

Chapter 9

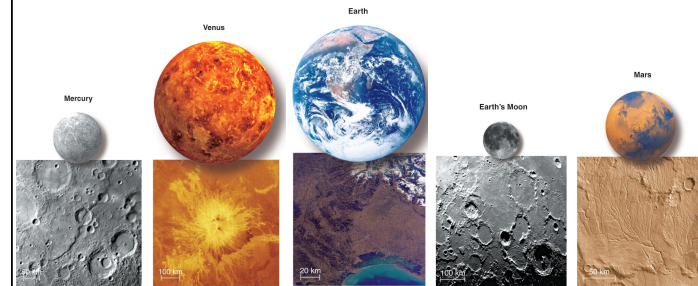
Planetary Geology

Earth and the Other Terrestrial Worlds



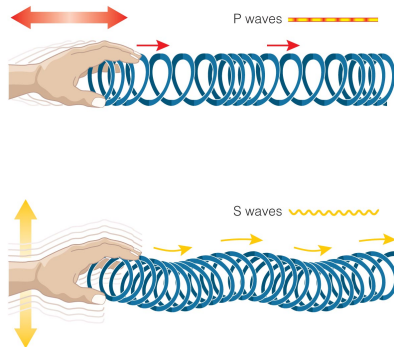
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What are terrestrial planets like on the inside?



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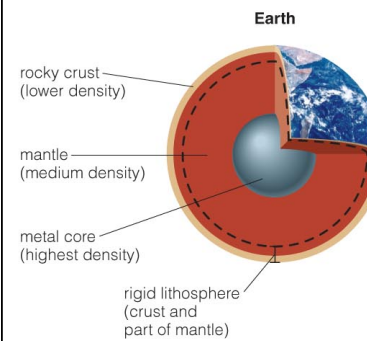
Seismic Waves



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

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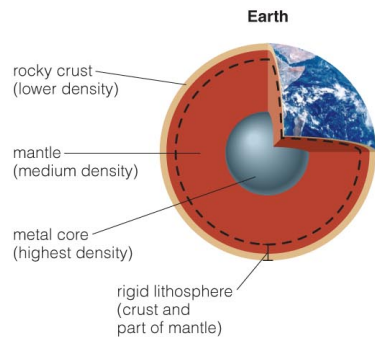
Earth's Interior



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

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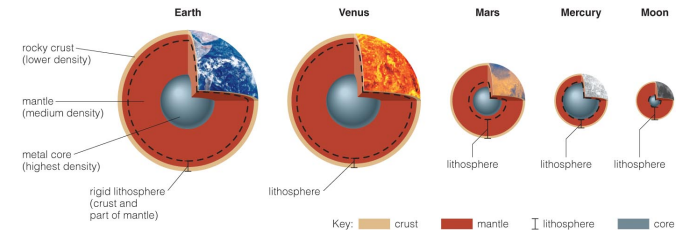
Lithosphere



- A planet's outer layer of cool, rigid rock is called the lithosphere
- It "floats" on the warmer, softer rock that lies beneath

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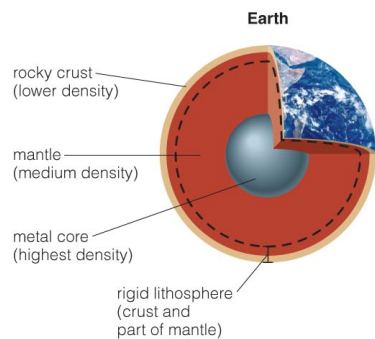
Terrestrial Planet Interiors



- Applying what we have learned about Earth's interior to other planets tells us what their interiors are probably like

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Differentiation



- Planet starts out hot and molten.
- Gravity pulls high-density material to center
- Lower-density material rises to surface
- Material ends up separated by density

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Thought Question

What is necessary for *differentiation* to occur in a planet?

- It must have metal and rock in it
- It must be a mix of materials of different density
- Material inside must be able to flow
- All of the above
- b and c

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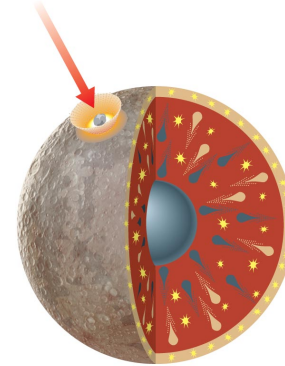
Thought Question

What is necessary for *differentiation* to occur in a planet?

