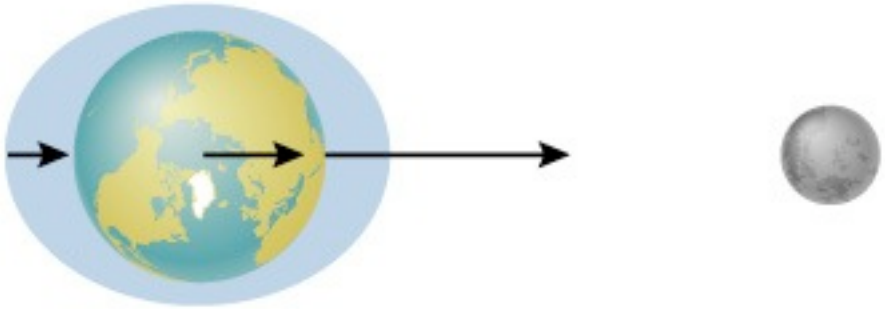
Today

- Gravity
  - tides
- Terrestrial Planets
  - Earth/moon, Venus, Mars, Mercury

- Homework 2 due now
- First Exam One Week from Today
  - closed book; no calculators
  - practice exam, lecture slides on-line

Tides



Tides are the result of differential gravity

Not to scale!

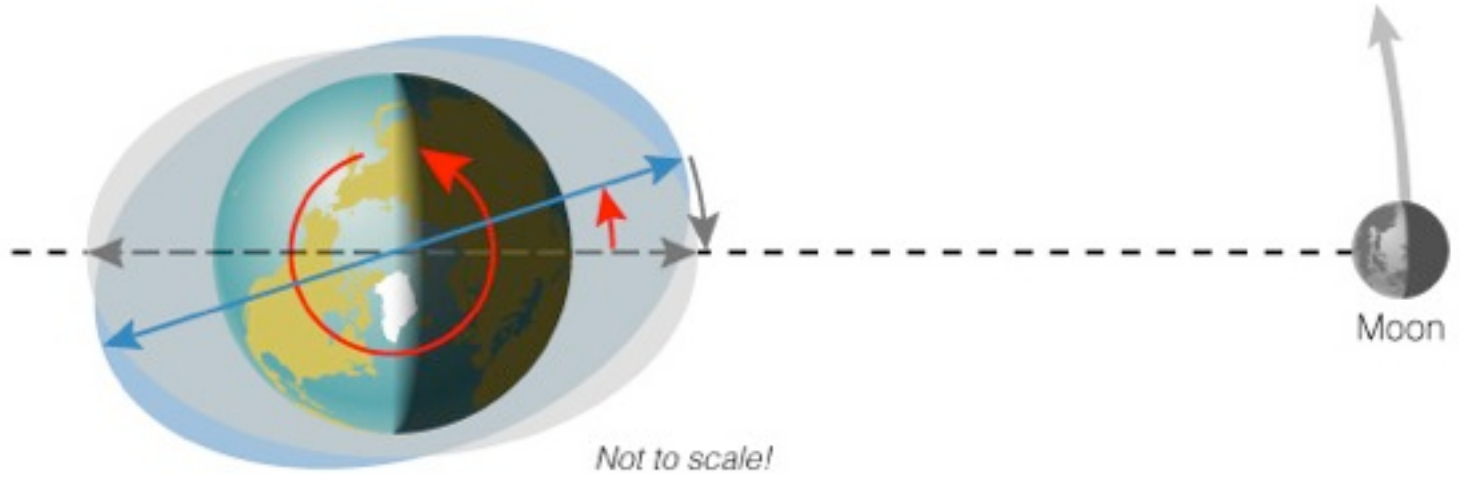
- The Moon's gravity pulls harder on near side of Earth than on far side (inverse square law).
- The difference in the Moon's gravitational pull stretches Earth.

Tides and Phases

Size of tides depends on the phase of the Moon.

Spring tides are stronger than neap tides because the sun and moon team up at new & full moon.

Tidal Friction



0.002 seconds per day per century

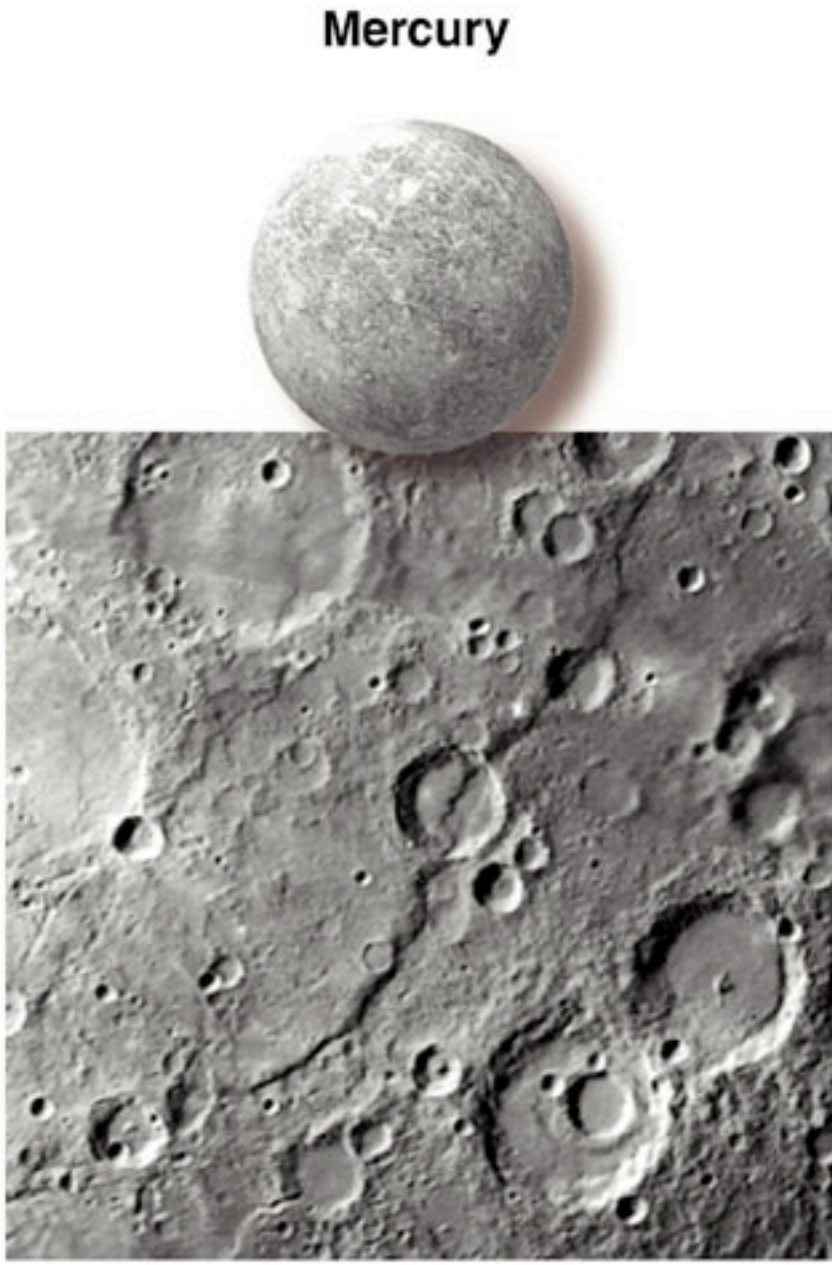
- Tidal friction gradually slows Earth rotation
  - Moon gradually drifts farther from Earth about one inch/year
  - conservation of angular momentum
- Moon once spun faster; tidal friction caused it to "lock" in synchronous rotation
  - orbit period:spin period = 1:1
  - keeps same face towards us all the time

