

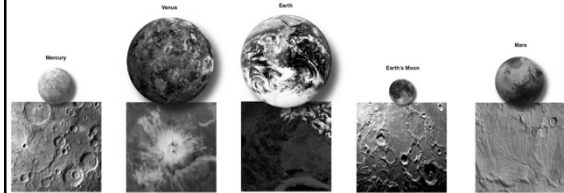
Chapter 9

Planetary Geology:

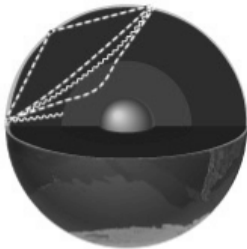
Earth and the Other Terrestrial Worlds



What are terrestrial planets like on the inside?

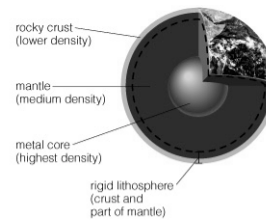


Seismic Waves



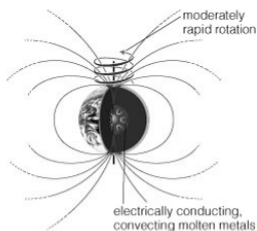
- Vibrations that travel through Earth's interior tell us what Earth is like on the inside

Earth's Interior



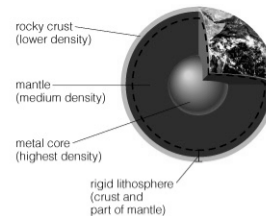
- **Core:** Highest density; nickel and iron
- Heavier atoms sunk to core by **differentiation**: gravity pulled high-density material to center while lower-density material rose to surface
- Solid inner core surrounded by liquid outer core

Source of Magnetic Field



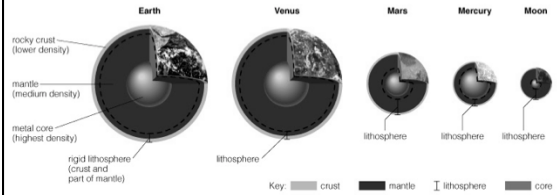
- Planet can have a magnetic field if charged particles are moving inside
- Need:
 - Molten interior
 - Convection (up-down)
 - Rotation

Earth's Interior



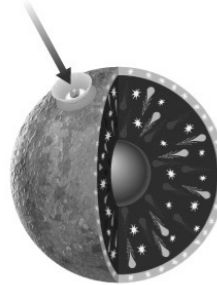
- **Mantle:** Moderate density; silicon, oxygen, etc.
- **Crust:** Lowest density; granite, basalt, etc.
- **Lithosphere:** outer layer of cool, rigid rock that "floats" on the warmer, softer rock beneath

Terrestrial Planet Interiors



- Other terrestrial planets have similar interiors
- Mercury has largest core (formed in hot part of nebula where iron may condense)

Heating of Interior



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

Cooling of Interior

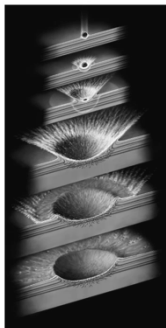


- **Convection** transports heat as hot material rises and cool material falls
- **Conduction** transfers heat from hot material to cool material
- **Radiation** sends energy into space

Processes that Shape Surfaces

- 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 Cratering

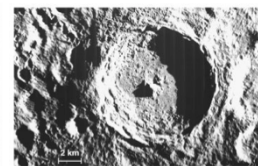


- Most cratering happened soon after Solar System formed
- Craters are about 10 times wider than object that made them
- Small craters greatly outnumber large ones

Impact Craters

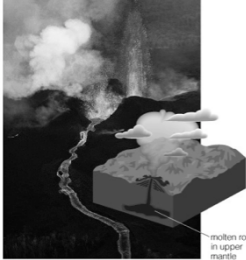


Meteor Crater (Arizona)



Tycho (Moon)

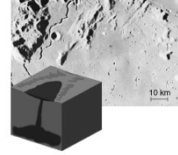
Volcanism



- Volcanism happens when molten rock (magma) finds a path through lithosphere to the surface
- Releases gases from interior into atmosphere (*outgassing*)
- Main source of water for oceans on Earth (originally from outer Solar System planetesimals?)