- a) It must have metal and rock in it
- b) It must be a mix of materials of different density
- c) Material inside must be able to flow
- d) All of the above
- e) b and c

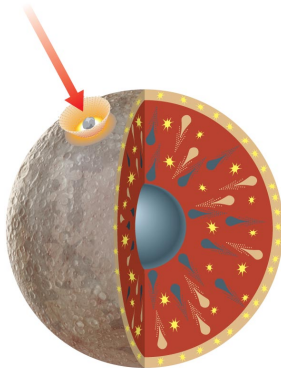
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What causes geological activity?



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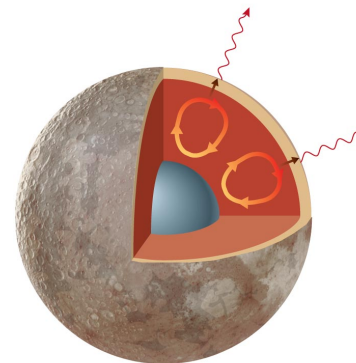
Heating of Interior



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

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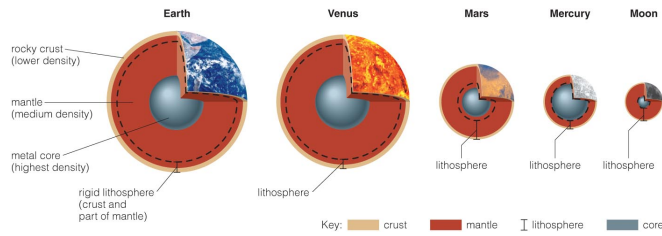
Cooling of Interior



- **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

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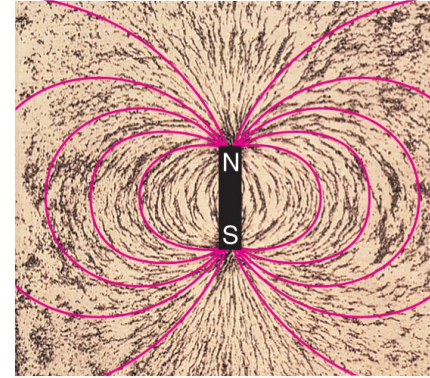
Role of Size



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

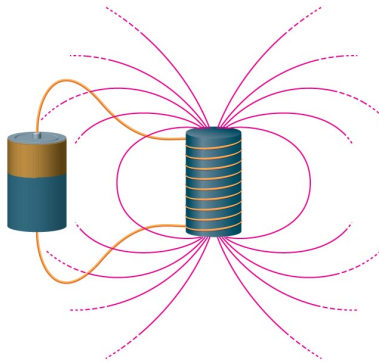
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Why do some planetary interiors create magnetic fields?



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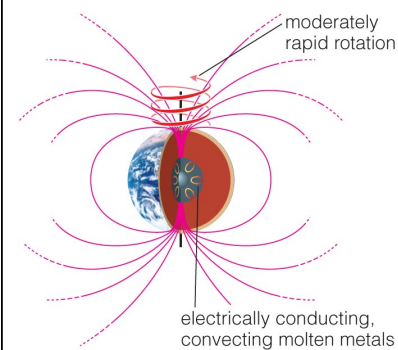
Sources of Magnetic Fields



- Motions of charged particles are what create magnetic fields

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Sources of Magnetic Fields



- A world can have a magnetic field if charged particles are moving inside
- 3 requirements:
 - Molten interior
 - Convection
 - Moderately rapid rotation

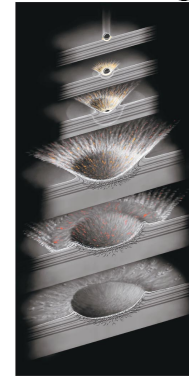
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Processes that Shape Surfaces

- 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

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Impact Cratering



Interactive Figure

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- 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



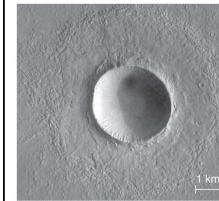
Meteor Crater (Arizona)