Summary

- Tides are caused by the differential gravity of the sun and moon
  - Spring tides occur when the sun and moon are aligned;
  - neap tides occur when they are perpendicular.

- Tidal friction gradually changes
  - the orbit of the moon
    - gradually drifts away (38 mm/year; 10^{-10}/year)
  - the spin of the earth
    - gradually slows down (15 seconds/million years)

Earth and the Terrestrial Worlds



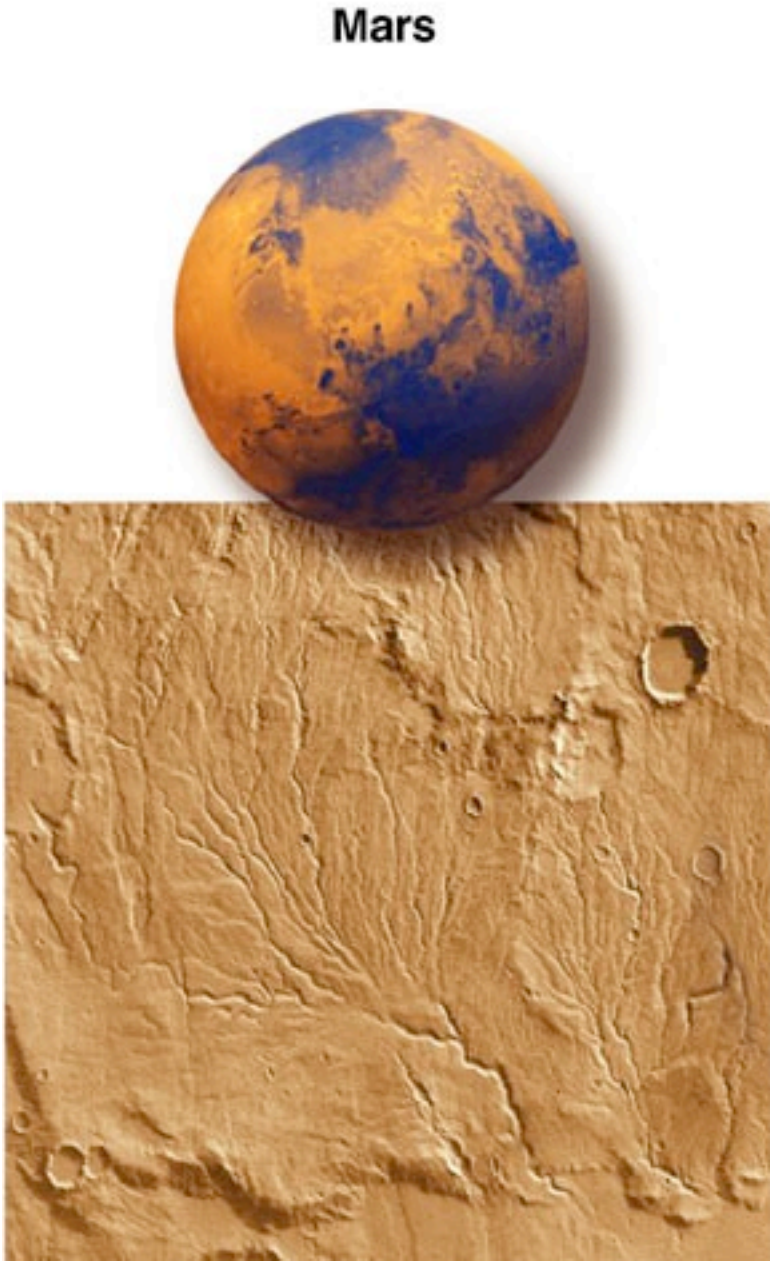
Mercury

craters
smooth plains
cliffs

Venus

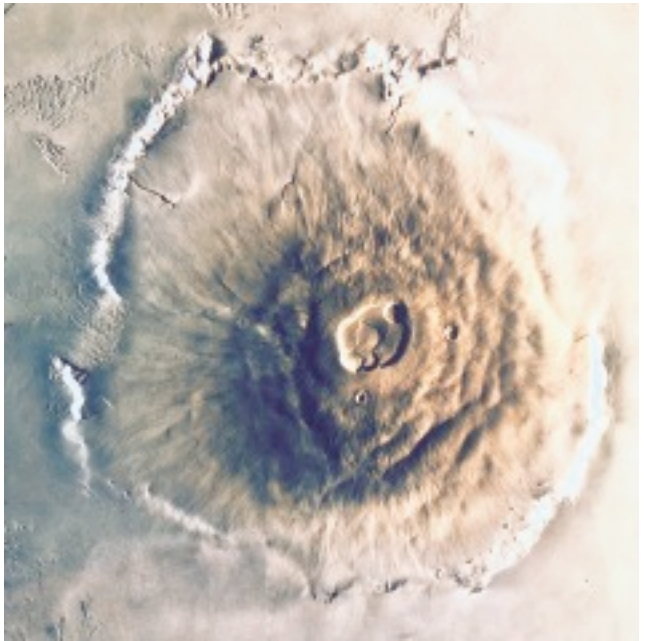
volcanoes
few craters

Radar view of a twin-peaked volcano



Mars

some craters
volcanoes
riverbeds?



