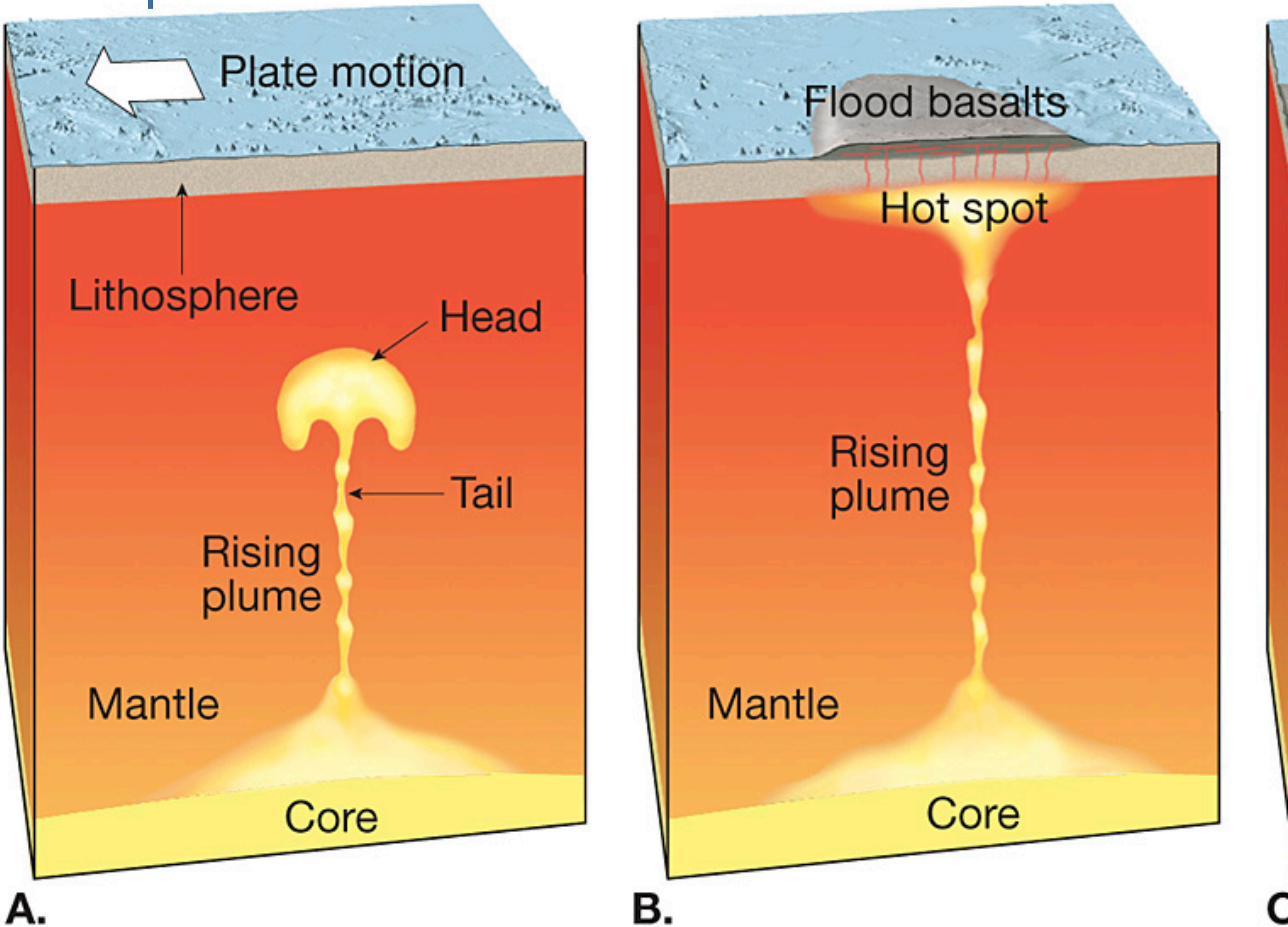
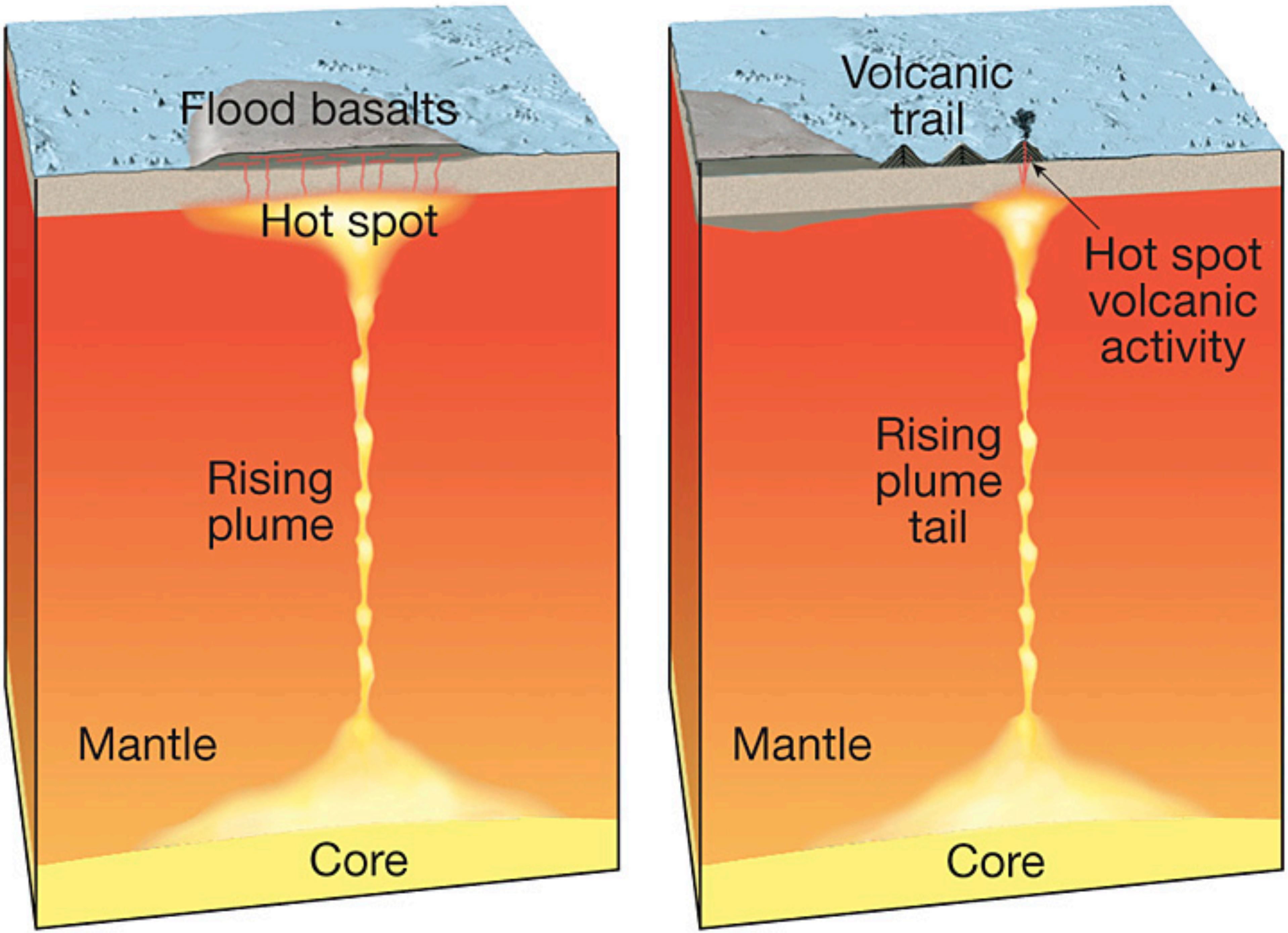


Plate motion
Lithosphere
Head
Tail
Rising plume
Mantle
Core
A.
Flood basalts
Hot spot
Rising plume
Mantle
Core
B.

