[15] Planetary Geology (10/19/17)

Upcoming Items

1. Homework #7 due on Tuesday.
2. Read Ch. 10 by next class and do the self-study quizzes.

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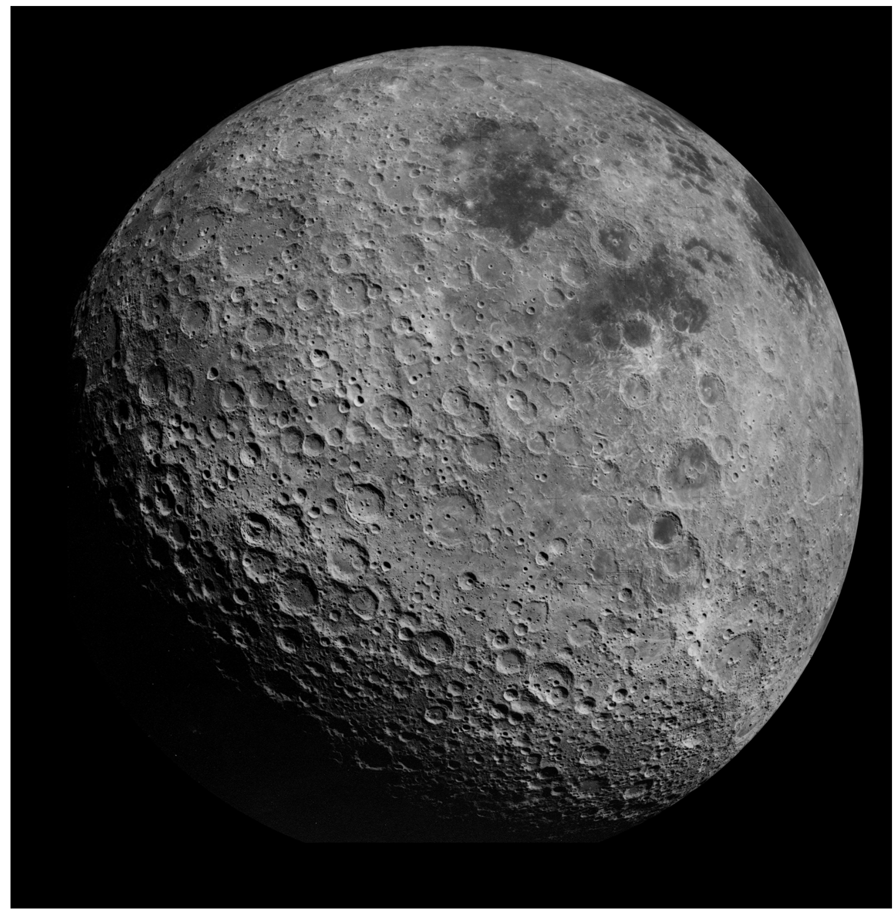
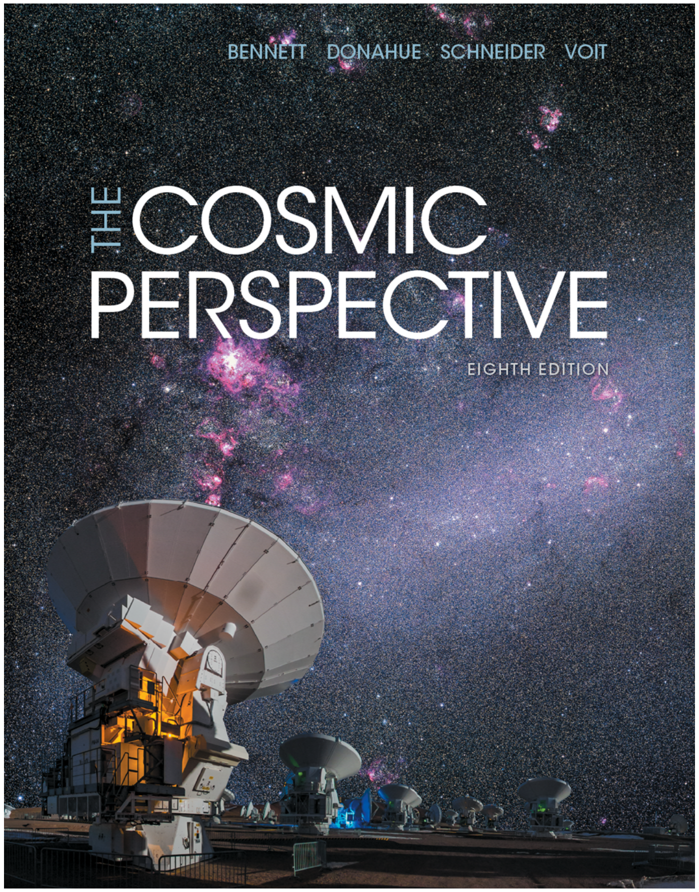


LEARNING GOALS

Chapters 9.1–9.2

For this class, you should be able to…

- … *predict the interior structure and geological activity of a terrestrial planet;*
- … *hypothesize what processes may be altering a planetary surface based on the type or lack of surface features.*



Any astro questions?

In-class Quiz

1. Which of a planet's main properties has the greatest effect on its level of volcanic and tectonic activity?
   (a) Size.
   (b) Distance from the Sun.
   (c) Rotation rate.

2. What do we conclude if a planet has few impact craters of any size?
   (a) The planet was never bombarded by asteroids or comets.
   (b) Its atmosphere stopped impactors of all sizes.
   (c) Other geological processes have wiped out craters.

Registration Appointments for Majors

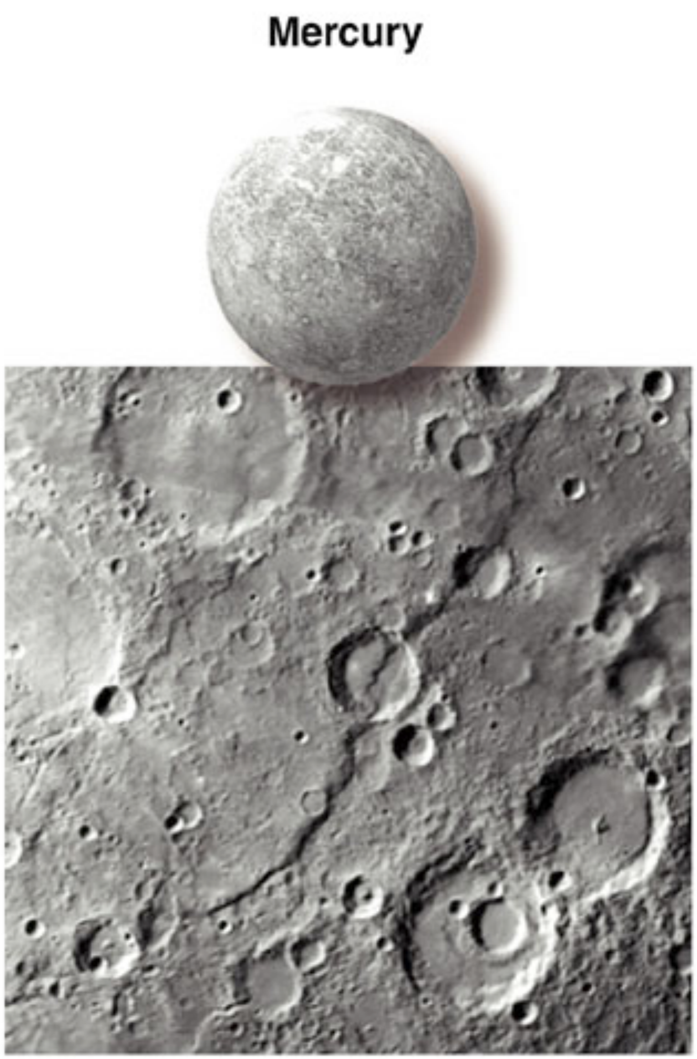
- If you have not received an e-mail from Dr. Melissa Hayes-Gehrke, please contact her: mhayesge@umd.edu
- This is to decide whether you would like to be an Astronomy major
- ASTR 121 (which is the continuation of this class, in the Spring of 2018) is limited to majors

Questions: Why are planets hot?

- Where does the heat come from?
- Where does it go?
- Why do smaller planets cool faster?

Why does heat lead to activity?

- How is heat transferred from the interior to the exterior?
- Which part cools first, and how does this affect activity?
- Which resurfacing processes depend on heat? How?



Mercury is heavily cratered, but also has long, steep cliffs—one is visible here as the long curve that passes through the center of the image.