Moon

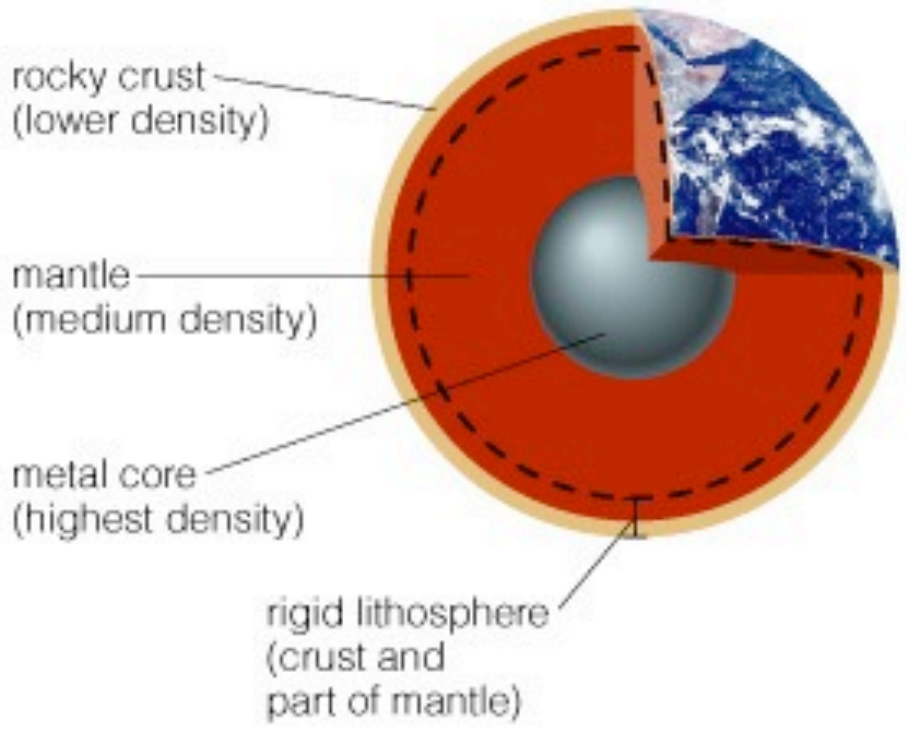
craters
smooth plains

Earth

volcanoes
craters
mountains
riverbeds

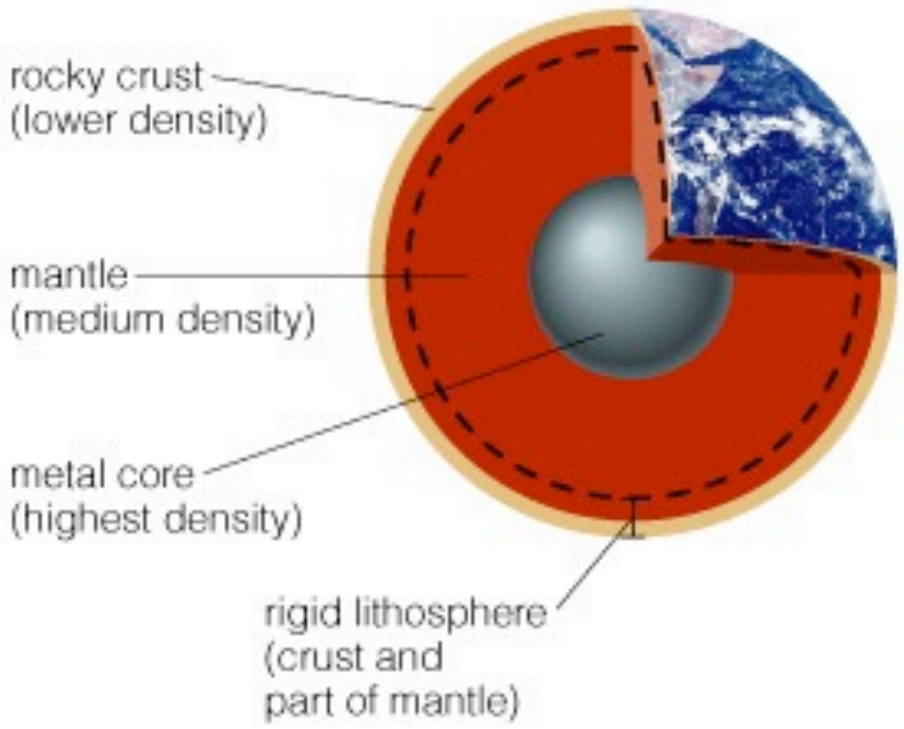
Why have the planets turned out so differently, even though they formed at the same time from the same materials?