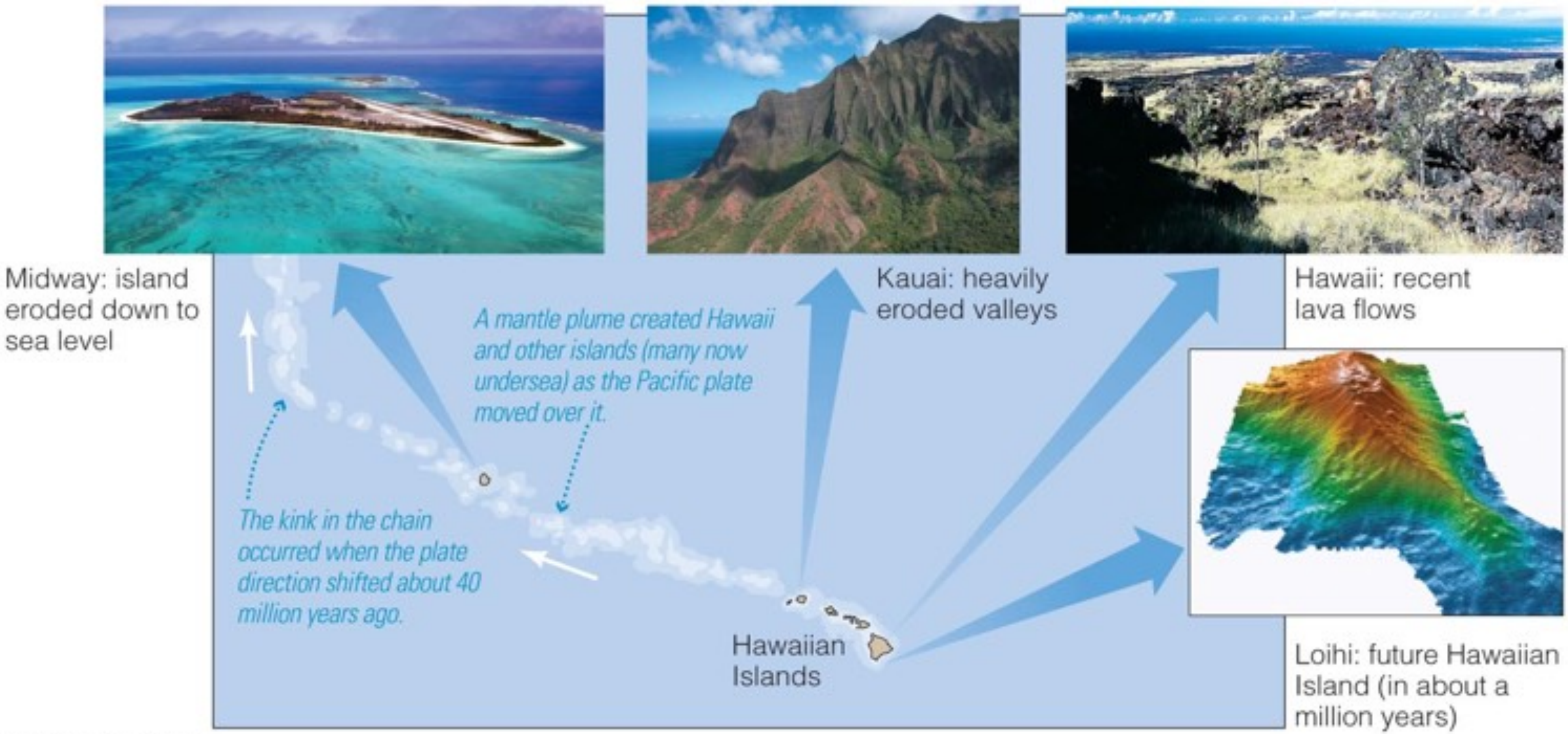
Hot Spots



Flood basalts
Hot spot
Rising plume
Mantle
Core
Volcanic trail
Hot spot volcanic activity
Rising plume tail
Mantle
Core

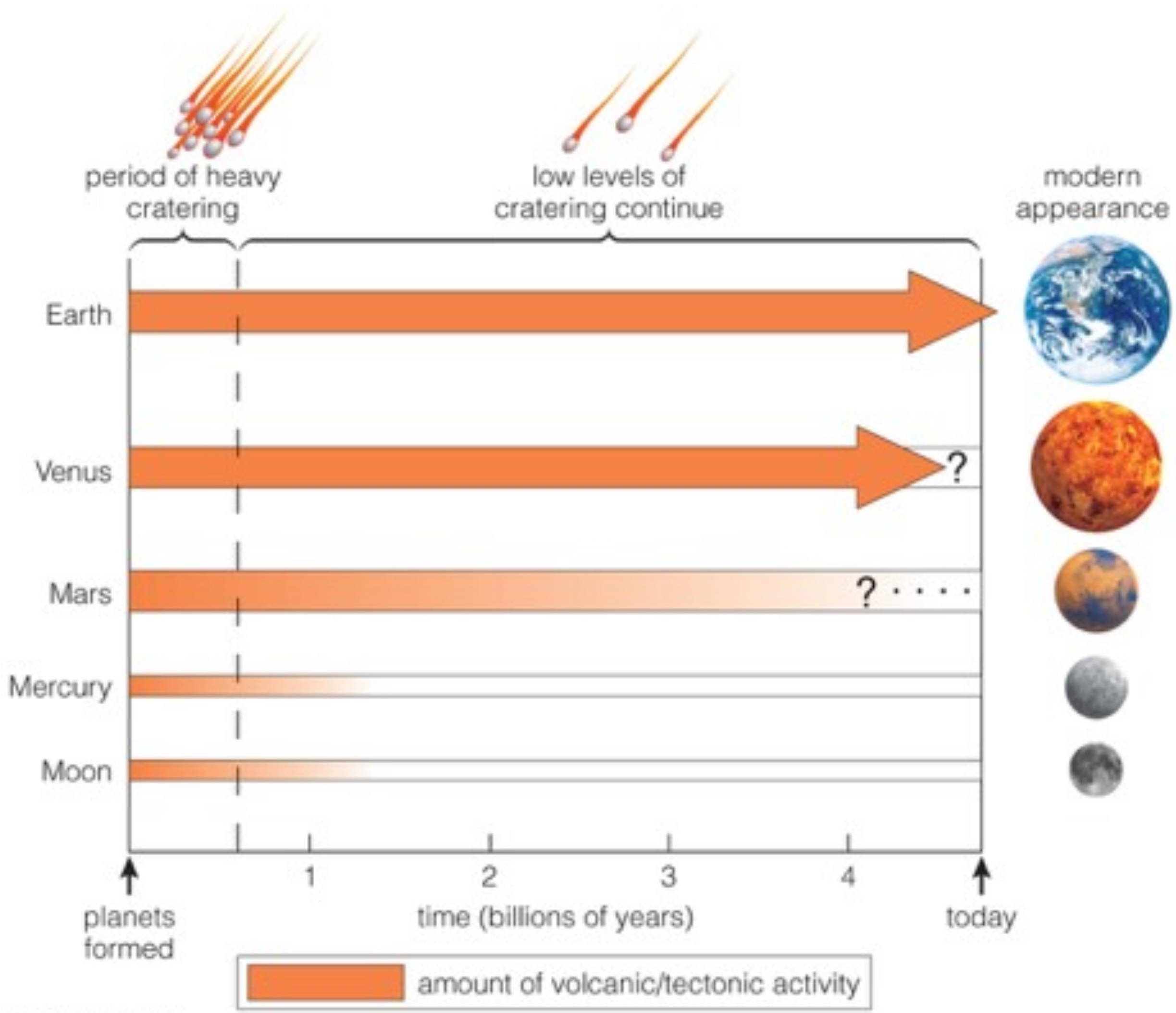
Hot Spots

Each Hawaiian Island starts as a growing volcano, goes extinct as the plate slides across the hot spot, then erodes back into the sea.