Mercury

craters,

smooth plains,

steep cliffs

Venus

volcanoes,

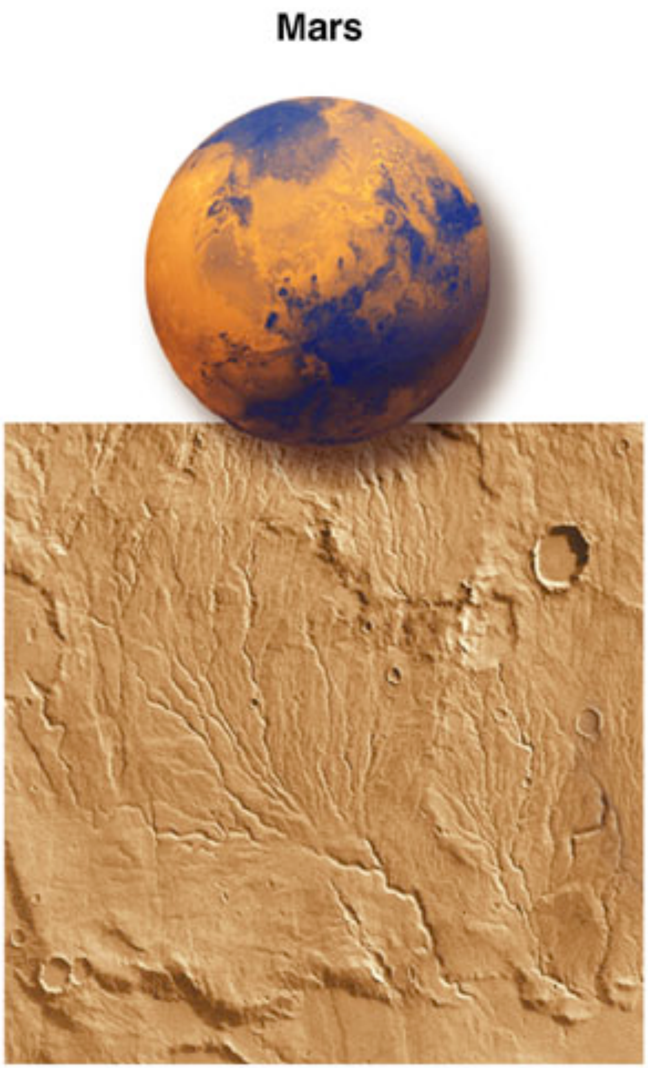
few craters

The central structure is a tall, twin-peaked volcano on Venus.

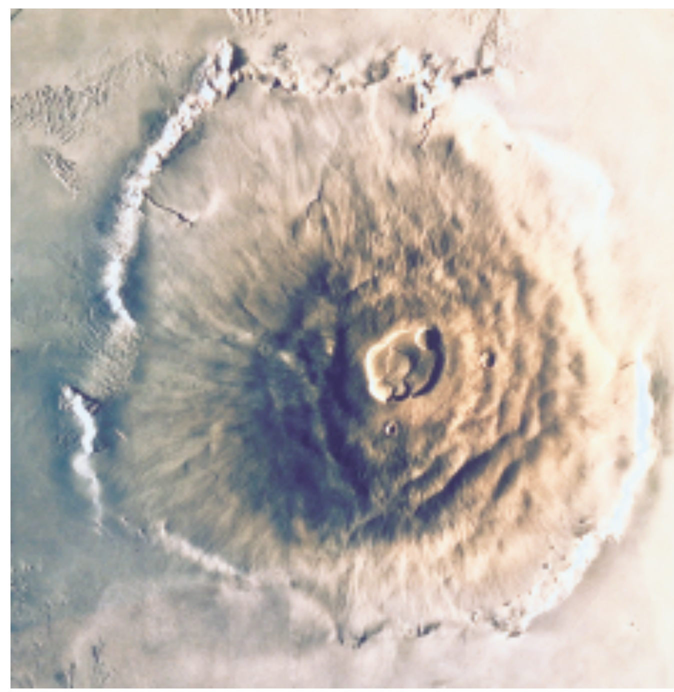
Radar view of a twin-peaked volcano

Mars

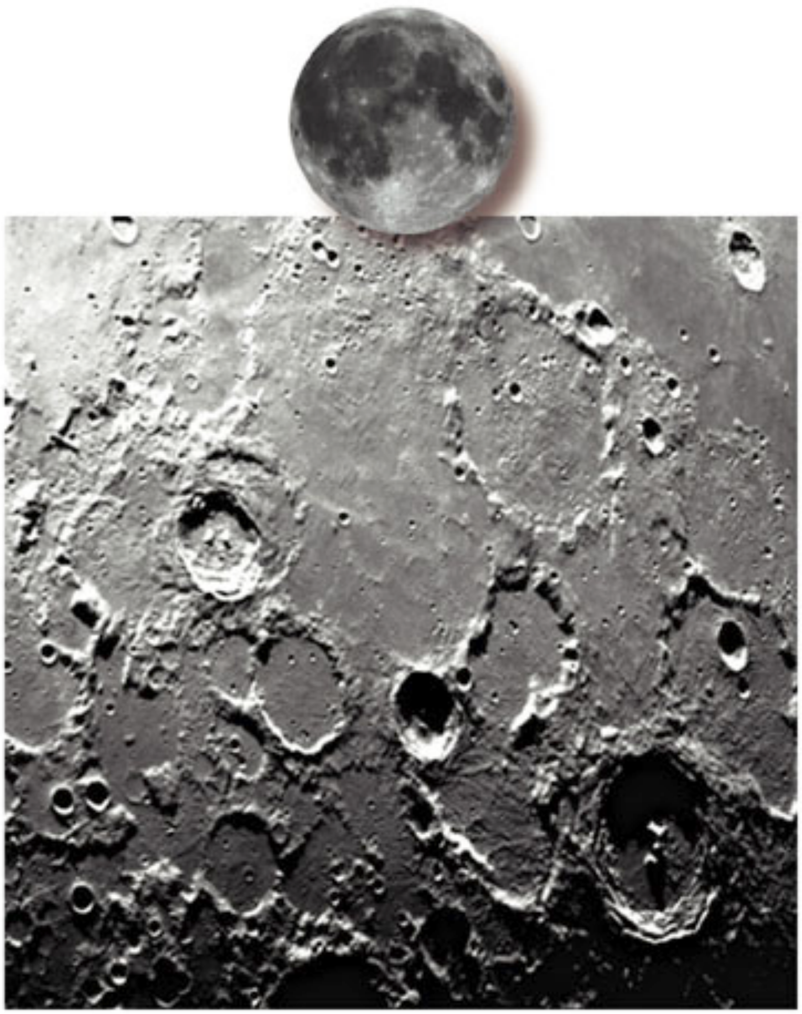
some craters,
volcanoes,
riverbeds



Mars has impact craters like the one near the upper right, but it also has features that look much like dried up riverbeds.



Earth's Moon



The Moon's surface is heavily cratered in most places.

Moon

craters,
smooth plains

Earth has a variety of geological features visible in this photo from orbit.

Earth

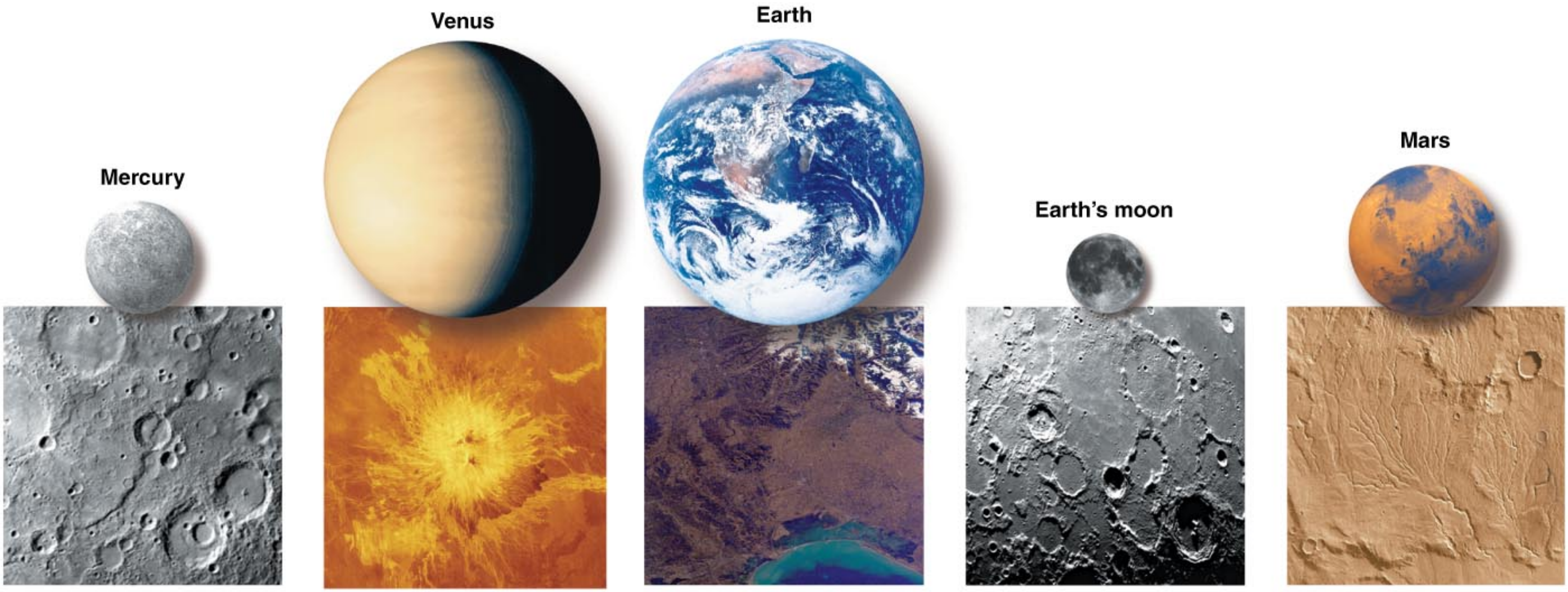
volcanoes,

craters,

mountains,

riverbeds

Why are the planets—especially Earth—so different, when they formed at the same time from the same materials?