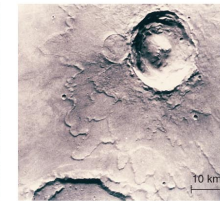
Tycho (Moon)

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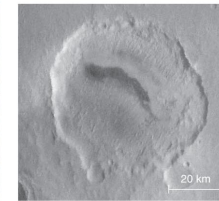
Impact Craters on Mars



"standard" crater



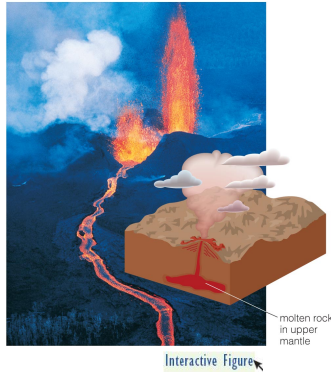
impact into icy ground



eroded crater

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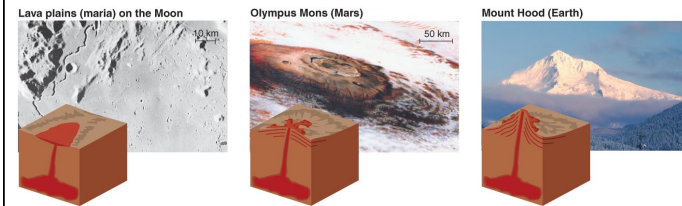
Volcanism



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

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Lava and Volcanoes



Runny lava makes flat lava plains

Slightly thicker lava makes broad *shield volcanoes*

Thickest lava makes steep *stratovolcanoes*

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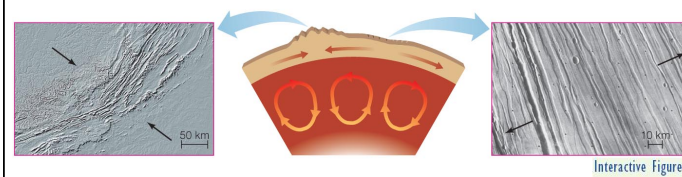
Outgassing



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

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Tectonics



- Convection of the mantle creates stresses in the crust called tectonic forces
- Compression forces make mountain ranges
- Valley can form where crust is pulled apart

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Plate Tectonics on Earth



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

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Erosion

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

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Erosion by Water



- Colorado River continues to carve Grand Canyon

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Erosion by Ice



- Glaciers carved the Yosemite Valley

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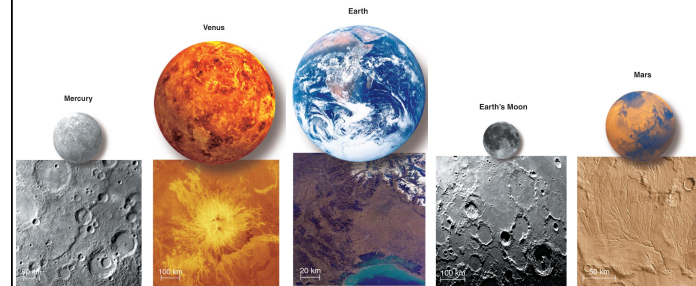
Erosion by Wind



- Wind wears away rock and builds up sand dunes

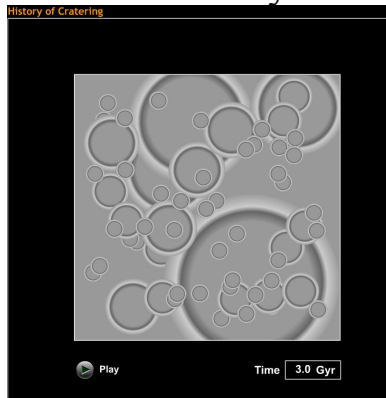
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How do impact craters reveal a surface's geological age?