- The Hawaiian islands have formed where a plate is moving over a volcanic hot spot.

Was Earth's geology destined from birth?



- Many of Earth's features are determined by its size, rotation, and distance from Sun.
- The reason for plate tectonics is not yet clear.

What have we learned?

- How is Earth's surface shaped by plate tectonics?
  - Measurements of plate motions confirm the idea of continental drift.
  - Plate tectonics is responsible for subduction, seafloor spreading, mountains, rifts, and earthquakes.

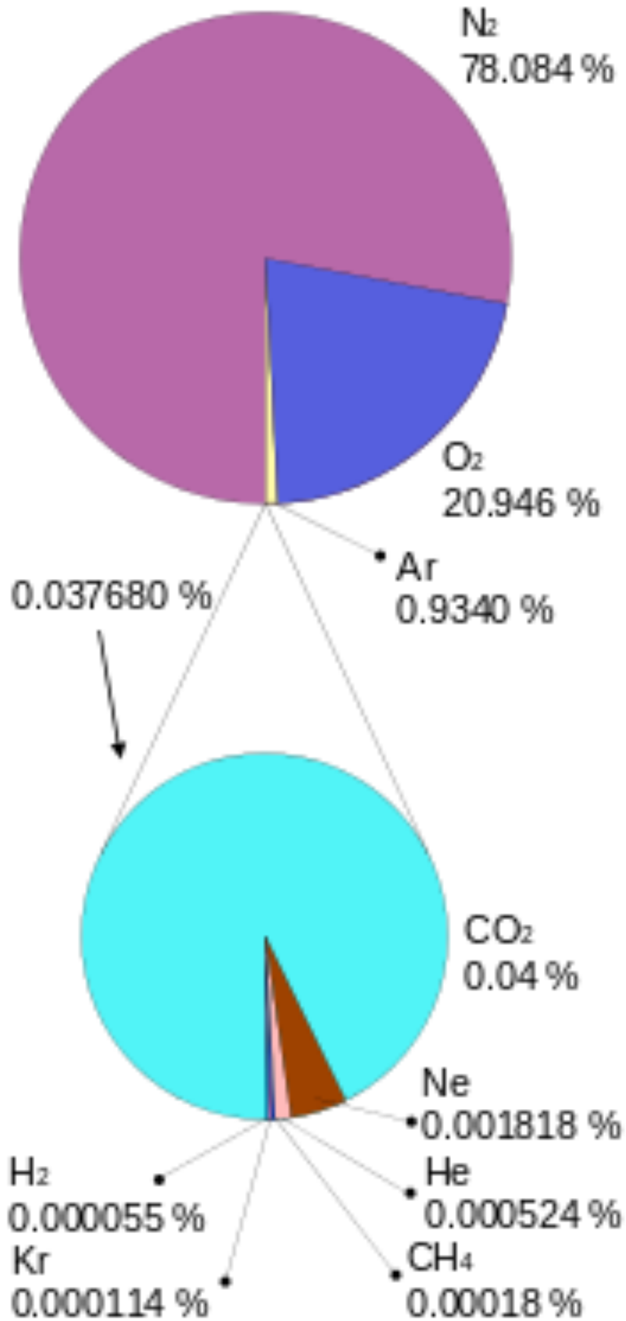
What is an atmosphere?

- An atmosphere is a layer of gas that surrounds a planet.
  - Terrestrial planet atmospheres are a very thin veil of gas between the solid surface and the vacuum of space

	Composition	Pressure	Temperature
Mercury	N/A	0	797 (day) -283 (night)
Venus	96% CO_2 3.5% N_2	90	878
Earth	78% N_2 21% O_2 <1% H_2O, CO_2	1	59 (global ave)
Moon	N/A	0	257 -283
Mars	95% CO_2 2.7% N_2	0.007	-58
		Earth Atm	Farenheit

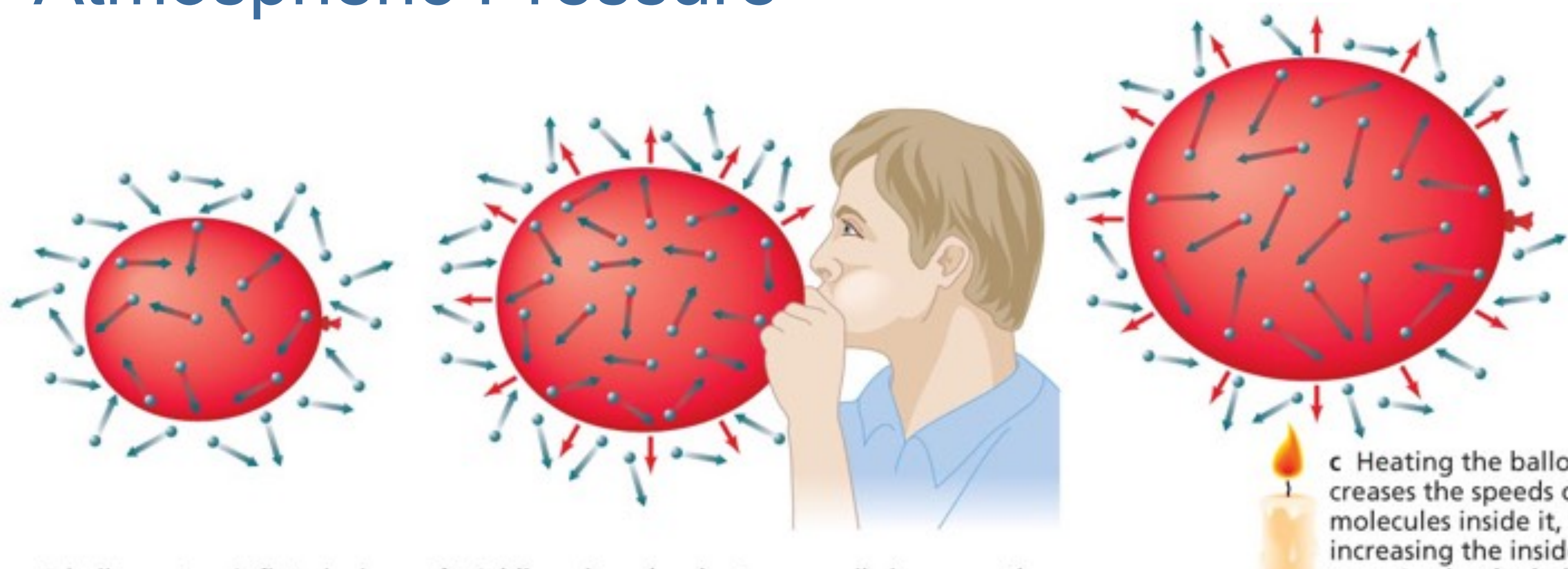
	Composition	Breathing?	Result
Mercury	N/A	nothing to breathe	death
Venus	96% CO_2 3.5% N_2	poisonous	death
Earth	78% N_2 21% O_2 <1% H_2O, CO_2	oxygen	life
Moon	N/A	nothing to breathe	death
Mars	95% CO_2 2.7% N_2	very little to breathe	death

Earth's Atmosphere



- About 10 kilometers thick, crudely speaking
- 78% N_2
- 21% O_2
- 1% Argon
- 0.4% H_2O (variable)
  – "humidity"
- 0.04% CO_2
- 0.00018% CH_4

Atmospheric Pressure



a A balloon stays inflated when the inside and outside pressures are balanced.

b Adding air molecules temporarily increases the pressure inside the balloon, so the balloon expands until the pressure balance is restored.

c Heating the balloon increases the speeds of air molecules inside it, thereby increasing the inside pressure. Again, the balloon expands until the pressure balance is restored.