Craters
Smooth Plains
Steep Cliffs

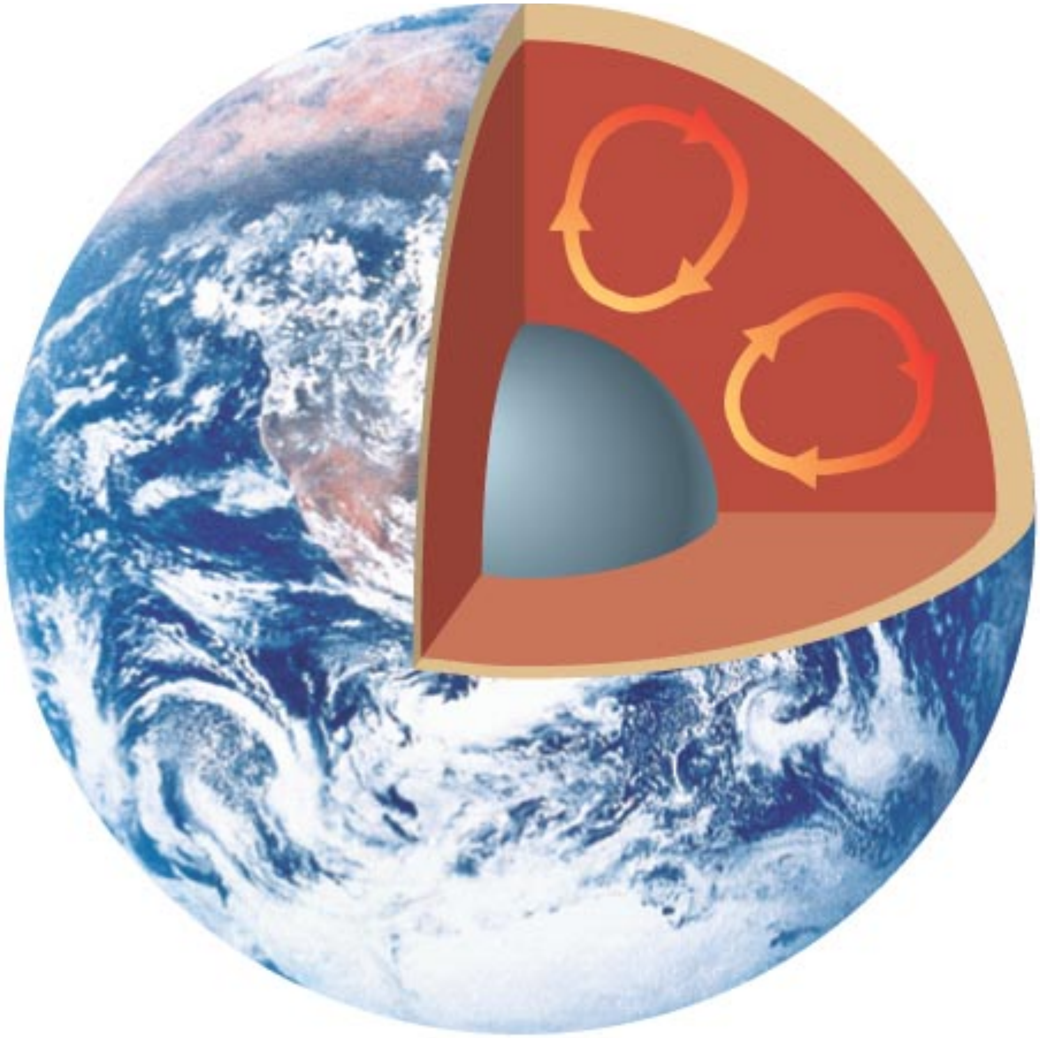
Volcanoes
Few Craters

Volcanoes
Craters
Mountains
Riverbeds

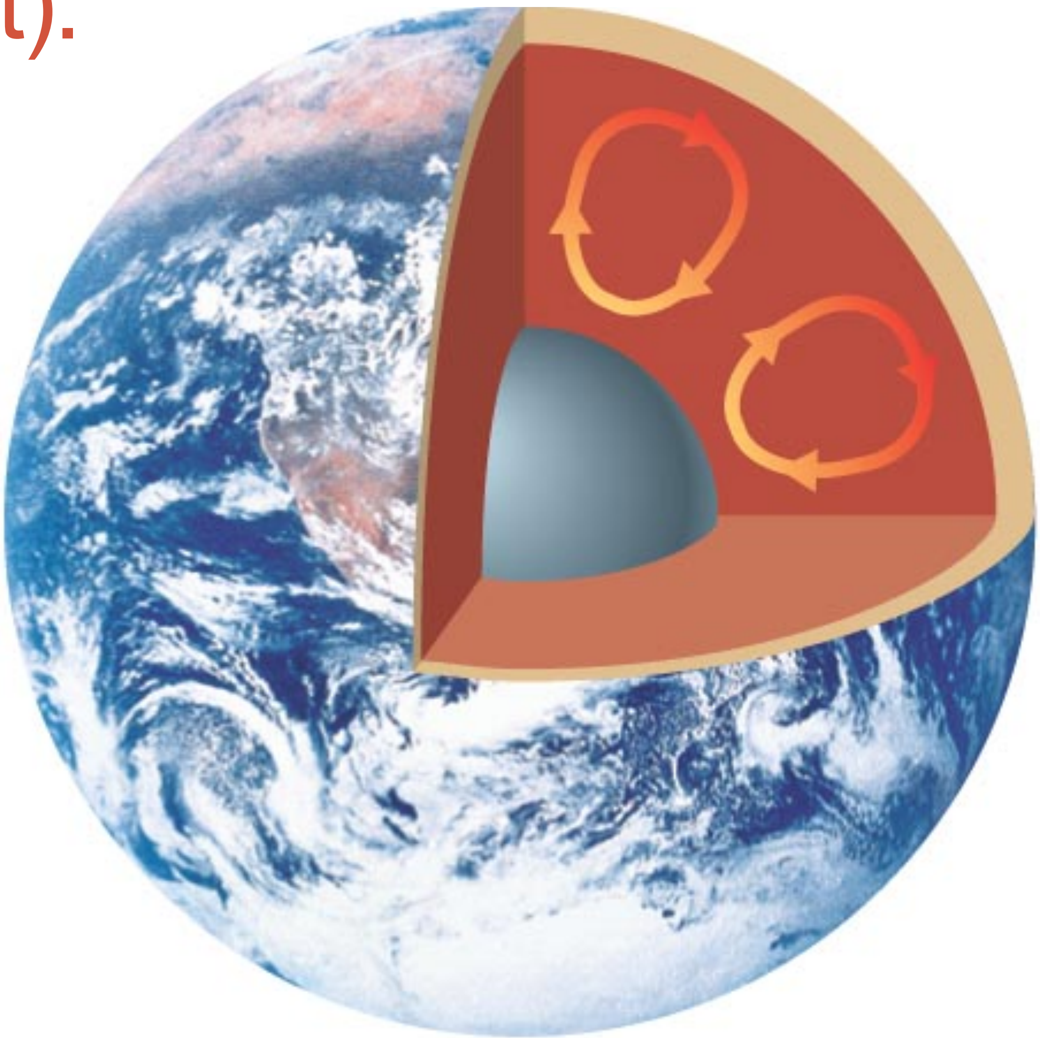
Craters
Smooth Plains

Some Craters
Volcanoes
Riverbeds

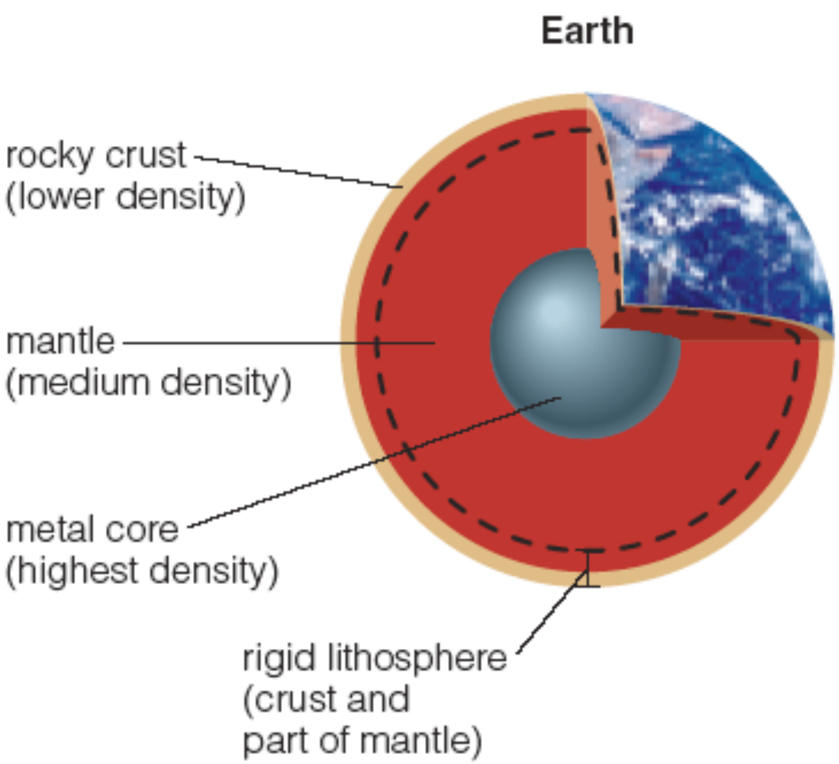
Short answer: The Earth is big enough to still have a hot interior.



Short answer: The Earth is big enough to still have a hot interior (and Venus' water was baked out).

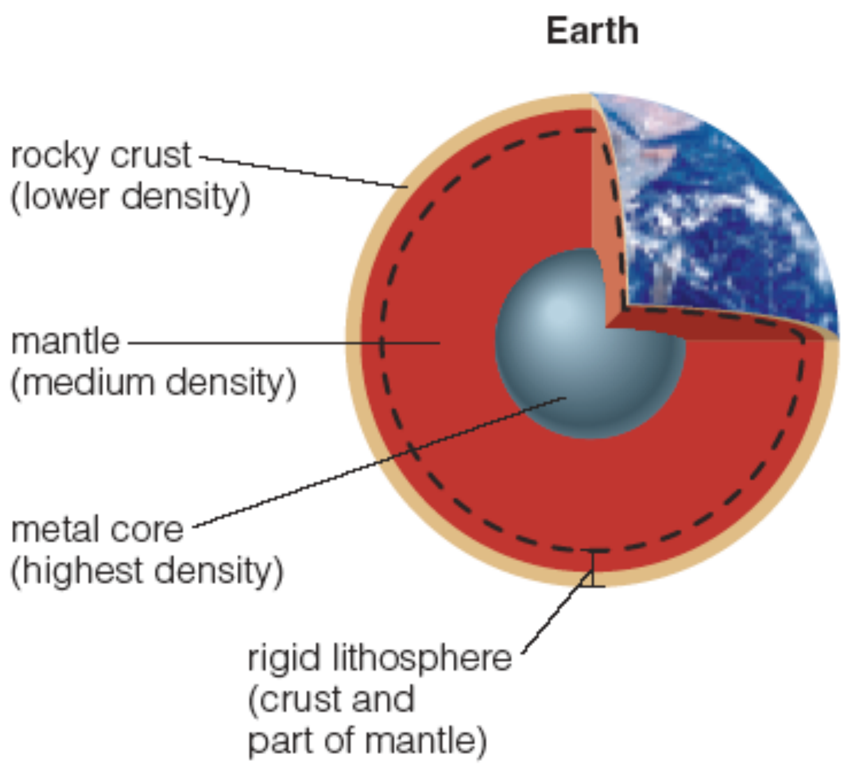