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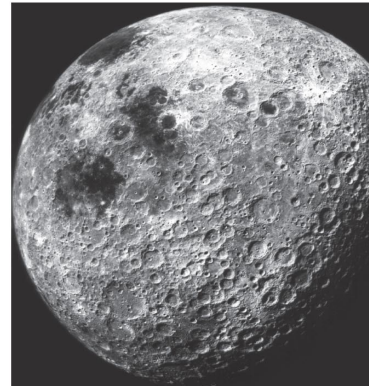
History of Cratering



- Most cratering happened in first billion years
- A surface with many craters has not changed much in 3 billion years

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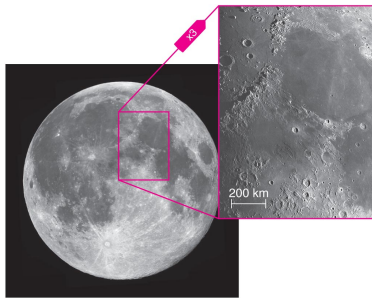
Cratering of Moon



- Some areas of Moon are more heavily cratered than others
- Younger regions were flooded by lava after most cratering

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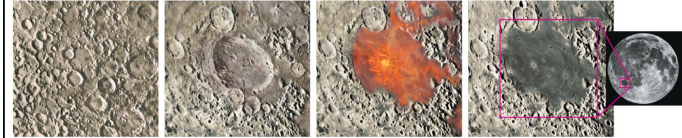
Lunar Maria



- Smooth, dark lunar maria are less heavily cratered than lunar highlands
- Maria were made by flood of runny lava

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Formation of Lunar Maria



Early surface covered with craters

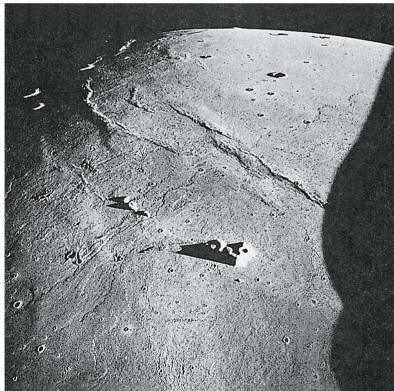
Large impact crater weakens crust

Heat build-up allows lava to well up to surface

Cooled lava is smoother and darker than surroundings

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Tectonic Features



- Wrinkles arise from cooling and contraction of lava flood

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Geologically Dead



- Moon is considered geologically "dead" because geological processes have virtually stopped

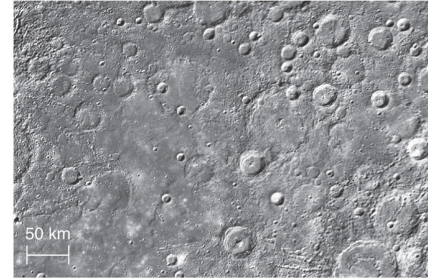
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What geological processes shaped Mercury?



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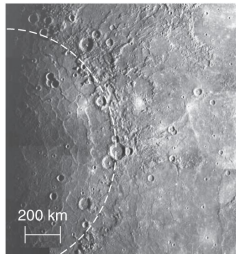
Cratering of Mercury



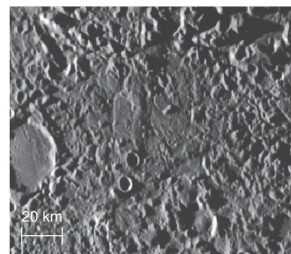
- A mixture of heavily cratered and smooth regions like the Moon
- Smooth regions are likely ancient lava flows

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Cratering of Mercury



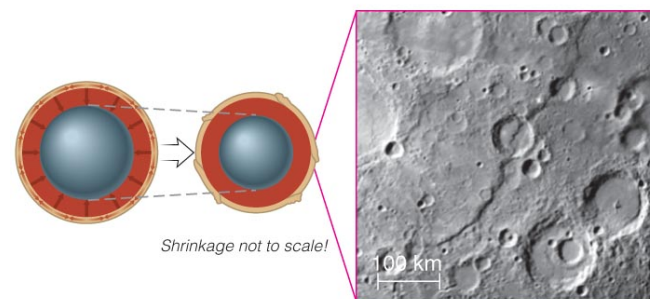
Caloris basin is largest impact crater on Mercury



Region opposite Caloris Basin is jumbled from seismic energy of impact

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Tectonics on Mercury

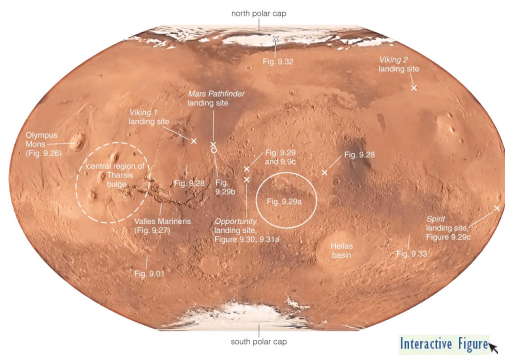


Shrinkage not to scale!