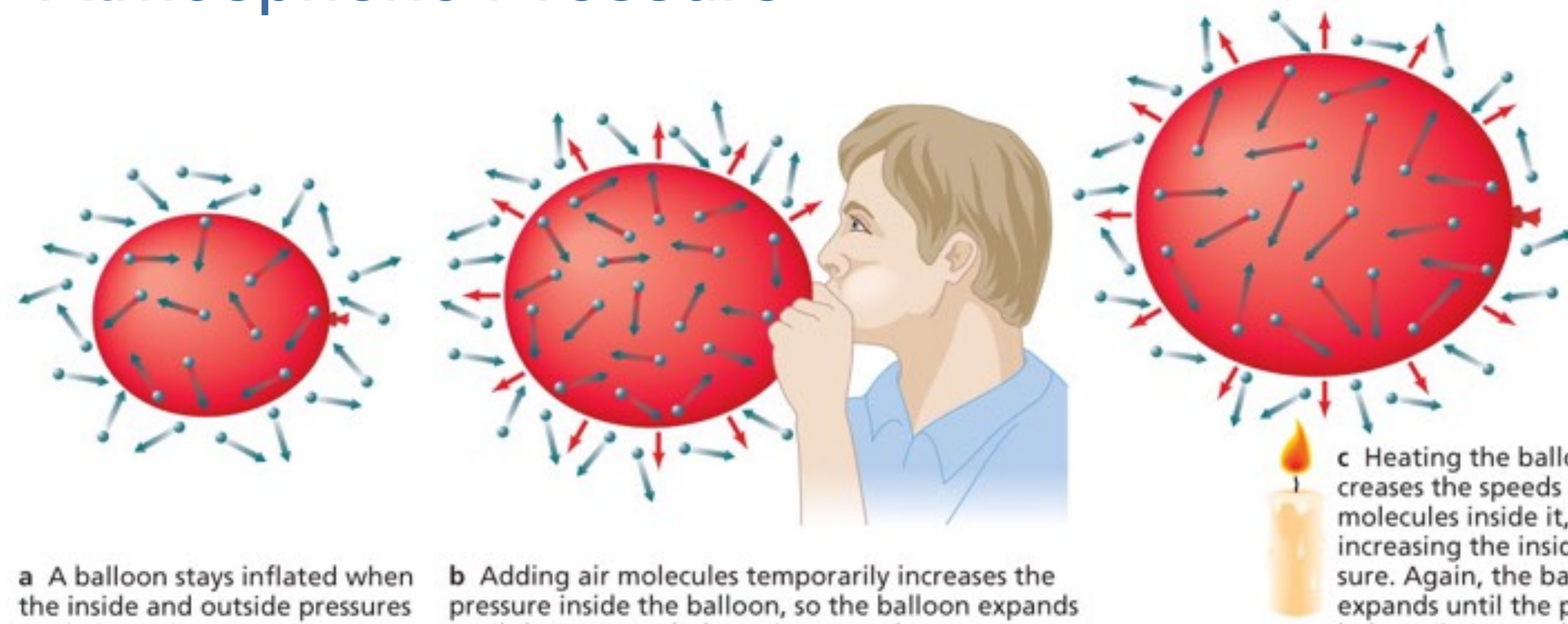
$$P = NkT$$

- P → Pressure
- N → Number density (# molecules per cubic centimeter)
- T → Temperature

More stuff → higher pressure

Higher temperature → higher pressure

Atmospheric Pressure



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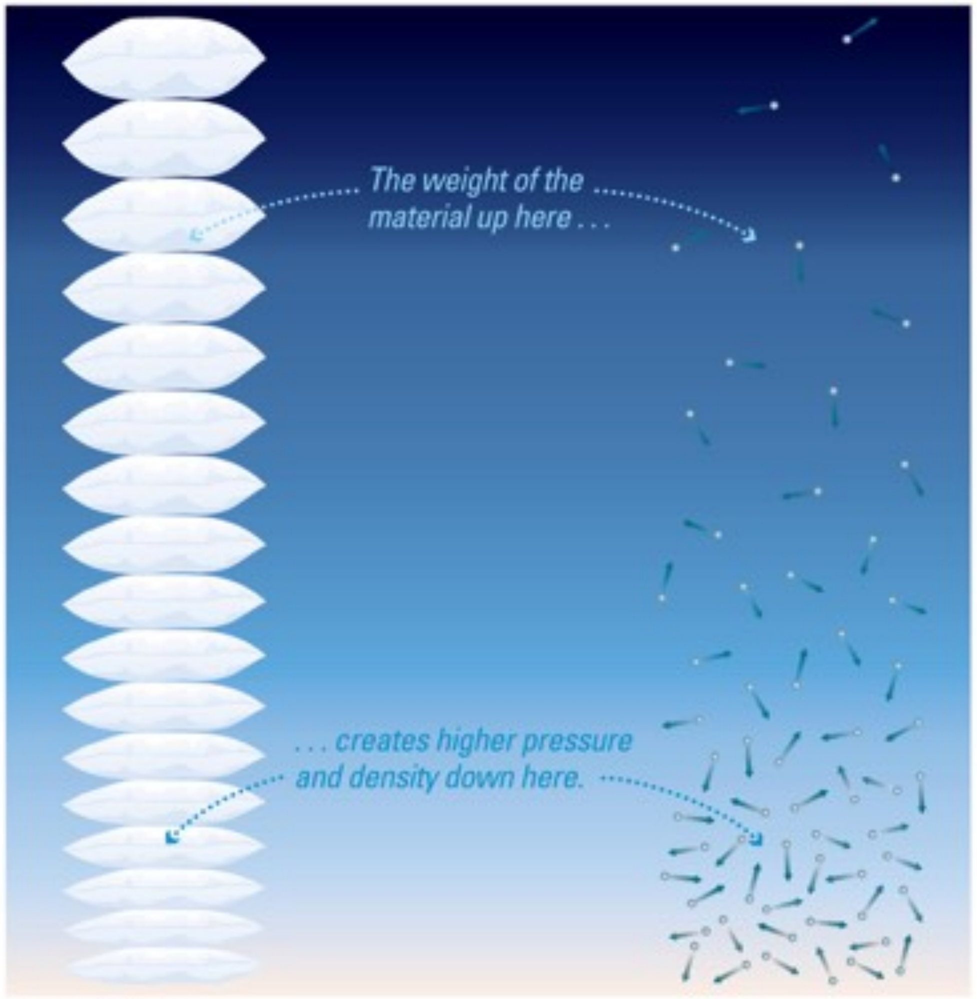
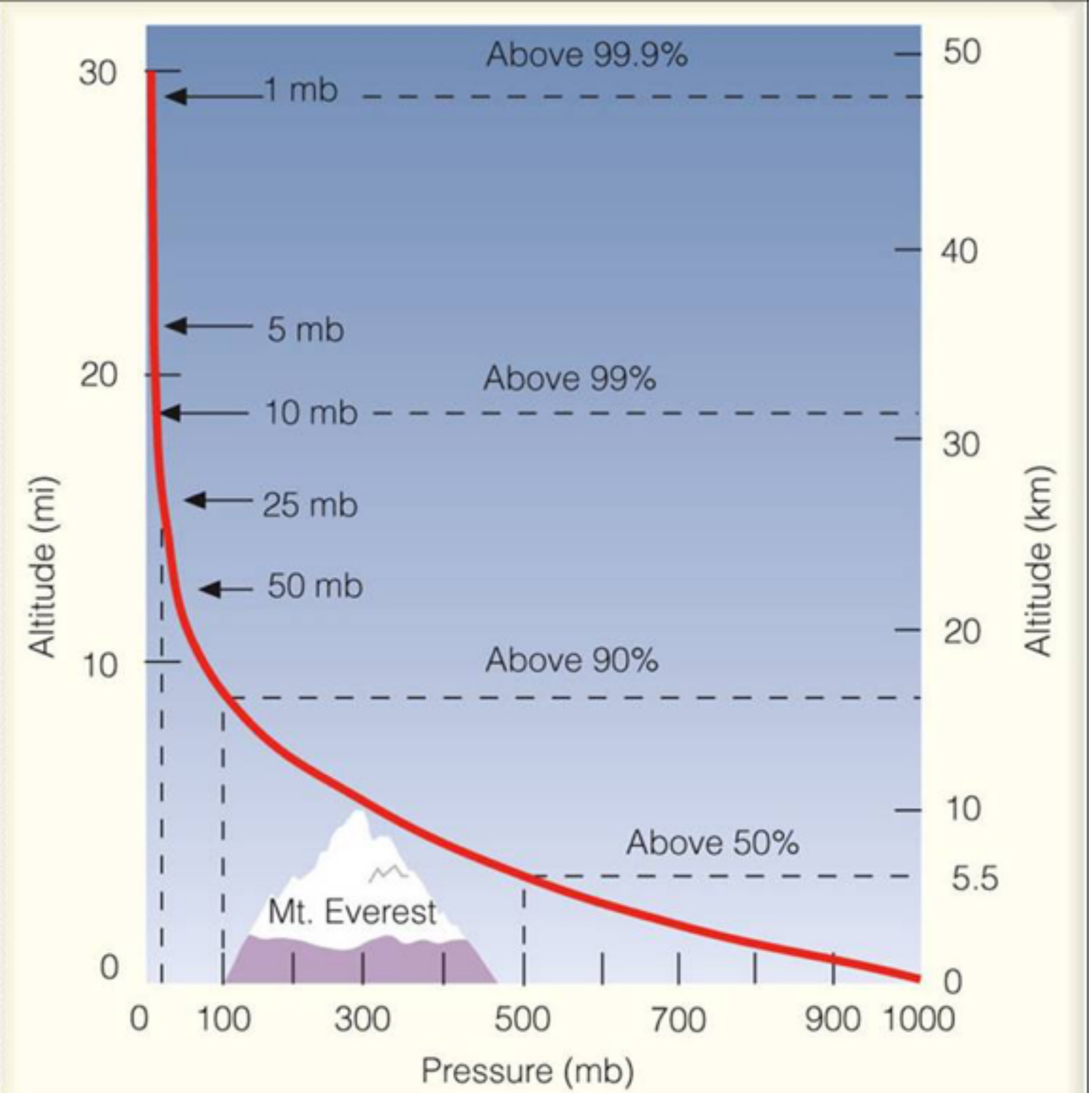
Things exist in pressure equilibrium with their surroundings:

- balloons
- sea level
- people (that’s why your ears pop at high altitude, or you get the bends if you come up too fast from a deep dive)

Atmospheric Pressure



- Pressure and density decrease with altitude because the weight of overlying layers is less.
- Earth's pressure at sea level is:
  - 1.03 kg per sq. meter
  - 14.7 lb per sq. inch
  - 1 bar / 1 Atmosphere



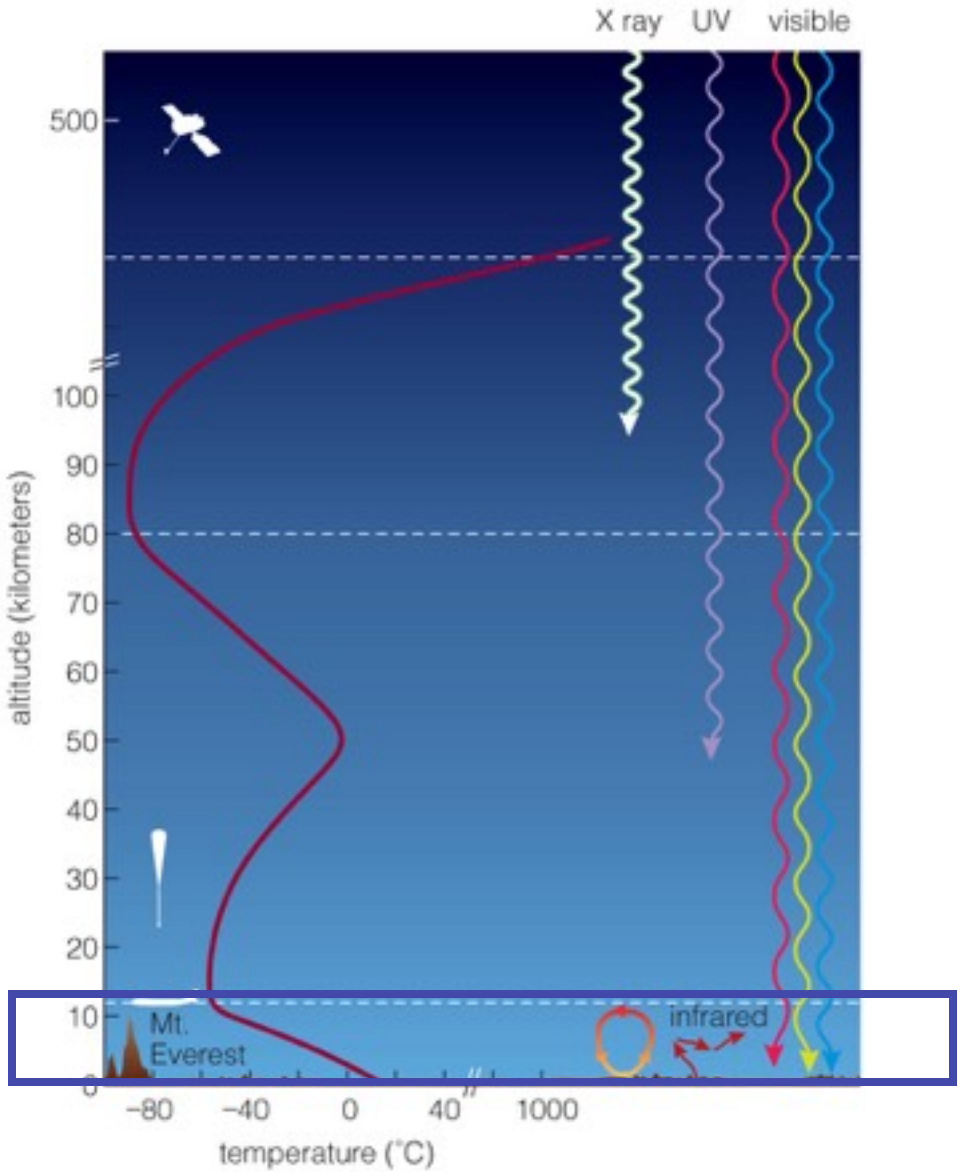
Atmospheric density and pressure decline with increasing altitude.

There is no clear "edge" to the atmosphere - just an exponential attenuation.