Earth's Interior



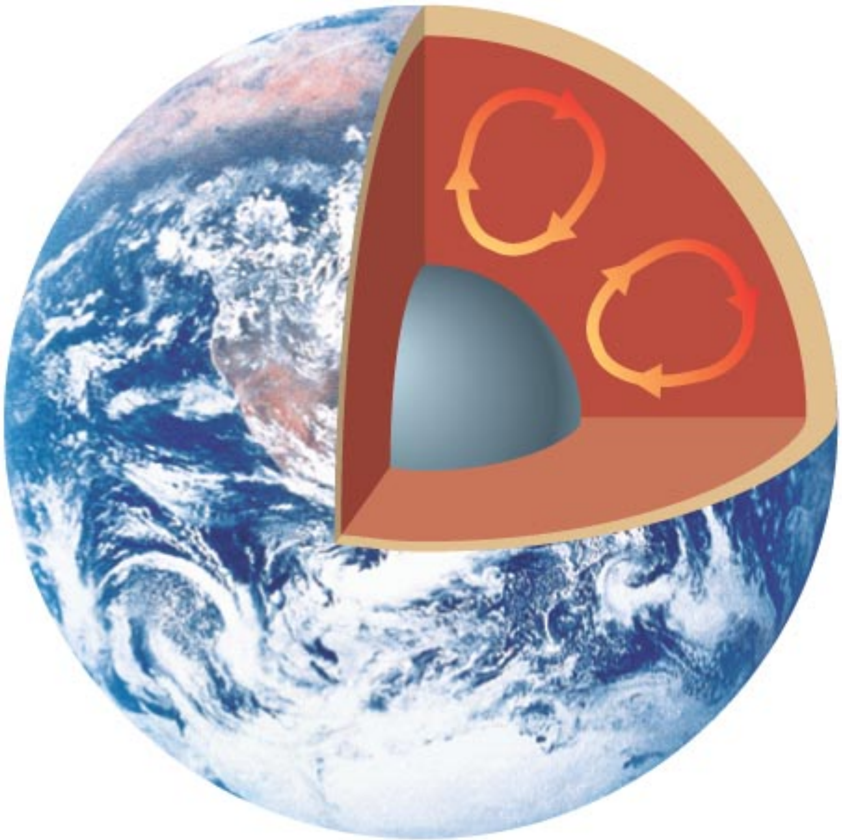
- **Core**: highest density; nickel and iron.
- **Mantle**: moderate density; silicon, oxygen, etc.
- **Crust**: lowest density; granite, basalt, etc.
- **Lithosphere**: crust and upper part of mantle.
- **How do we know all this?**
  Seismic waves!

Differentiation



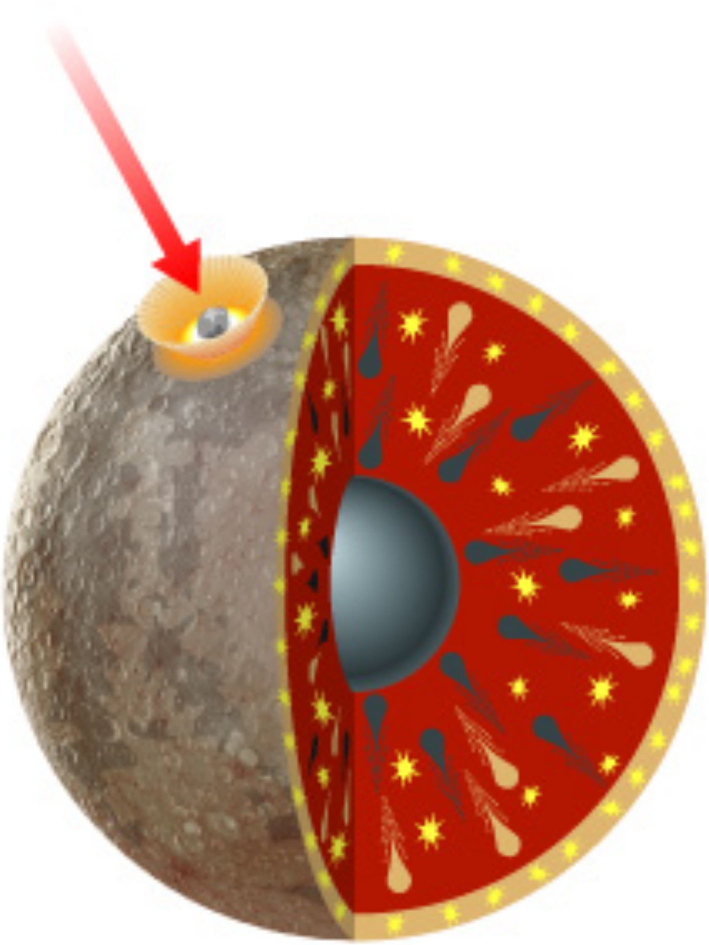
- Gravity pulls high-density material to center.
- Lower-density material rises to the surface.
- Material ends up separated by density.