Earth's Interior



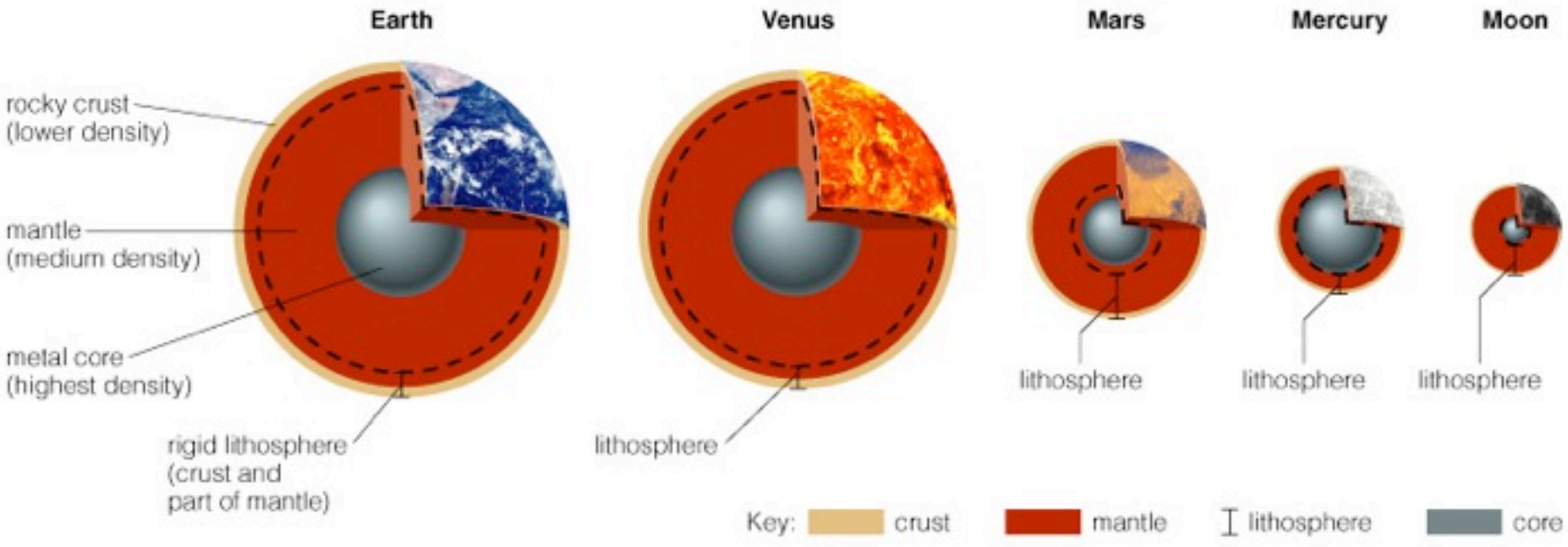
- **Core:** Highest density; nickel and iron
- **Mantle:** Moderate density; silicon, oxygen, etc.
- **Crust:** Lowest density; granite, basalt, etc.

Differentiation



- Gravity pulls high-density material to center
- Lower-density material rises to surface
- Material ends up separated by density

Terrestrial Planet Interiors

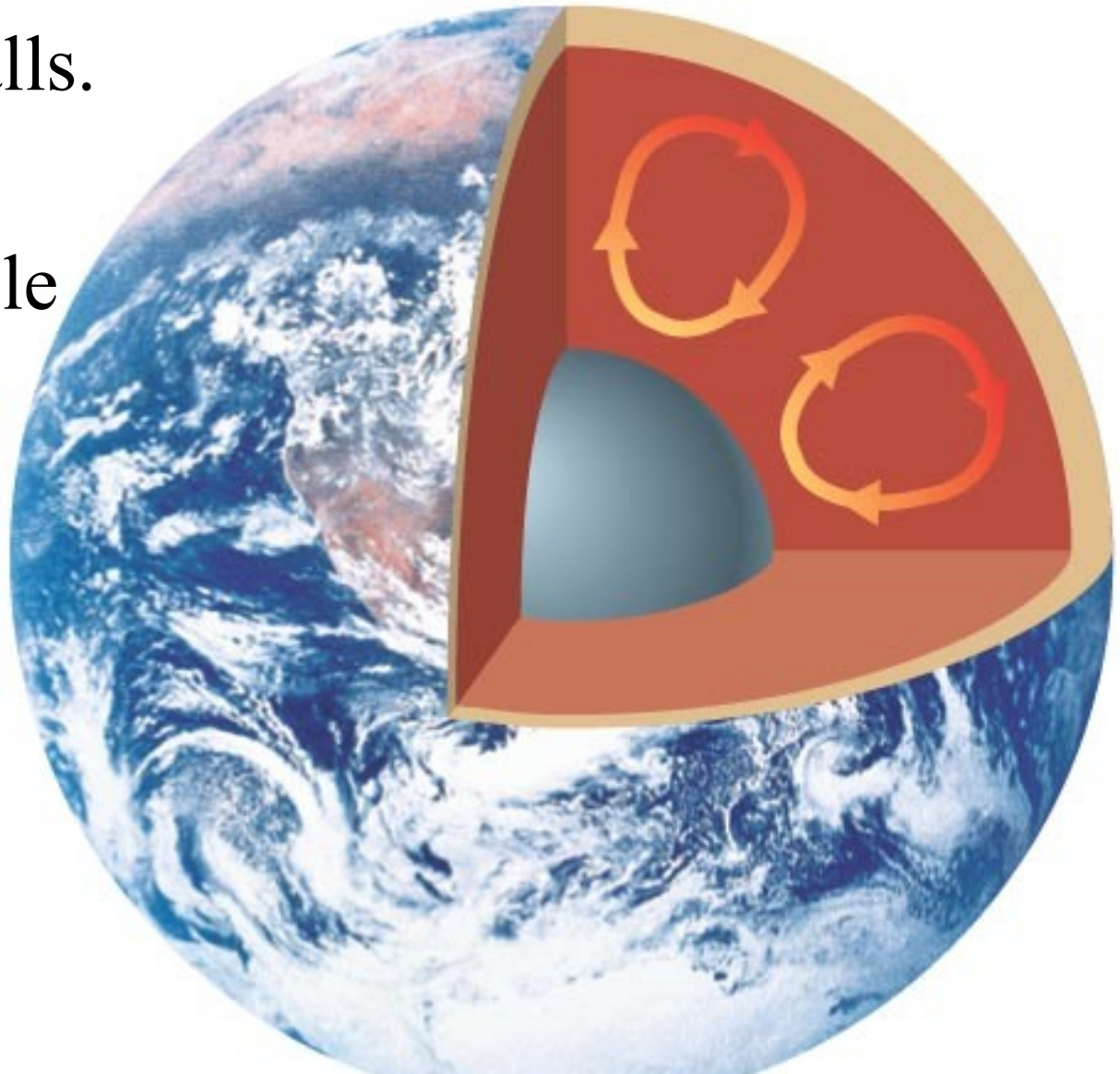


- Applying what we know about Earth's interior to other planets tells us what their interiors may be like.