- Long cliffs indicate that Mercury shrank early in its history

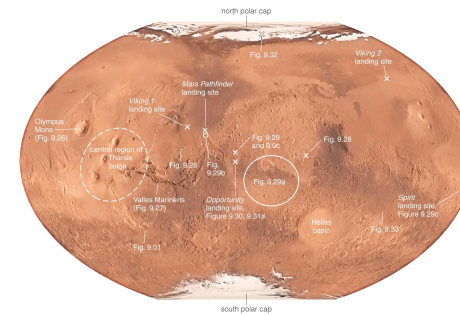
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What are the major geological features of Mars?



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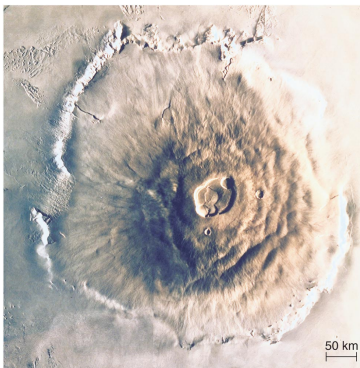
Cratering on Mars



- Amount of cratering differs greatly across surface
- Many early craters have been erased

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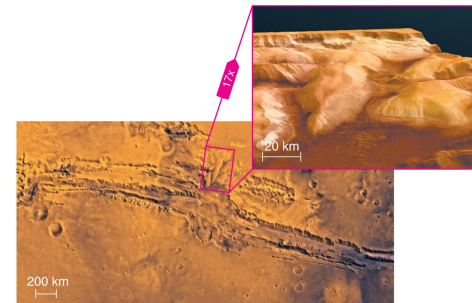
Volcanism on Mars



- Mars has many large shield volcanoes
- Olympus Mons is largest volcano in solar system

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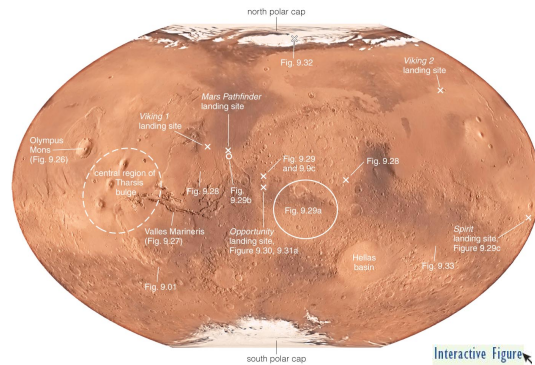
Tectonics on Mars



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

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What geological evidence tells us that water once flowed on Mars?



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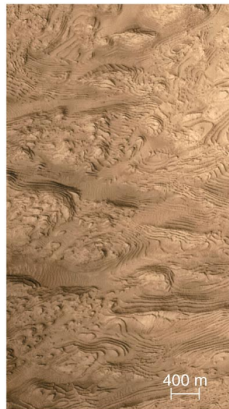
Dry Riverbeds



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

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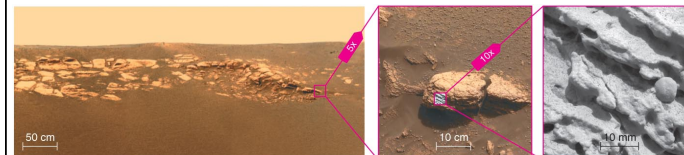
Erosion of Craters