Heat drives geological activity



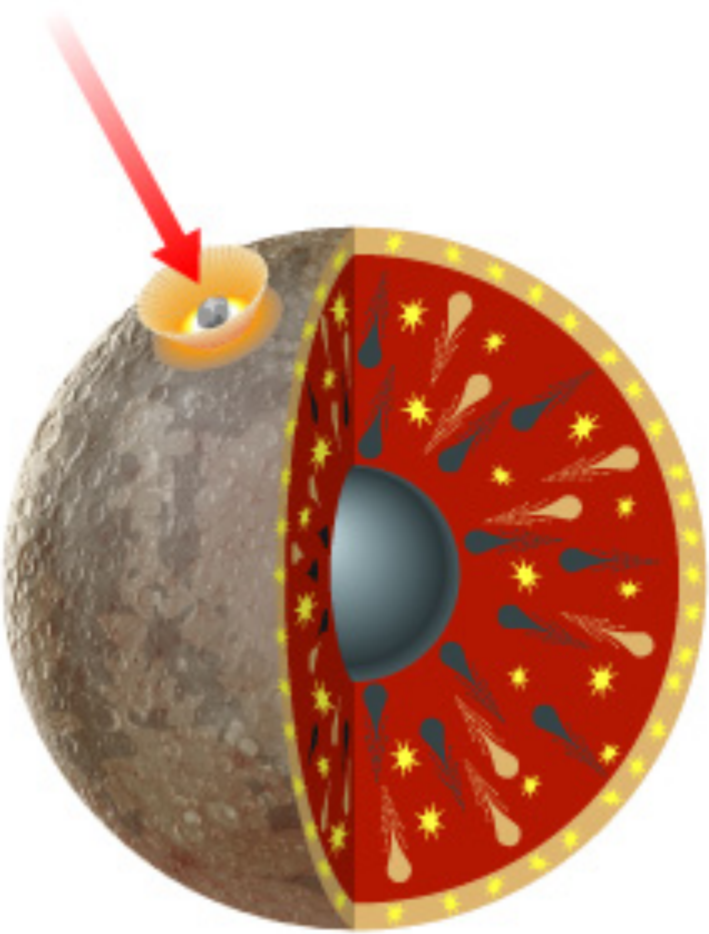
- Convection: hot rock rises, cool rock falls.
- One convection cycle takes 100 million years on Earth.

Sources of Internal Heat



- Gravitational potential energy of accreting planetesimals.
- Differentiation.
  Can you understand how this would be a source of heat, based on the release of gravitational potential energy?
- Radioactivity.

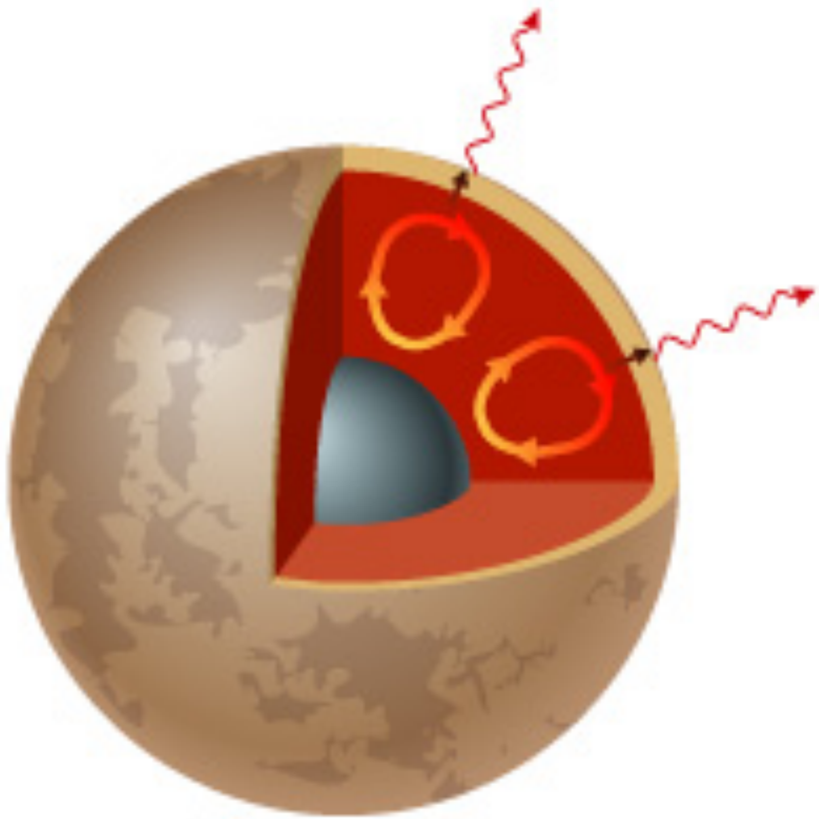
Heating of Planetary Interiors



- Accretion and differentiation occurred when planets were young.

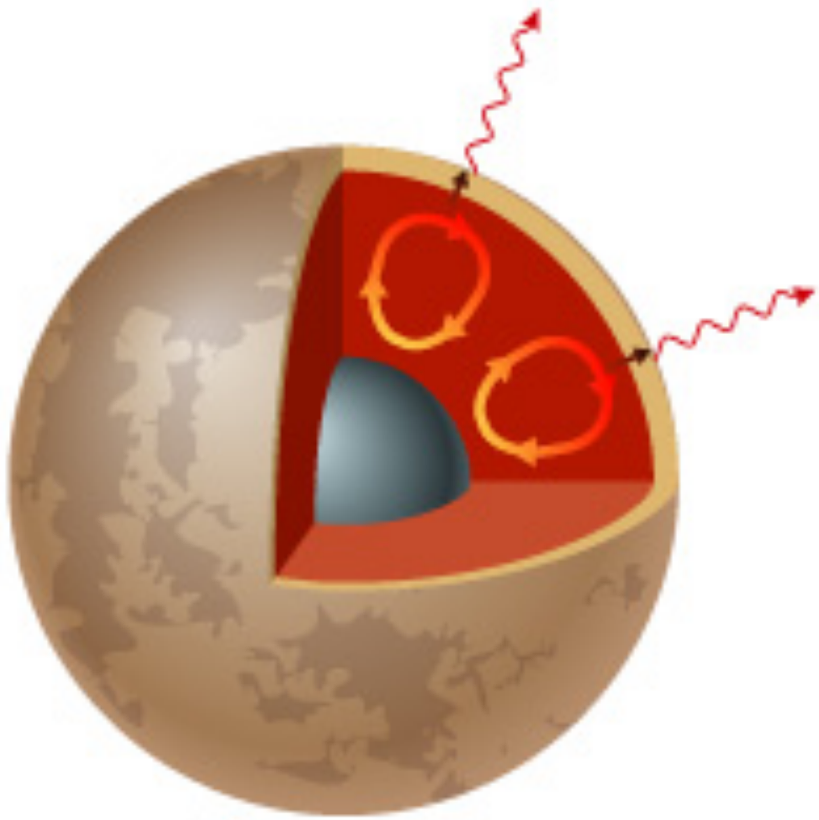
- Radioactive decay is the most important heat source today.

Cooling of Planetary Interiors



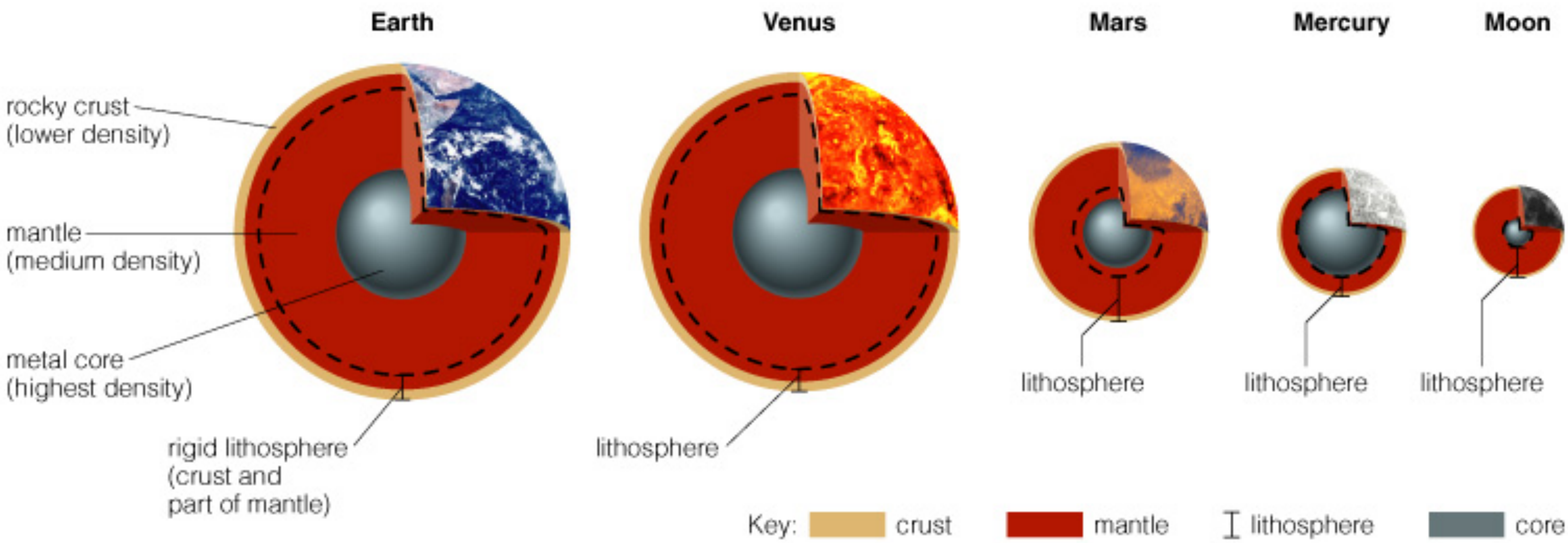
- ***Convection*** transports heat as hot material rises and cool material falls.
- ***Conduction*** transfers heat from hot material to cool material.
- ***Radiation*** sends energy into space.