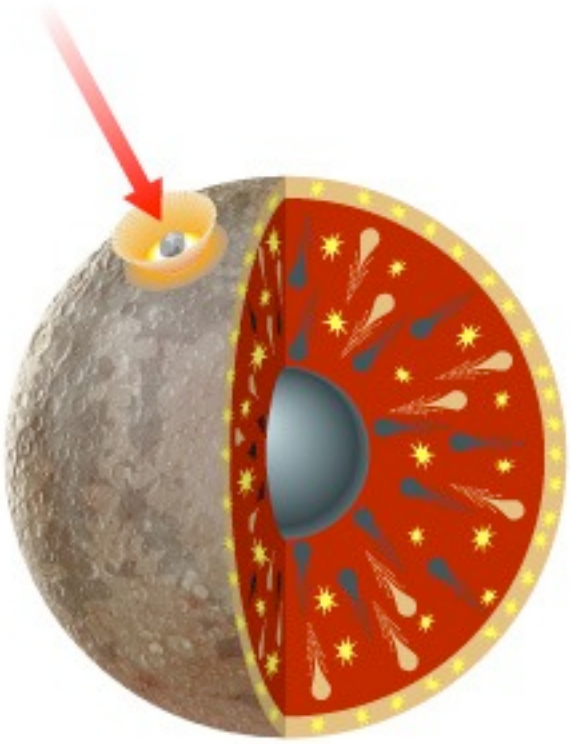
Heat Drives Geological Activity

Convection: hot rock rises, cool rock falls.

One convection cycle takes 100 million years on Earth.

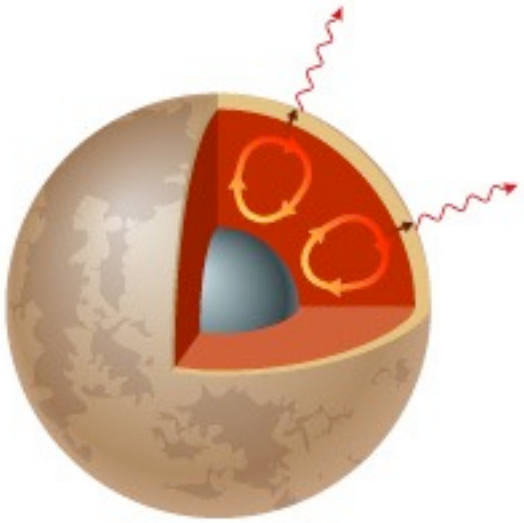


Heating of Interior over Time



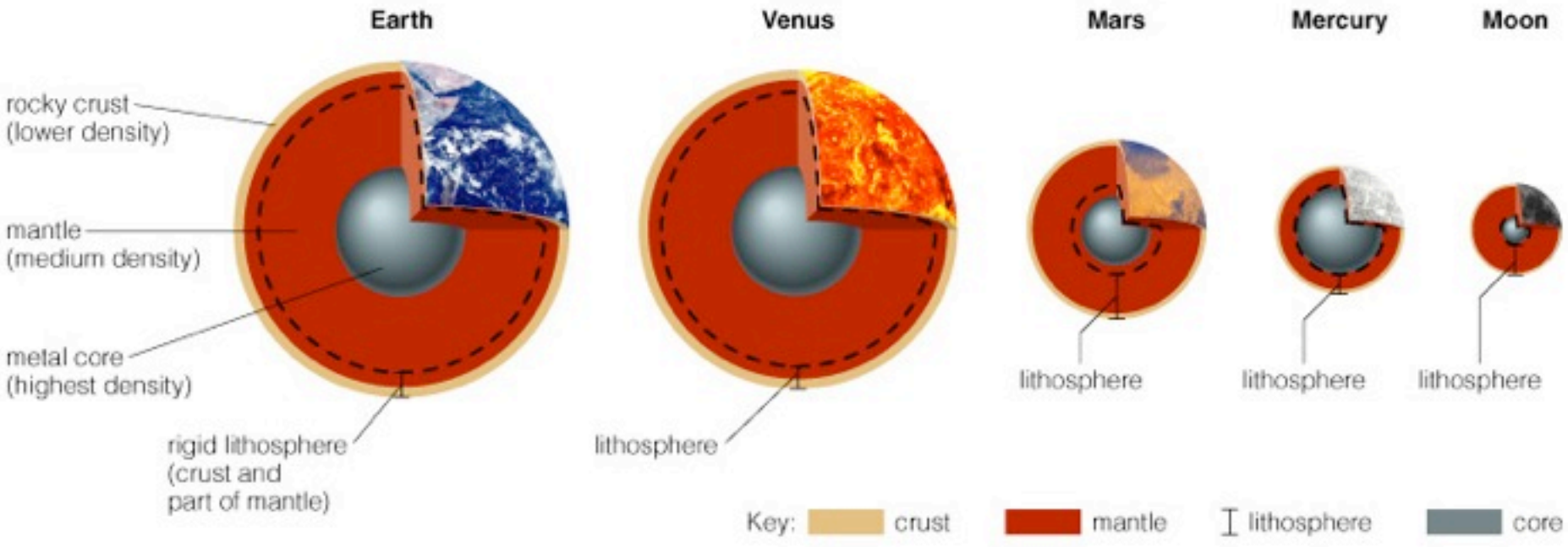
- Accretion and differentiation when planets were young
- Radioactive decay is most important heat source today

Cooling of Interior



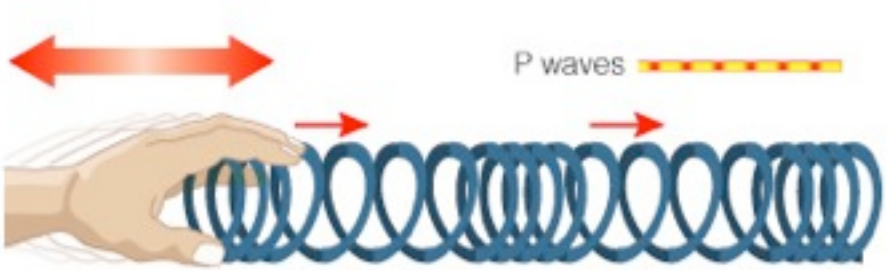
- **Convection** transports heat as hot material rises and cool material falls
- **Conduction** transfers heat from hot material to cool material
- **Radiation** sends energy into space