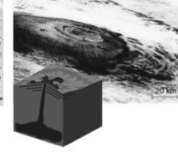
Lava and Volcanoes

Lava plains (maria) on the Moon



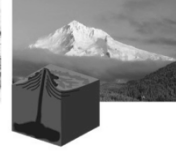
Runny lava → flat lava plains

Olympus Mons (Mars)



Thicker lava → broad *shield volcanoes*

Mount Hood (Earth)



Thickest lava → steep *stratovolcanoes*

Tectonics



- Convection of the mantle creates stresses in the crust
- Compression forces make mountain ranges
- Valley can form where crust is pulled apart
- Continents slide around on separate plates of crust

Erosion by Water



- Colorado River continues to carve Grand Canyon

Erosion by Ice



- Glaciers carved the Yosemite Valley

Erosion by Wind



- Wind wears away rock and builds up sand dunes

Differences: Planetary Size



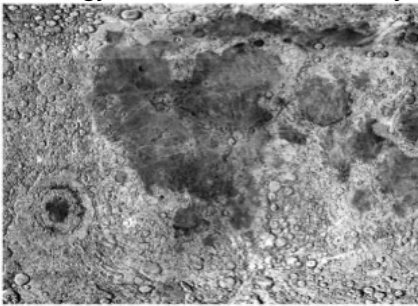
- Smaller worlds cool off faster, harden earlier
- Larger worlds remain warm inside, promoting volcanism and tectonics

Differences: Distance from Sun

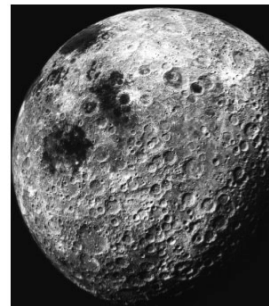


- Planets close to Sun are too hot for rain, snow, ice and so have less erosion
- Planets far from Sun are too cold for rain, limiting erosion

Small to Large Worlds: Geology of the Moon and Mercury

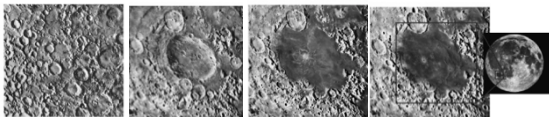


Cratering of Moon



- Some areas of Moon are more heavily cratered than others (ex. back side)
- Younger regions were flooded by lava after most cratering finished

Formation of Lunar Maria



Early surface covered with craters

Large impact crater weakens crust

Heat build-up allows lava to well up to surface

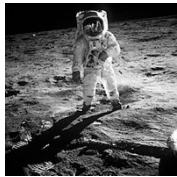
Cooled lava is smoother and darker than surroundings

Geological Processes Finished on Moon

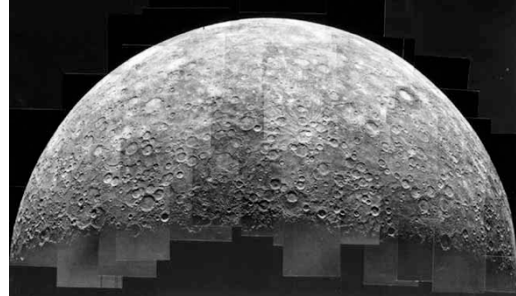


Apollo Missions to the Moon

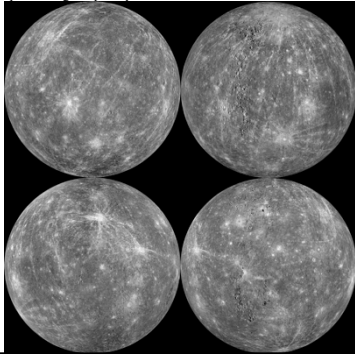
- Apollo 11 (1969) to 17 (1972)
- http://www.youtube.com/watch?v=DYDqB_G5PCo



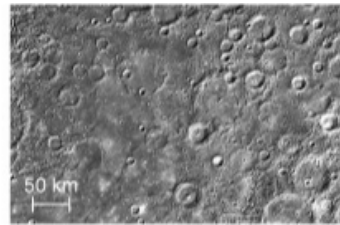
Similar Geology on Mercury



- NASA Messenger spacecraft in orbit
<http://messenger.jhuapl.edu/video/movie.html>
<http://apod.nasa.gov/apod/ap130805.html>

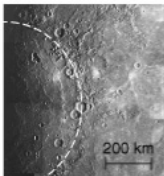


Cratering of Mercury

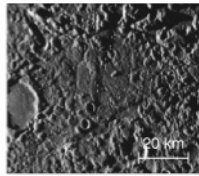


- Mixture of heavily cratered and smooth regions like the Moon
- Smooth regions are likely ancient lava flows