Cooling of Planetary Interiors



- ***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.
- **Key point:** convection and conduction move energy around, but only radiation causes *loss* of energy

Role of Size



- Smaller worlds cool off faster and harden earlier.
- Moon and Mercury are now geologically “dead” (rigid).

Volume-to-surface-area Ratio

- Heat content depends on volume.
- Loss of heat through radiation depends on surface area.
- Time to cool depends on volume divided by surface area:

$$\text{cooling time} = \frac{\text{heat content}}{\text{cooling rate}} \propto \frac{\text{volume}}{\text{area}}$$

$$= \frac{\frac{4}{3}\pi R^3}{4\pi R^2} \propto R.$$

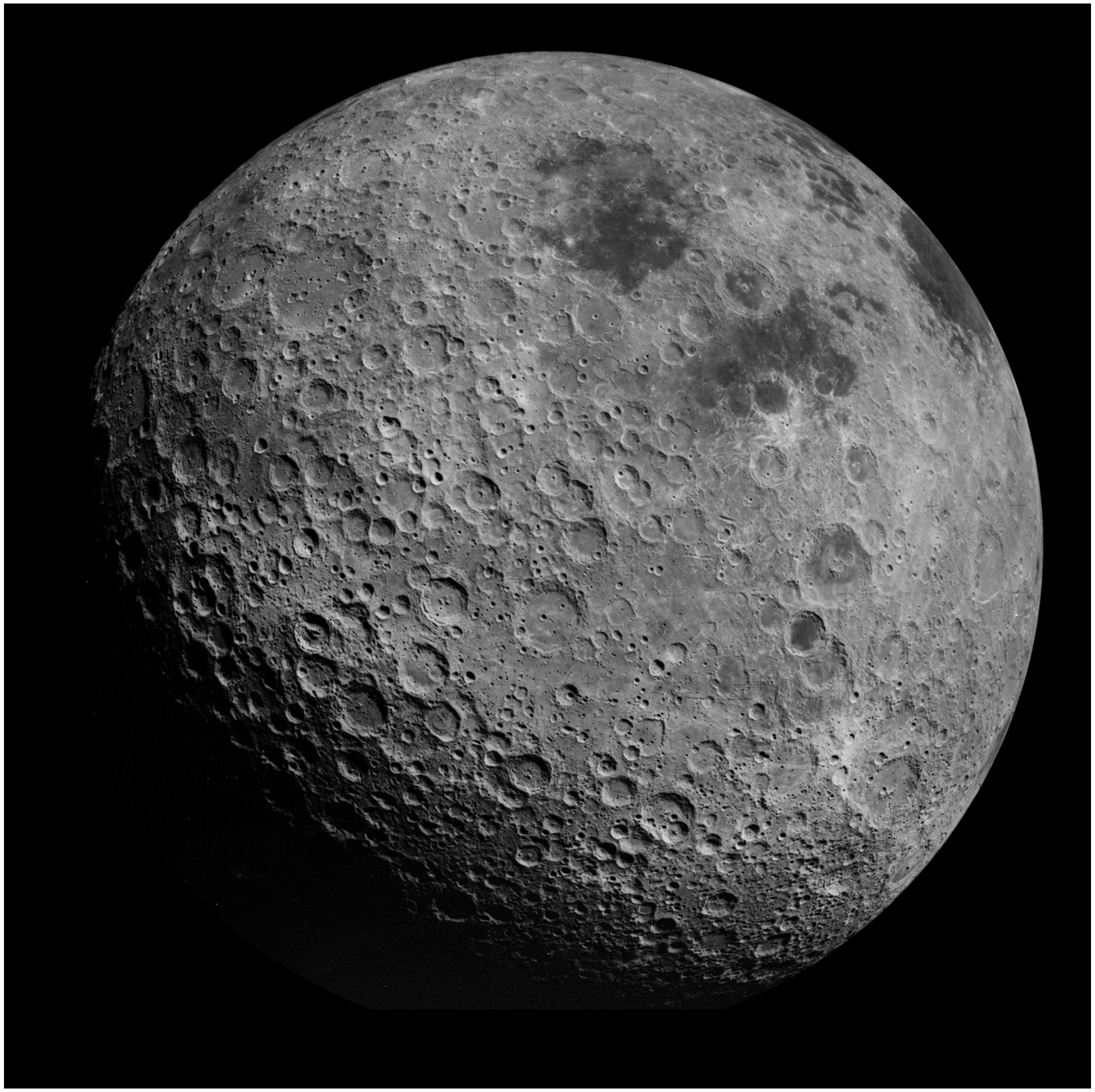
- Larger objects have a larger ratio and take longer to cool.
  Think about taking a pie out of the oven!

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.

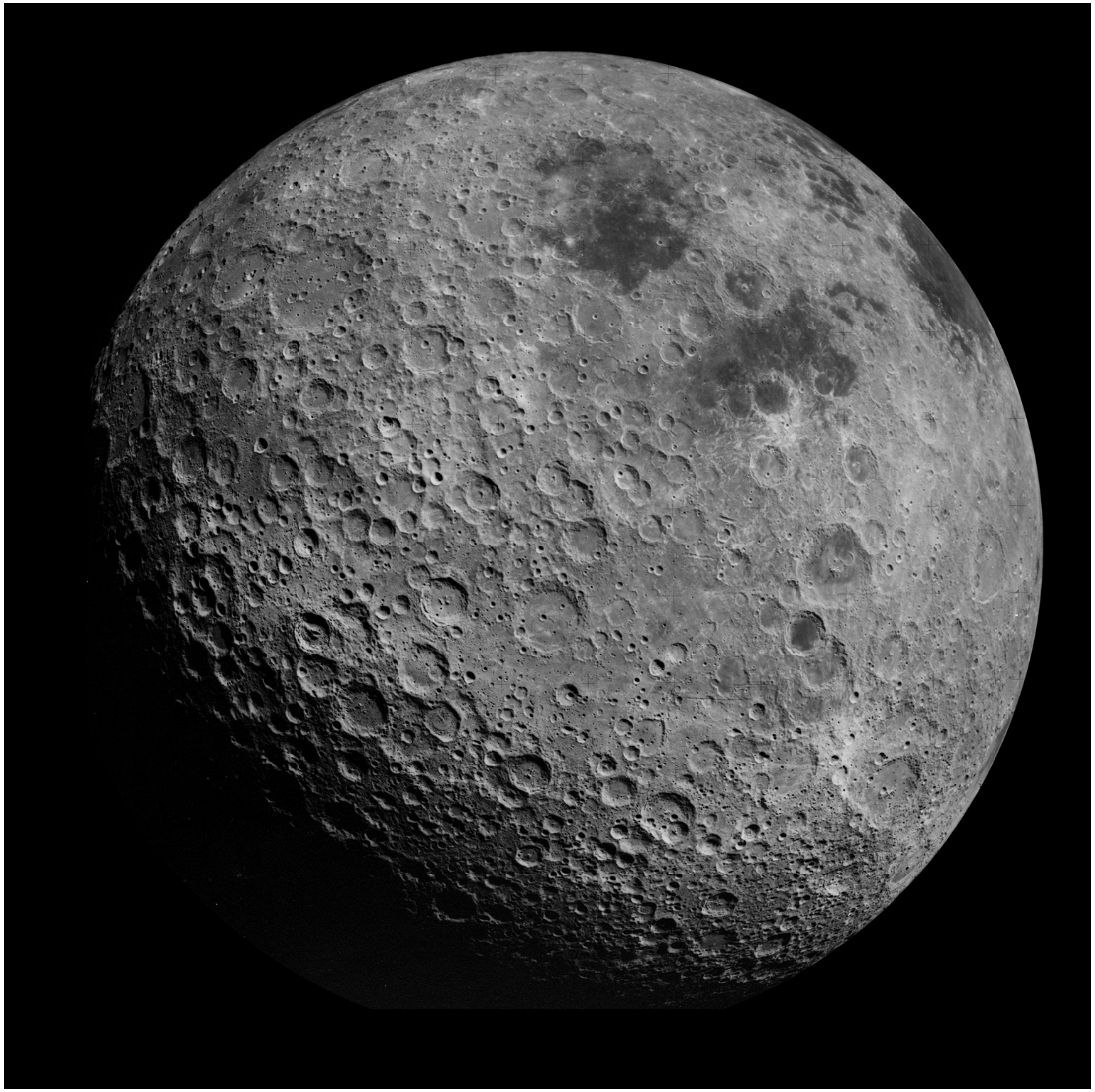
Group Q: Impact Cratering

- Here we have the dark side of the Moon.
- Open question for group discussion: what are the properties you see about the craters?
- Is this what you would expect from impacts?