Role of Size

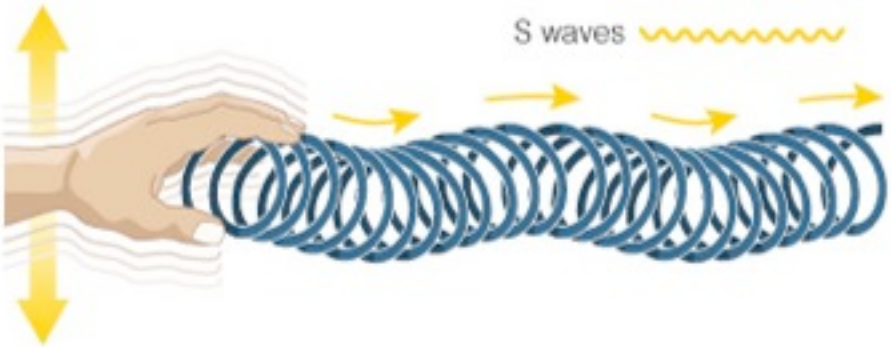


- Smaller worlds cool off faster and harden earlier.
- Moon and Mercury are now geologically "dead."

Special Topic:
How do we know what's inside a planet?



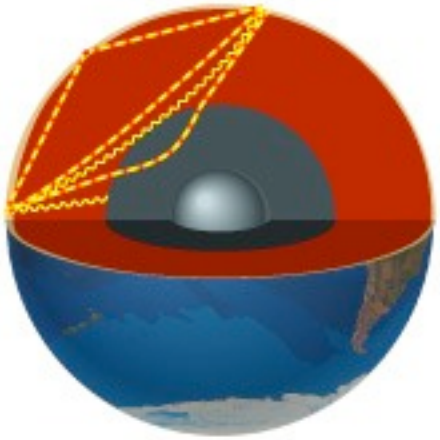
- P waves push matter back and forth.



- S waves shake matter side to side.

G3-21 transverse waves on long spring

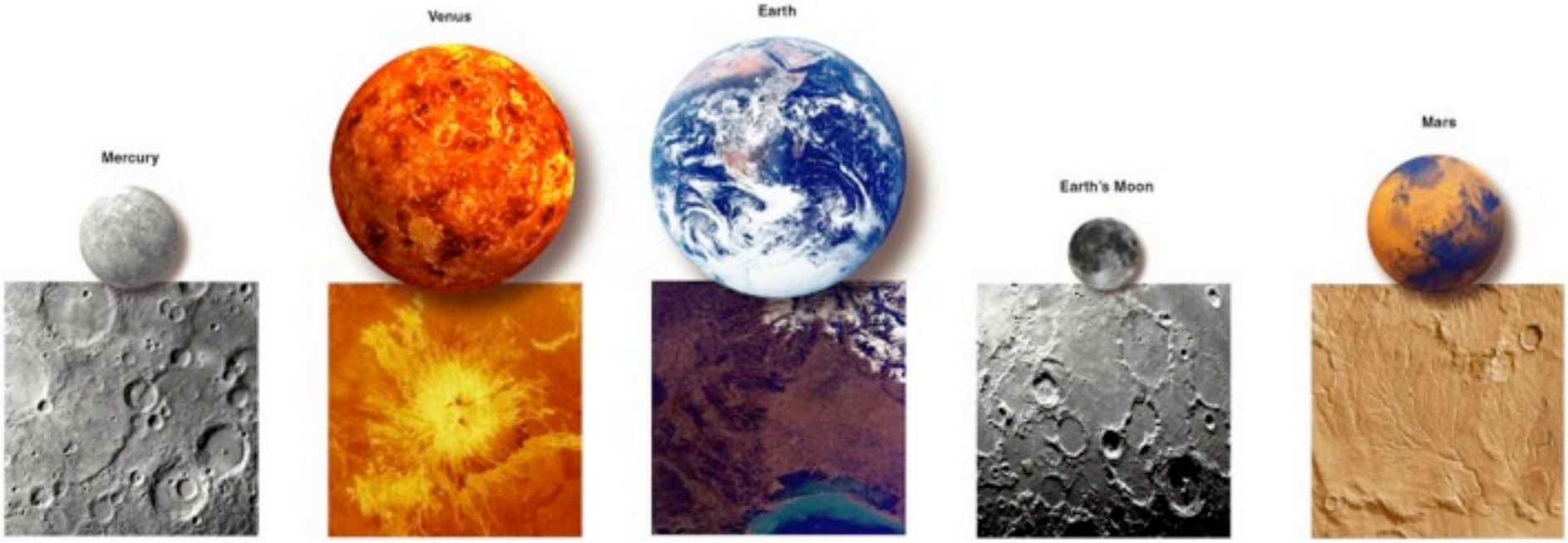
Special Topic:
How do we know what's inside a planet?



- P waves go through Earth's core, but S waves do not.

- We conclude that Earth's core must have a liquid outer layer.

What processes shape a planet's surface?