Cratering of Mercury

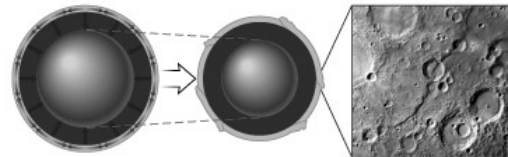


Caloris basin is largest impact crater on Mercury



Region opposite Caloris Basin is jumbled from seismic energy of impact

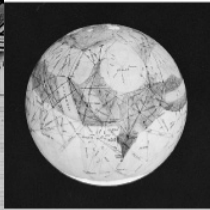
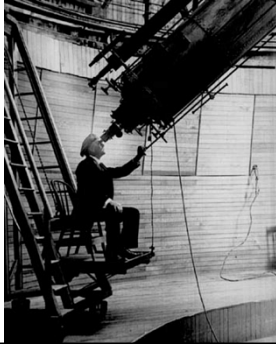
Tectonics on Mercury



Shrinkage not to scale!

- Long cliffs indicate that Mercury shrank early in its history

Geology of Mars - “Canals”?



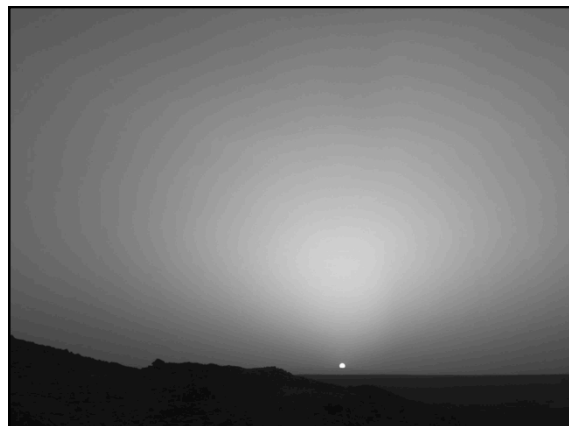
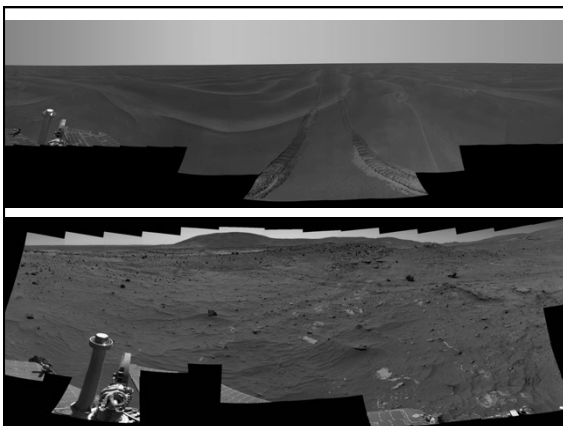
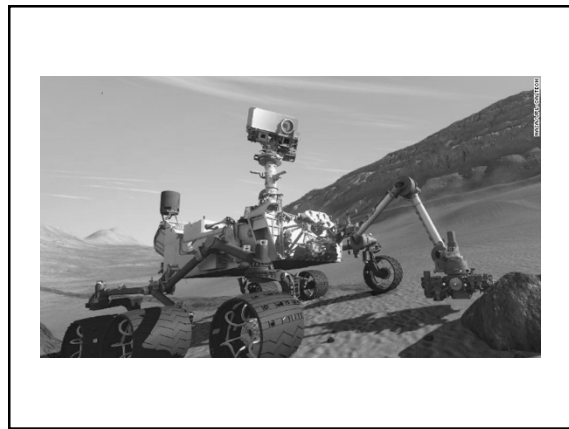
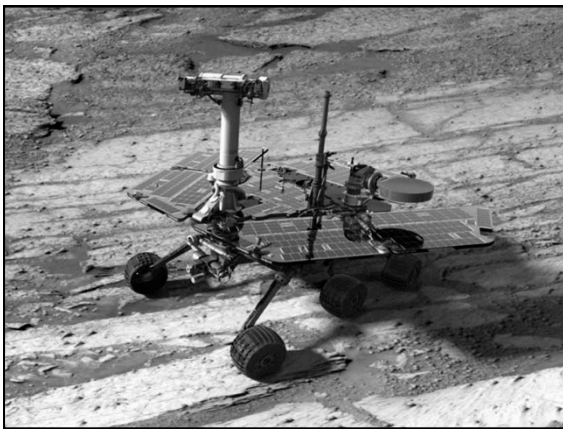
- Percival Lowell misinterpreted surface features seen in telescope