Group Q: Impact Cratering

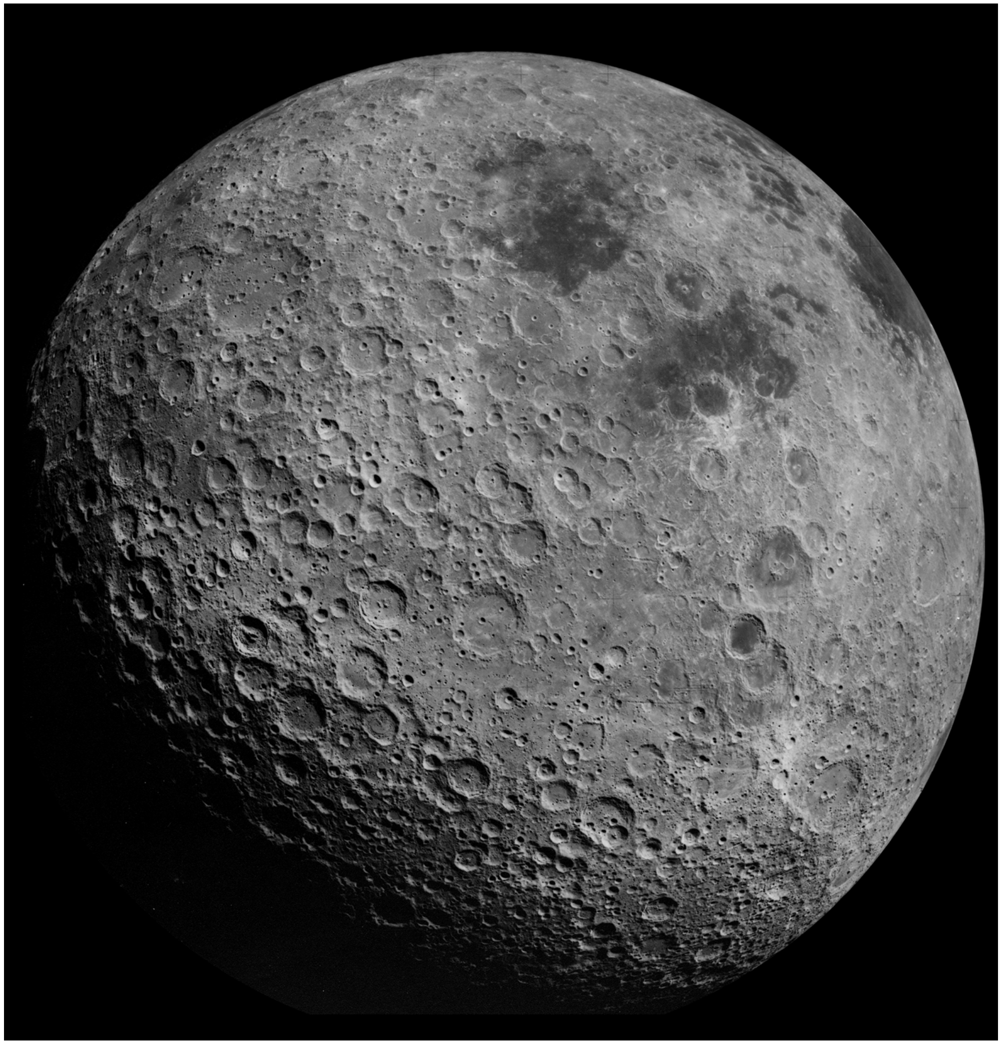
- Here we have the ***far*** side of the Moon.
- Open question for group discussion: what are the properties you see about the craters?
- Is this what you would expect from impacts?



Far side of the moon (photo credit on first slide)

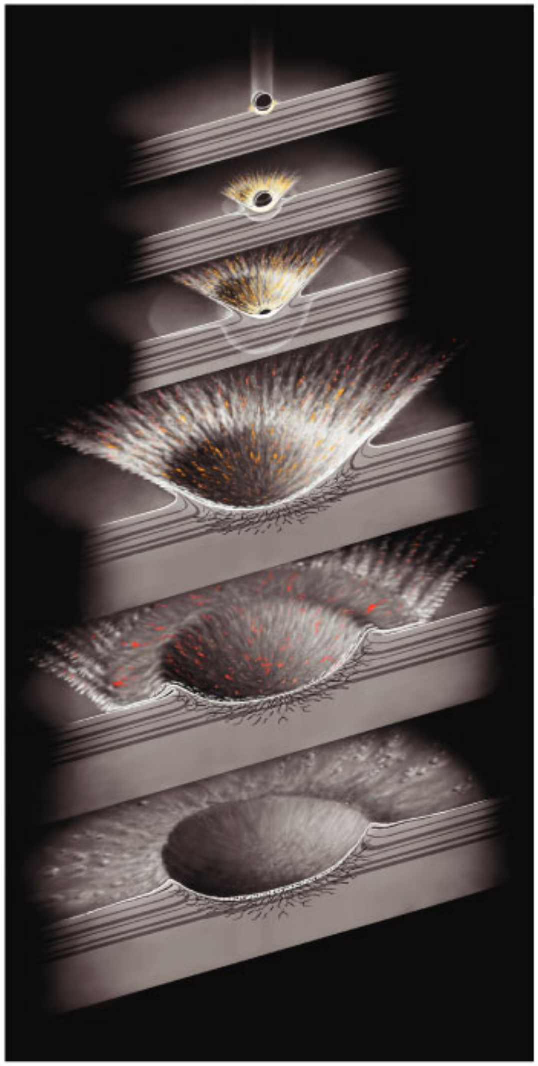
Group Q: Impact Cratering

- Here we have the far side of the Moon.
- Open question for group discussion: what are the properties you see about the craters?
- Is this what you would expect from impacts?
  All ~circular. Why no trenches? Oblique impacts?
- Apparent non-sequitor: it's because impact speed is much larger than sound speed
  Why does that explain it???



Far side of the moon (photo credit on first slide)

Impact Cratering



- Most cratering happened soon after the solar system formed.
- Craters are about 10 times wider than the objects that created them.
- Small craters greatly outnumber large craters.