Jet cruising altitude ~ 10 km

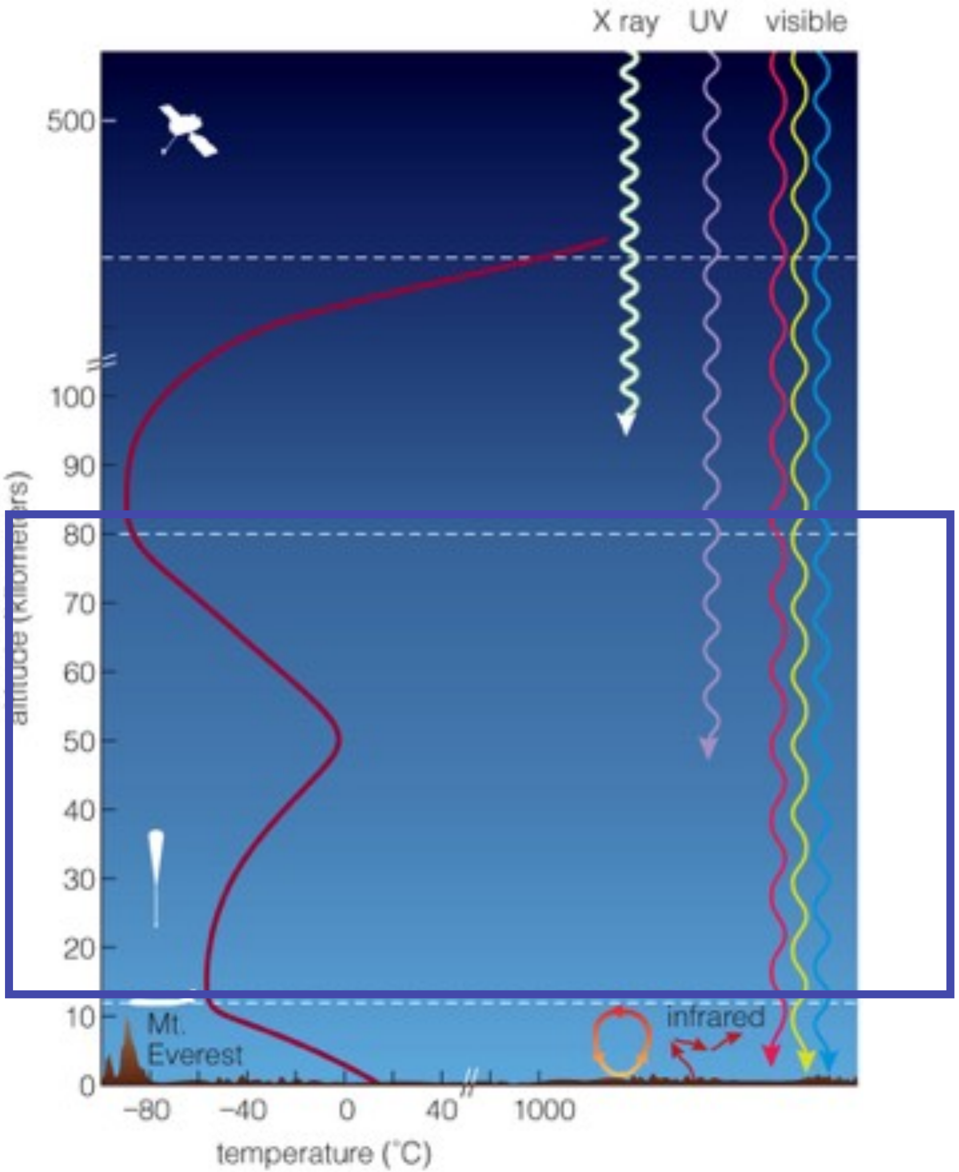
Death zone: > 8 km

Earth's Atmospheric Structure



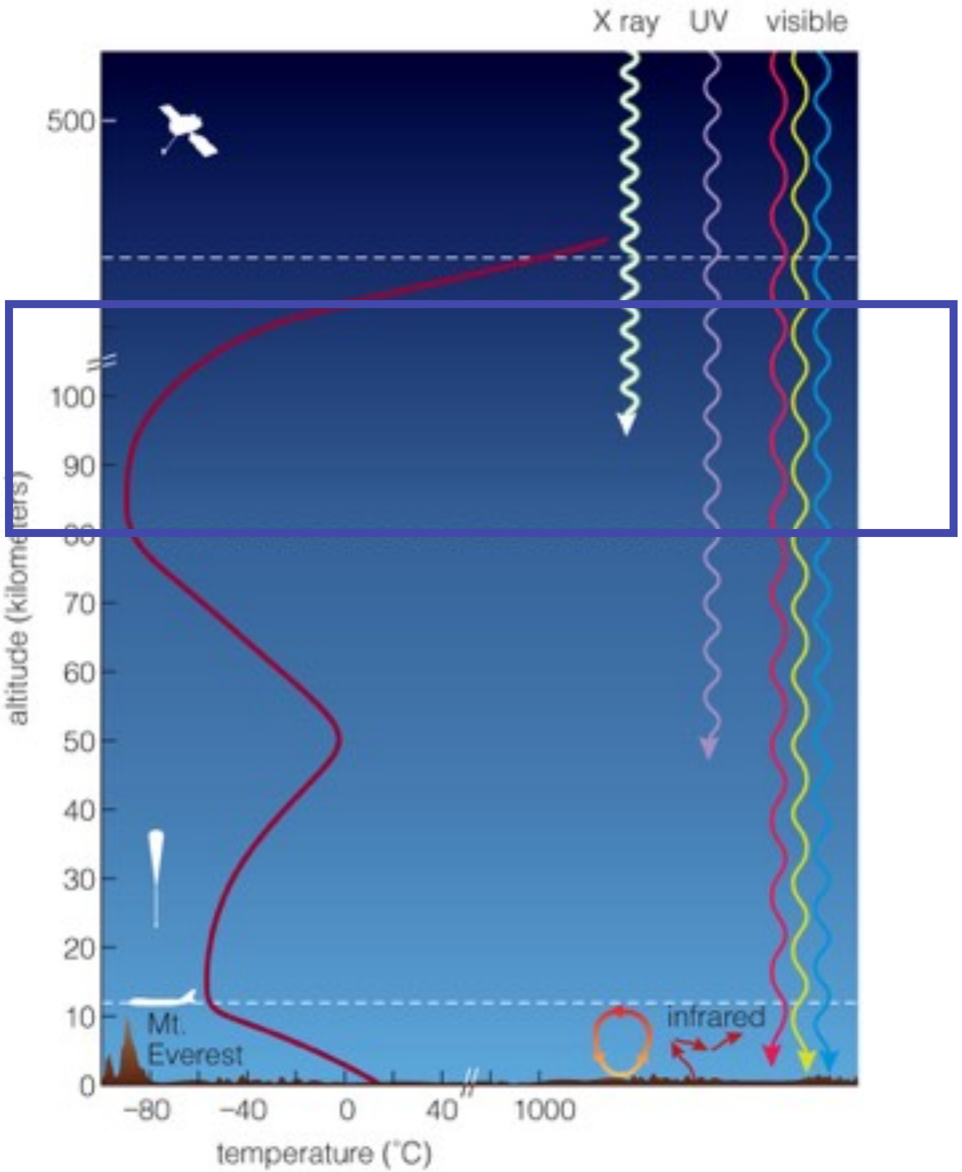
- Troposphere: lowest layer of Earth's atmosphere
- Temperature drops with altitude.
- Warmed by infrared light from surface and convection