Missions to Mars

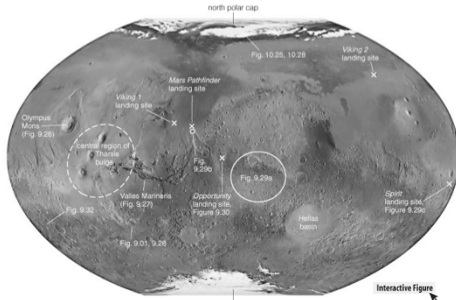
- Viking landers (1976)
- Mars Global Surveyor (1997)
- Mars Rovers
Spirit (2004-2010),
Opportunity (2004-present),
Curiosity (2012-present)



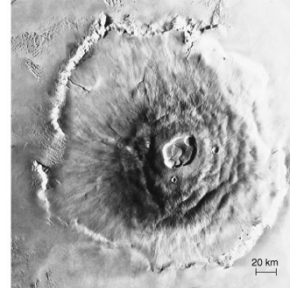
<http://www.amnh.org/explore/news-blogs/news-posts/happy-anniversary-curiosity?gclid=CJW7rlqevb0CFUYV7AodhGkArg>



Geological features of Mars from spacecraft observations



Volcanism on Mars



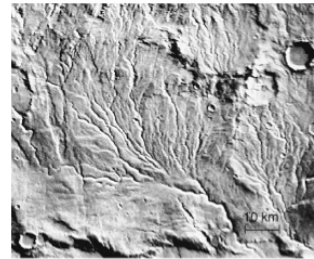
- Mars has many large shield volcanoes
- Olympus Mons is largest volcano in Solar System (26 km high)

Tectonics on Mars



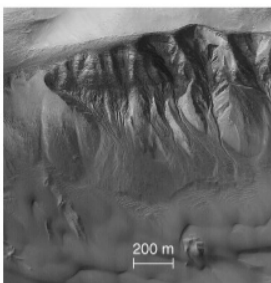
- System of valleys known as Valles Marineris thought to originate from tectonics

Evidence of past water: Dry Riverbeds



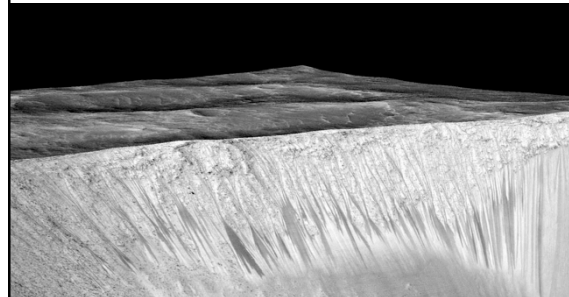
- Close-up photos of Mars show what appear to be dried-up riverbeds

Evidence of past water: Crater Walls

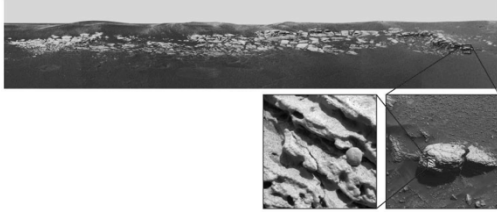


- Gullies on crater walls suggest occasional liquid water flows have happened less than a million years ago

Dark narrow streaks emanate from the walls of Gari Crater on Mars, in this view constructed from observations by the NASA's Mars Reconnaissance Orbiter: they darken and appear to flow down steep slopes during warm seasons, and then fade in cooler seasons.



Evidence of past water: Martian Rocks



- Mars rovers have found rocks that appear to have formed in water

Evidence of past water: Hydrogen Content

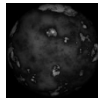


- Map of hydrogen content (blue) shows that low-lying areas contain more water ice
→ sites of ancient seas?

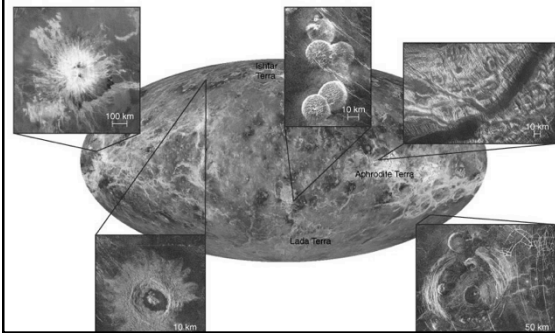
Geology of Venus



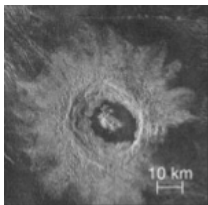
Radar mapping of features hidden by dense clouds:
Magellan (1990-1993)



Radar Mapping

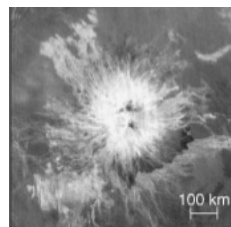


Cratering on Venus



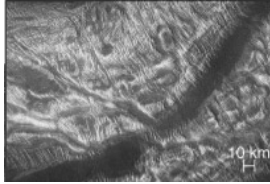
- Impact craters, but fewer than Moon, Mercury, Mars

Volcanoes on Venus



- Many volcanoes, including both shield volcanoes and stratovolcanoes

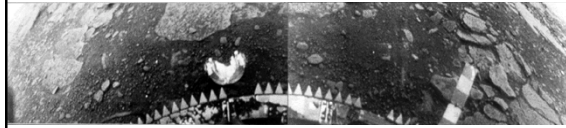
Tectonics on Venus



- Fractured and contorted surface indicates tectonic stresses

Erosion on Venus?