Impact Cratering

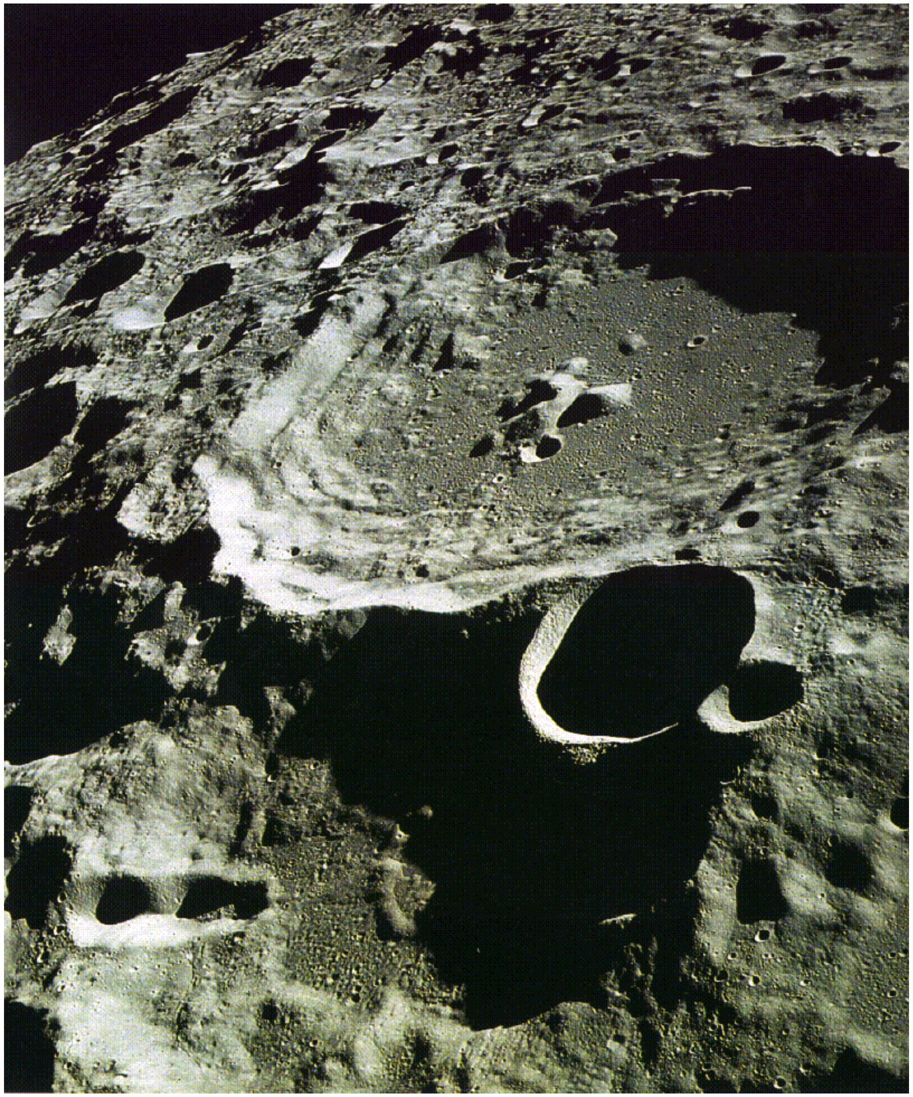
Barringer Meteorite Crater, Arizona

Impact Cratering

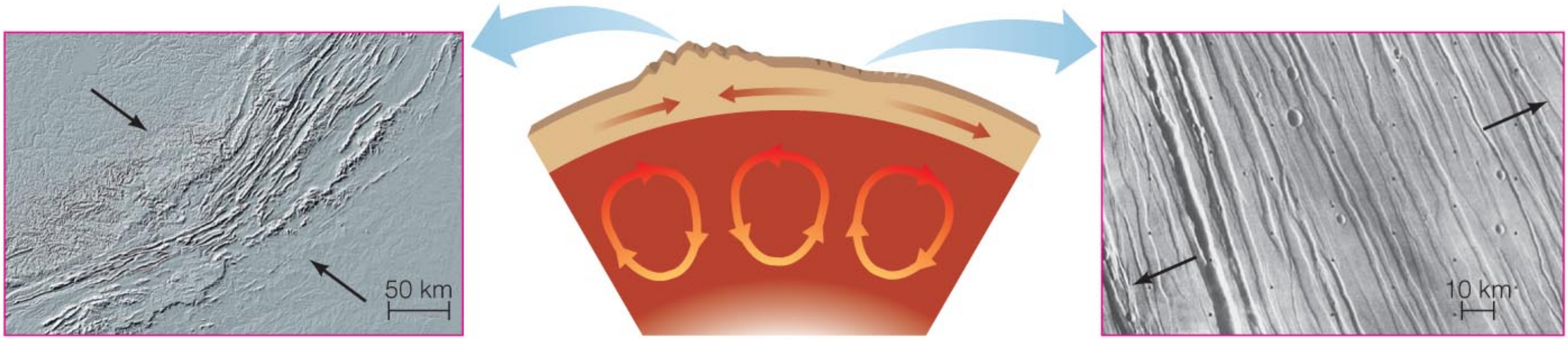
- Moon must be hit as often as Earth.
- Where are Earth's craters?
- Erased by volcanic activity and erosion.

The more craters, the older the surface.

Most cratering happened in the first billion years.



Tectonics



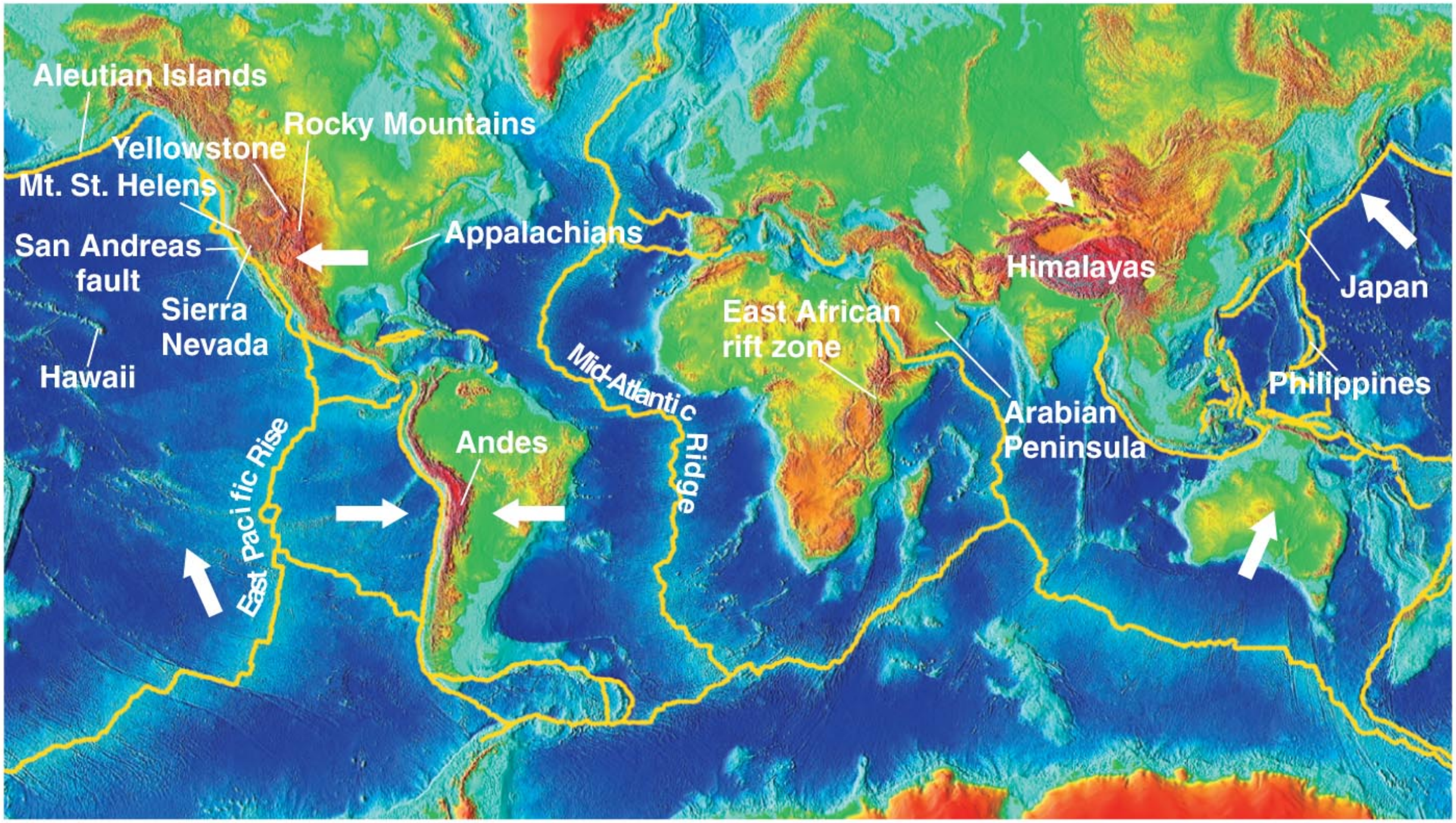
Appalachian Mountains in eastern United States

Ceraunius Valleys on Mars

- Convection of the mantle creates stresses in the crust called *tectonic* forces.
- Compression of crust makes mountain ranges.
- Valleys can form where the crust is pulled apart.

Plate Tectonics on Earth

- Earth's continents slide around on separate plates of crust.



Maximum height of Mountains

- Earth: 8.8 km
- Venus: 11 km; surface gravity 0.91 times Earth's
  8.8 km/0.91~10 km
- Mars: 22 km; surface gravity 0.38 times Earth's
  8.8 km/0.38~23 km
- Is it coincidence that the maximum height is roughly inversely proportional to surface gravity?
- No! Think about pressure: force per area. Force is mg. Mass per area is the density times the height. If the density is constant, and the maximum pressure is the same, then height x surface gravity = constant, so h~1/g.
  Why same max pressure? Strength limit of rock!
- Mercury, Moon, do not follow relation; suggests that they did ***not*** have mountains pushed up to limit (impacts, instead)