Earth's Atmospheric Structure



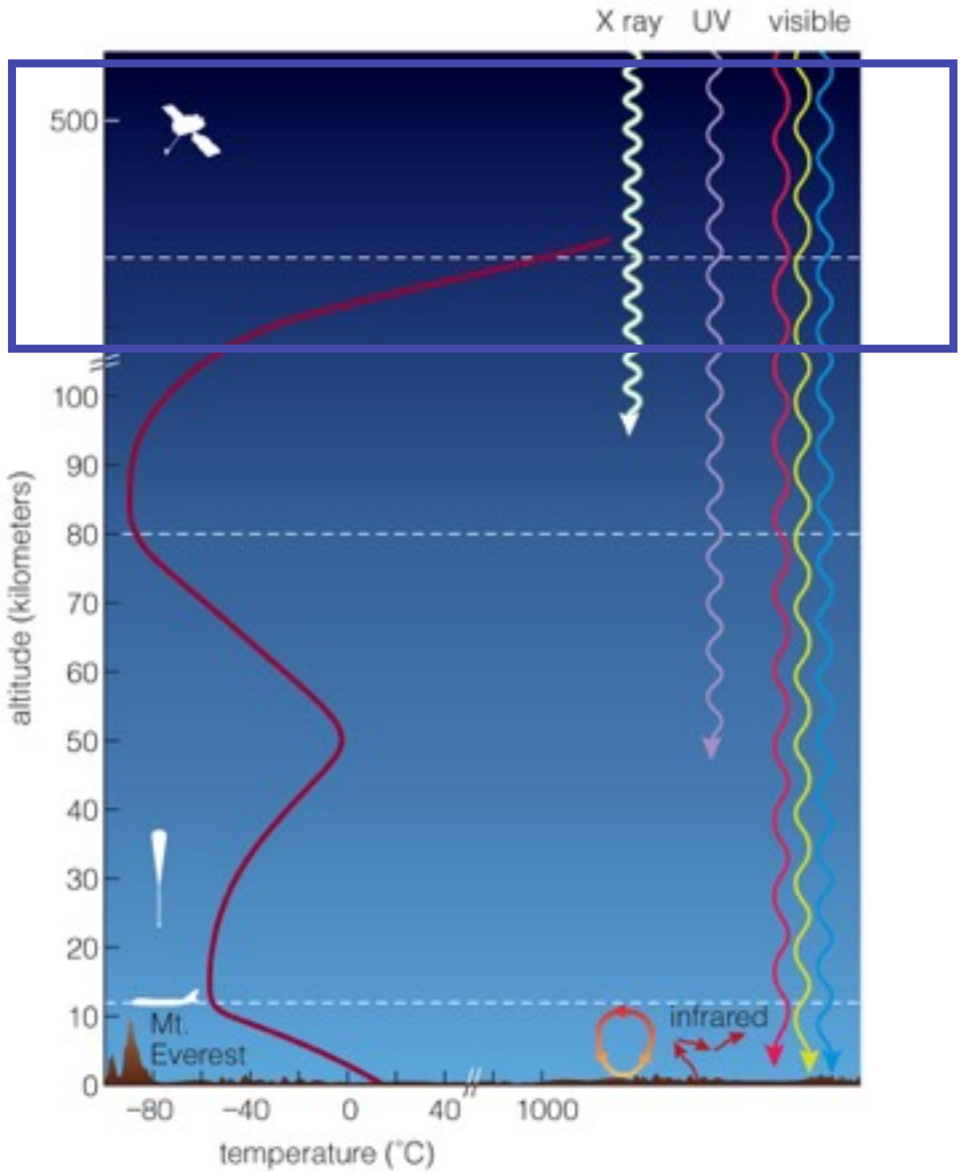
- Stratosphere: layer above the troposphere
- Temperature rises with altitude in lower part, drops with altitude in upper part.
- Warmed by absorption of ultraviolet sunlight

Earth's Atmospheric Structure



- Thermosphere: layer at about 100 kilometers altitude
- Temperature rises with altitude.
- X rays and ultraviolet light from the Sun heat and ionize gases.

Earth's Atmospheric Structure

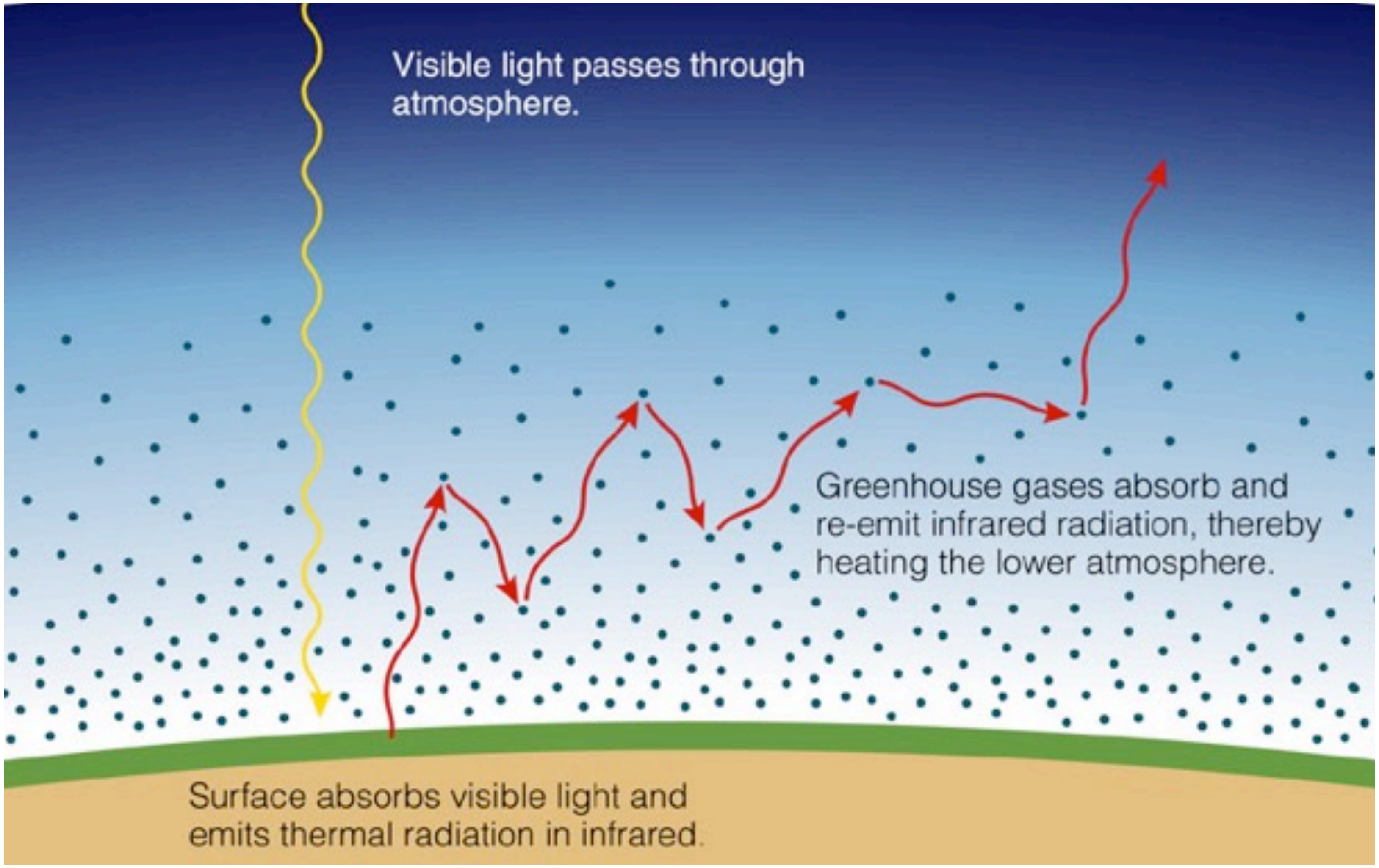


- Exosphere: highest layer in which atmosphere gradually fades into space
- Temperature rises with altitude; atoms can escape into space.
- Warmed by X rays and UV light