- Details of some craters suggest they were once filled with water

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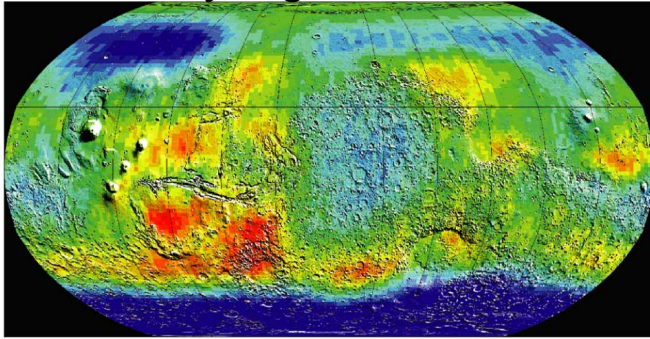
Martian Rocks



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

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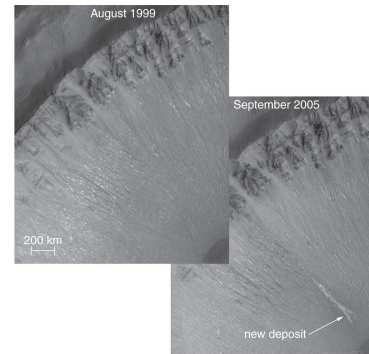
Hydrogen Content



- Map of hydrogen content (blue) shows that low-lying areas contain more water ice underneath surface

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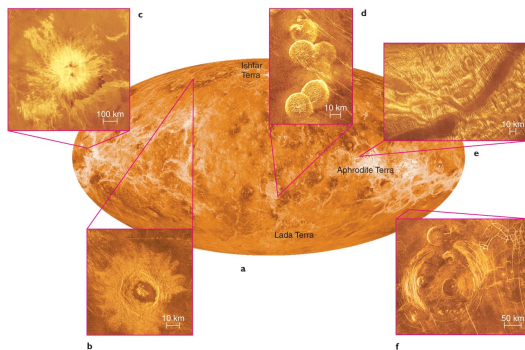
Crater Walls



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

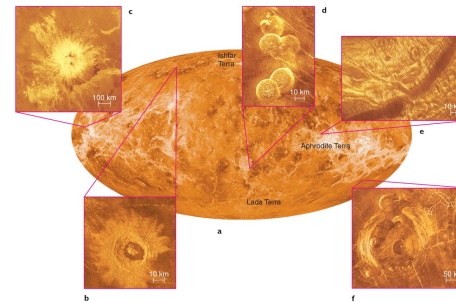
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What are the major geological features of Venus?



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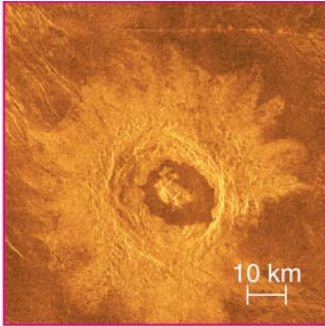
Radar Mapping



- Thick atmosphere forces us to explore Venus' surface through radar mapping

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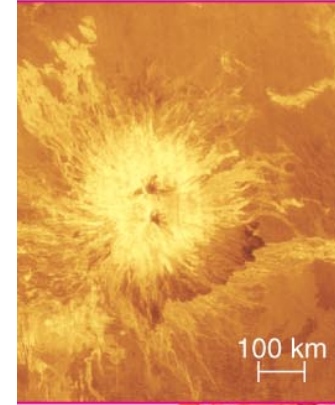
Cratering on Venus



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

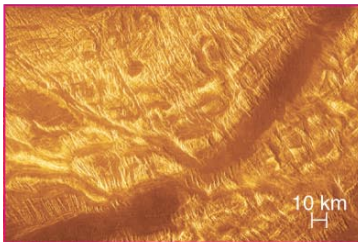
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Volcanoes on Venus



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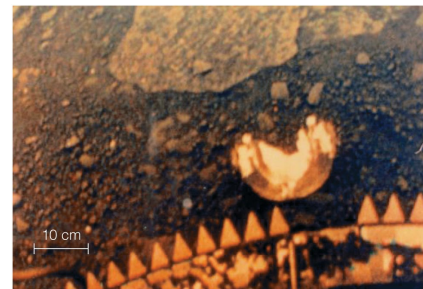
Tectonics on Venus