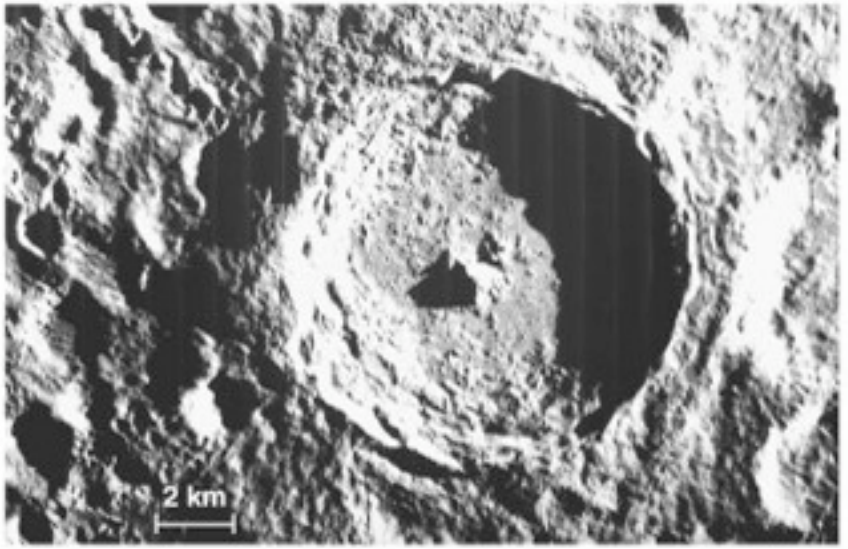


Geological Processes

- Impact cratering
  — Impacts by asteroids or comets
- Volcanism
  — Eruption of molten rock onto surface
- Tectonics
  — Disruption of a planet's surface by internal stresses
- Erosion
  — Surface changes made by wind, water, or ice

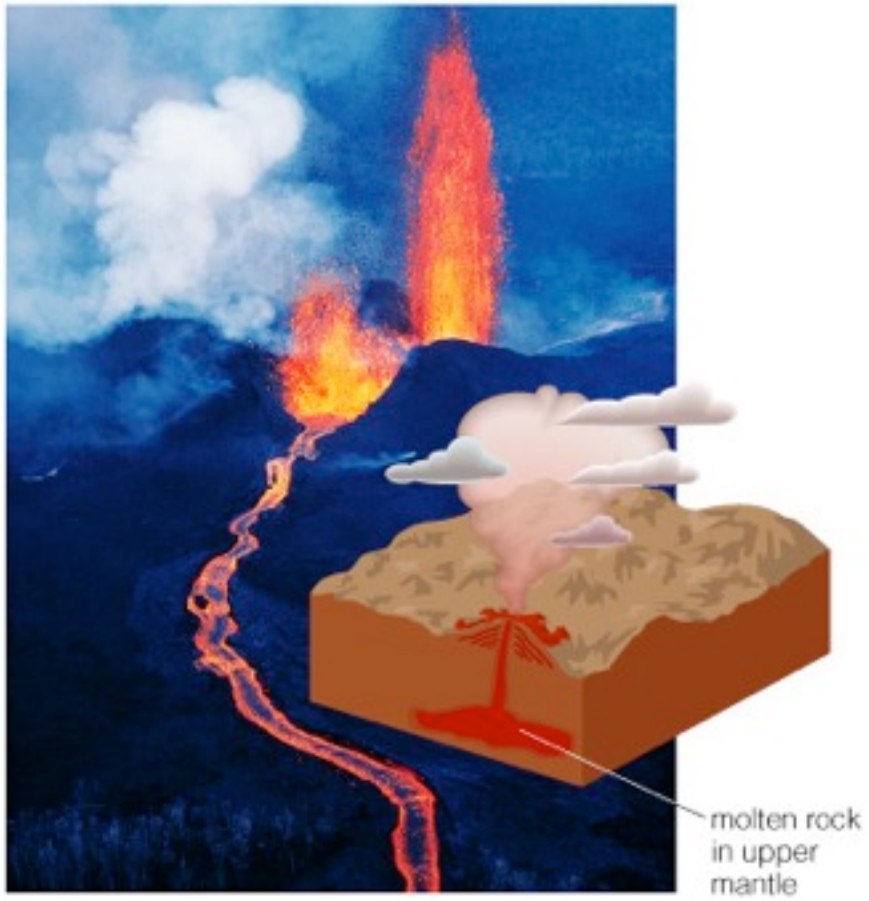
Impact Craters

Meteor Crater (Arizona)



Tycho (Moon)

Volcanism

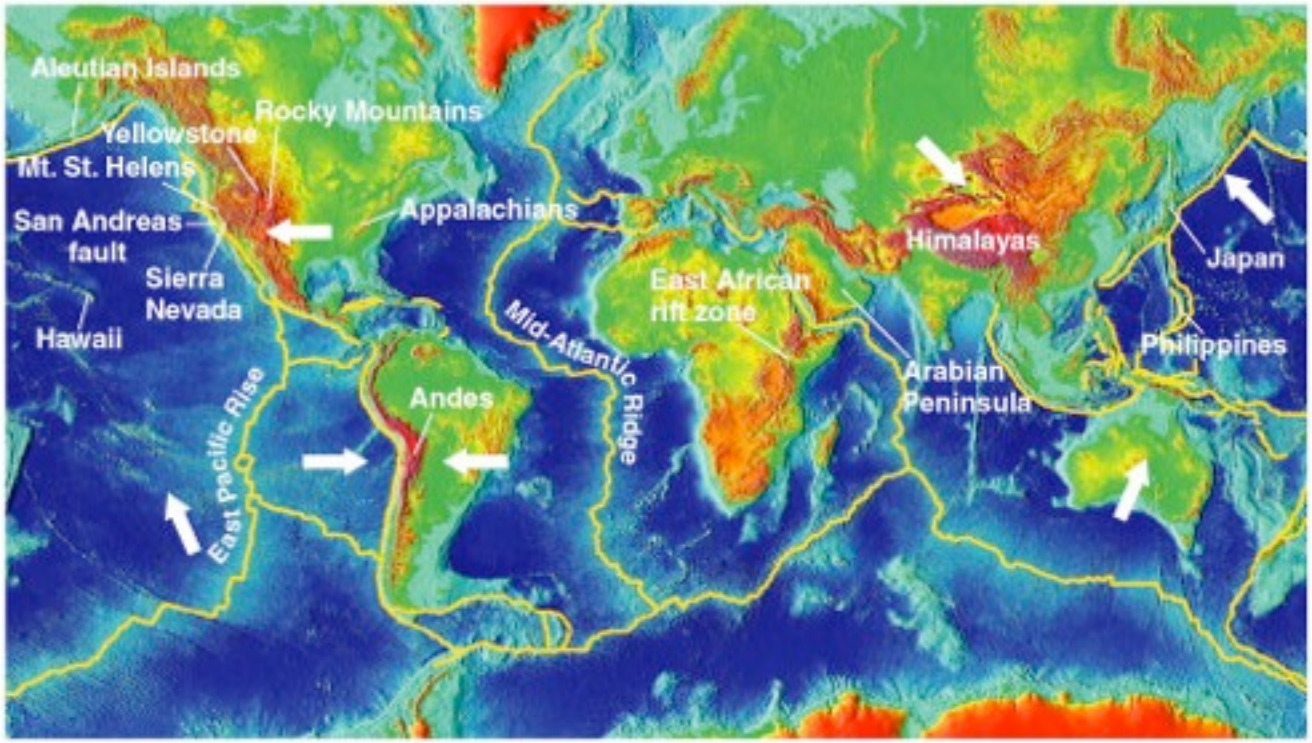


- Volcanism happens when molten rock (magma) finds a path through lithosphere to the surface.
- Molten rock is called *lava* after it reaches the surface.