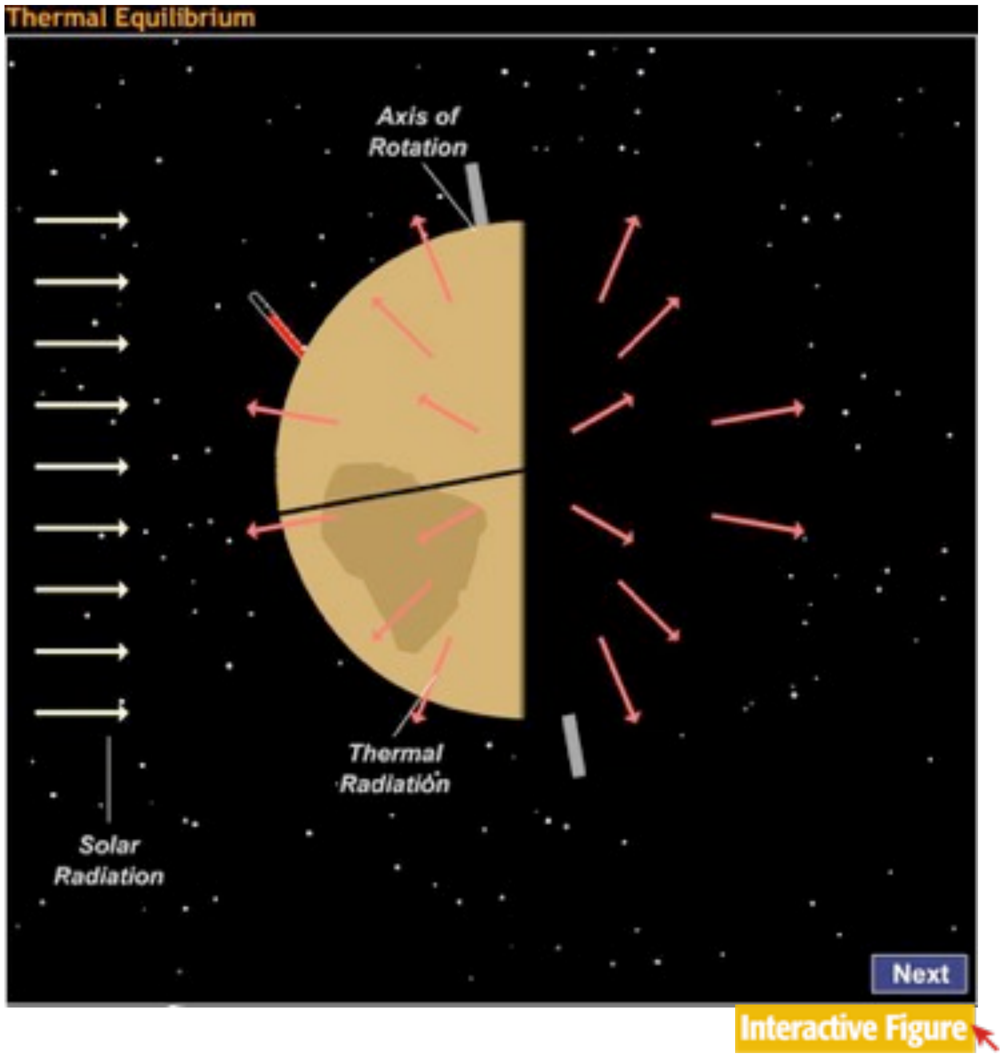
Planetary climates

- Temperature depends on balance between
- Heat input from sun
  - distance dependent
  - albedo dependent (reflection vs. absorption)
- Heat loss to space
  - atmosphere dependent (natural greenhouse effect)
  - heat trapping “greenhouse” gases (e.g., H_2O, CO_2) important even if only present in trace quantities
    - they are the IR-opaque shade to the transparent glass of the primary atmospheric gases

The Greenhouse Effect

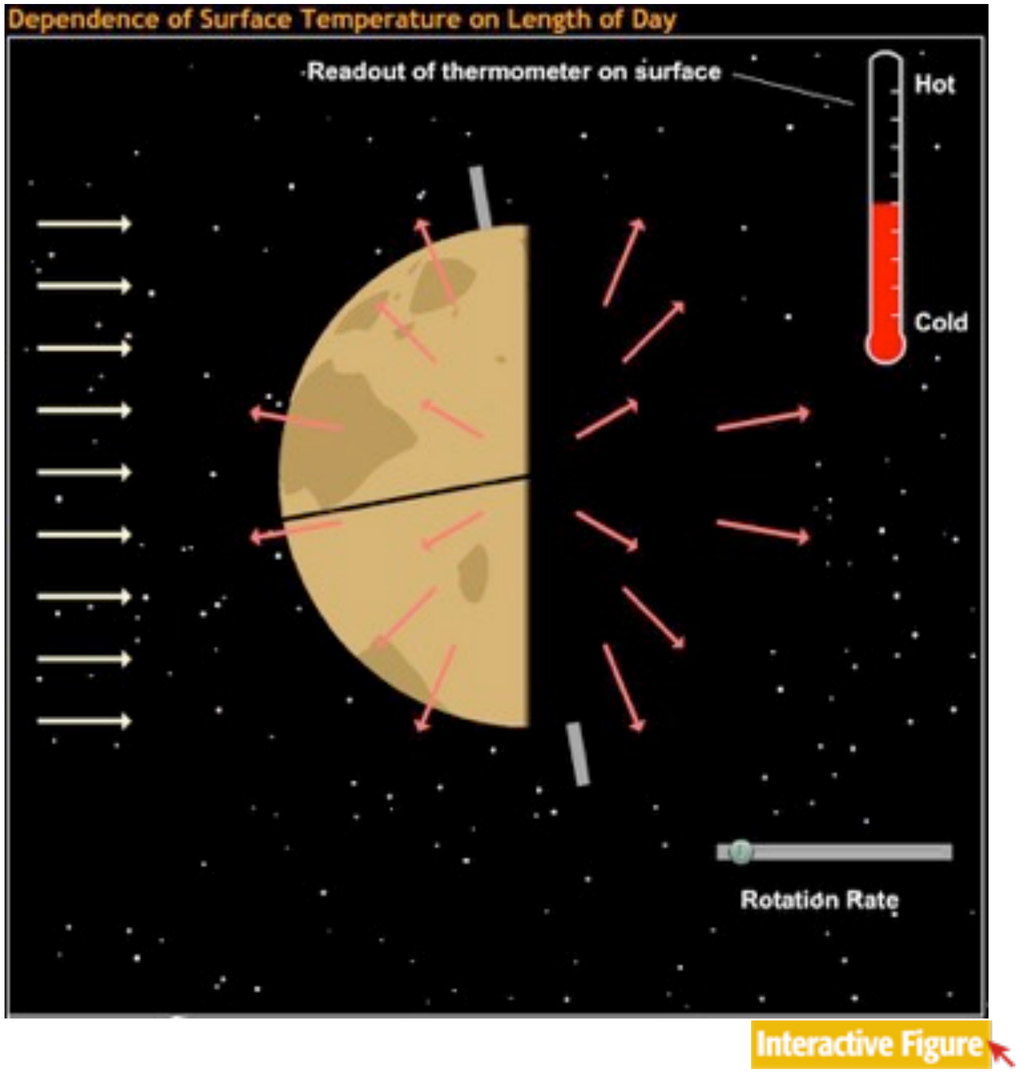


Planetary Temperature



- A planet's surface temperature is determined by the balance between energy from sunlight it absorbs and energy of outgoing thermal radiation.

Temperature and Rotation



- A planet's rotation rate affects the temperature differences between day and night.
- Rapid rotation evens out temperature variations
- Slow rotation exaggerates temperature variations

Temperature and Reflectivity

- A planet's reflectivity (or albedo) is the fraction of incoming sunlight it reflects.
- Planets with low albedo absorb more sunlight, leading to hotter temperatures.
- On planets without an atmosphere, like Mercury and the moon, that’s it
  - the surface heats up during the day, and
  - cools off at night

"No Greenhouse" Temperatures

Atmospheres act like blankets, trapping heat.

TABLE 10.2 The Greenhouse Effect on the Terrestrial Worlds

World	Average Distance from Sun (AU)	Reflectivity	"No Greenhouse" Average Surface Temperature*	Actual Average Surface Temperature	Greenhouse Warming (actual temperature minus "no greenhouse" temperature)
Mercury	0.387	12%	163°C	day: 425°C night: −175°C	—
Venus	0.723	75%	−40°C	470°C	510°C
Earth	1.00	29%	−16°C	15°C	31°C
Moon	1.00	12%	−2°C	day: 125°C night: −175°C	—
Mars	1.524	16%	−56°C	−50°C	6°C

*The "no greenhouse" temperature is calculated by assuming no change to the atmosphere other than lack of greenhouse warming. For example, Venus has a lower "no greenhouse" temperature than Earth even though it is closer to the Sun, because the high reflectivity of its bright clouds means that it absorbs less sunlight than Earth.

- Venus would be 510°C colder without greenhouse effect.
- Earth would be 31°C colder (below freezing on average).

Planetary climates

close to sun

- Mercury (no atmosphere)
  - Hot on day side, cold on night side
- Venus (thick atmosphere)
  - Hot all the time (hotter than Mercury!)
- Earth (“nice” atmosphere)
  - “just right”
- Moon (no atmosphere)
  - Hot on day side, cold on night side
- Mars (thin atmosphere)
  - colder now than in past

same distance from sun

far from sun