- Photos from hot surface made by Soviet *Venera 13* probe (1982) and others
- Photos show little erosion

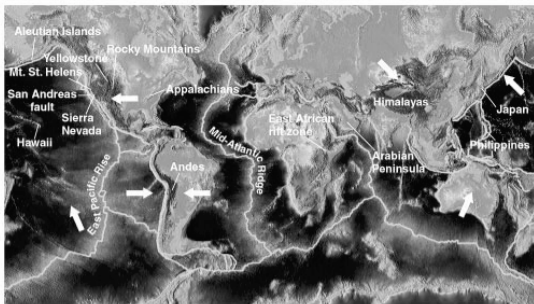


Does Venus have plate tectonics?

- Most of Earth's major geological features can be attributed to plate tectonics, which gradually remakes Earth's surface
- Venus does not appear to have plate tectonics, but entire surface seems to have been "repaved" 750 million years ago

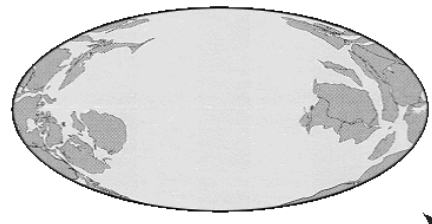
The Unique Geology of Earth

- Surface in motion
- Plate tectonics
- Was Earth's geology destined from birth?

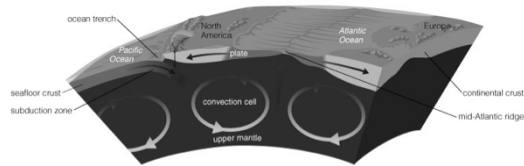


- Motion of continents can be measured with GPS (few cm per year)

Plate Tectonics for Last 750 Million Years

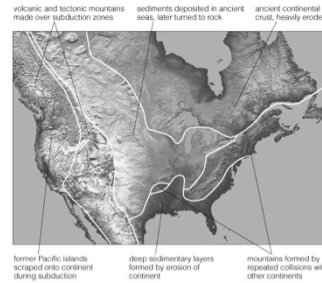


Seafloor Recycling



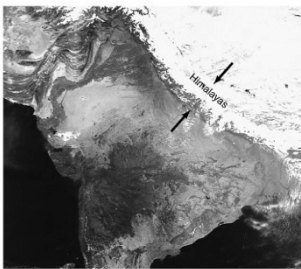
- Seafloor is recycled through a process known as subduction

Surface Features



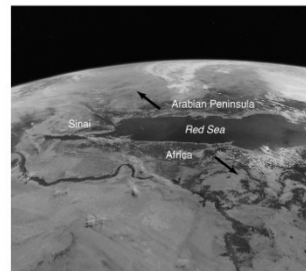
- Major geological features of North America record history of plate tectonics

Surface Features



- Himalayas are forming from a collision between plates

Surface Features



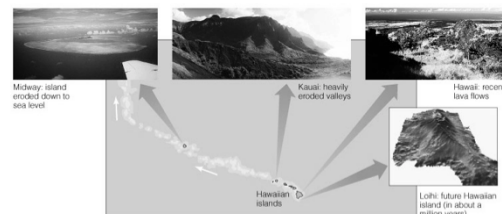
- Red Sea is forming where plates are pulling apart

Rifts, Faults, Earthquakes



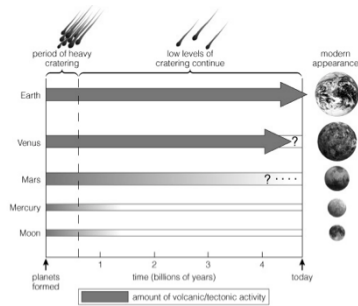
- San Andreas fault in California is a plate boundary
- Motion of plates causes earthquakes

Hot Spots



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

Earth's geological destiny



Next time:

- Chapter 10:
Planetary Atmospheres
please read pages 270 – 302
[especially 295 – 302]
in text.