Outgassing

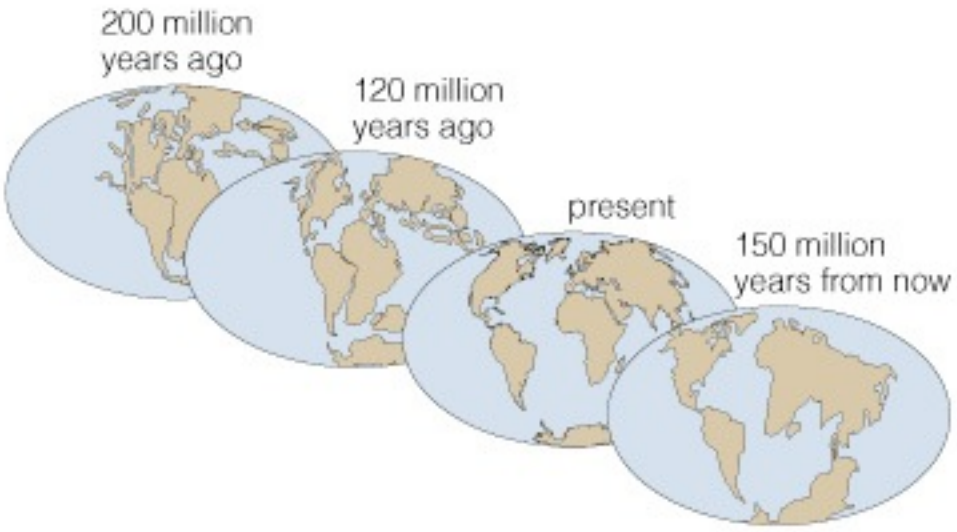
- Volcanism also releases gases from Earth's interior into the atmosphere.

Plate Tectonics



- Motion of continents can be measured with GPS

Plate Motions



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

Erosion

- Erosion is a blanket term for weather-driven processes that break down or transport rock.
- Processes that cause erosion include
  - — Glaciers
  - — Rivers
  - — Wind

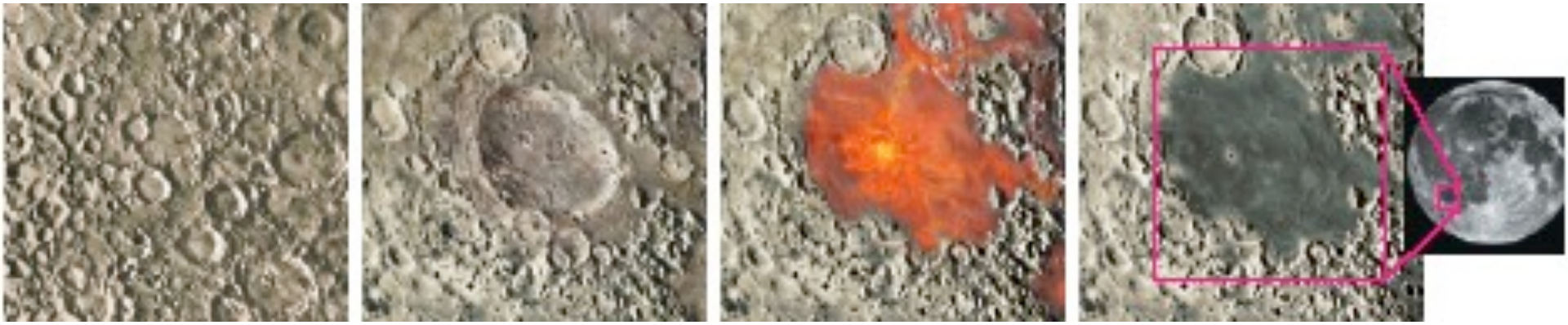
Erosion by Water

- The Colorado River continues to carve the Grand Canyon.

Erosion by Wind

- Wind wears away rock and builds up sand dunes.

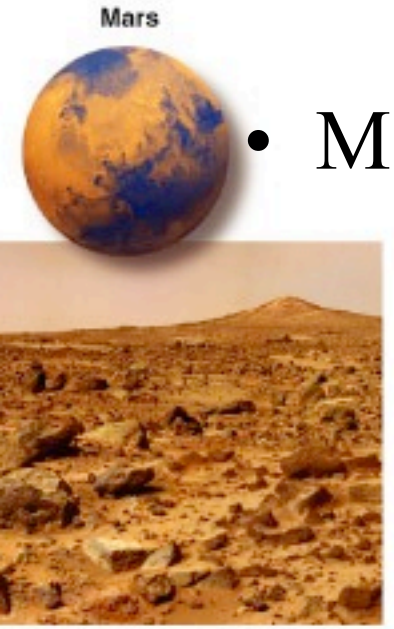
Moon



- Some volcanic activity 3 billion years ago must have flooded lunar craters, creating *lunar maria*.
- The Moon is now geologically dead.

Mars versus Earth

- 50% Earth's radius, 10% Earth's mass
- 1.5 AU from the Sun
- Axis tilt about the same as Earth
- Similar rotation period
- Thin CO_2 atmosphere: little greenhouse



- Main difference: Mars is SMALLER

Terrestrial planet surfaces

- Craters are the normal state
  - need geological activity to erase
- e.g.,
  - Volcanism
  - Erosion
  - Plate tectonics