- Fractured and contorted surface indicates tectonic stresses

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Erosion on Venus



- Photos of rocks taken by lander show little erosion

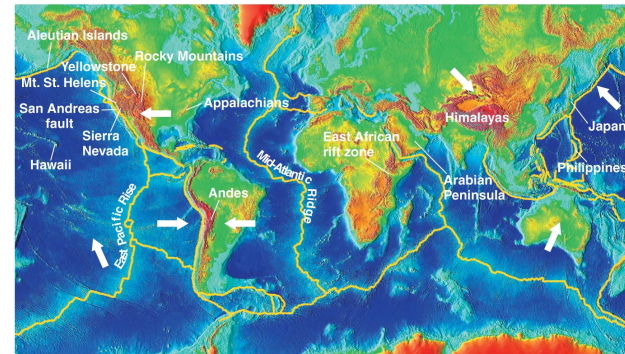
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Does Venus have plate tectonics?

- 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

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How do we know Earth's surface is in motion?



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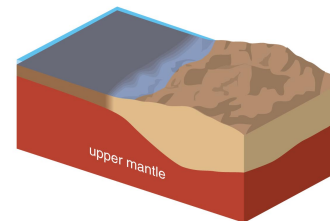
Continental Motion



- Idea of continental drift was inspired by puzzle-like fit of continents
- Mantle material erupts where seafloor spreads

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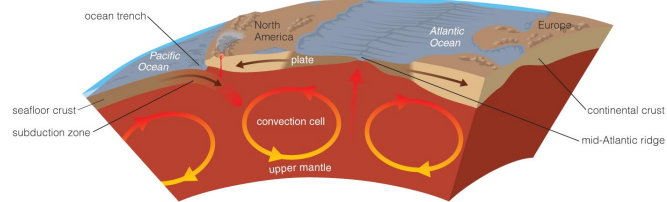
Seafloor Crust



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

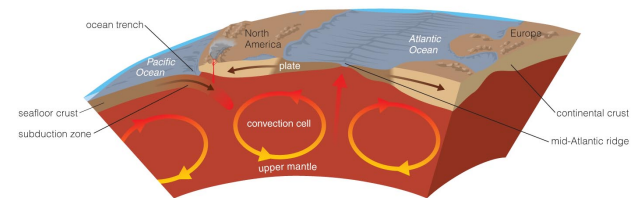
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How is Earth's surface shaped by plate tectonics?



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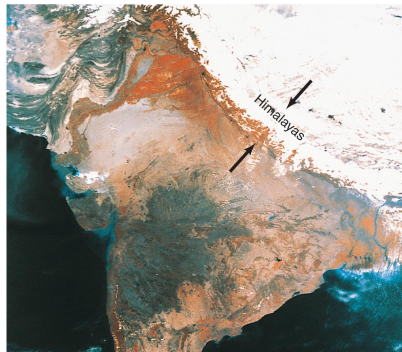
Seafloor Recycling



- Seafloor is recycled through a process known as subduction

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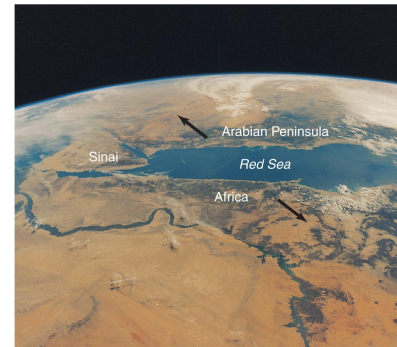
Surface Features



- Himalayas are forming from a collision between plates

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Surface Features



- Red Sea is forming where plates are pulling apart

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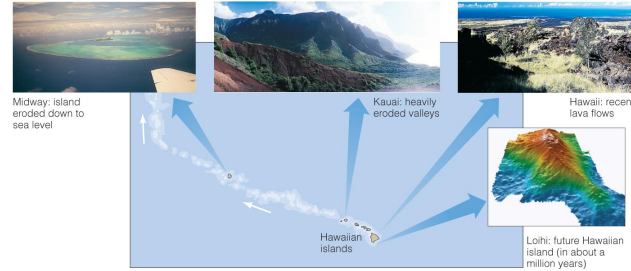
Rifts, Faults, Earthquakes



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

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Hot Spots



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

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