

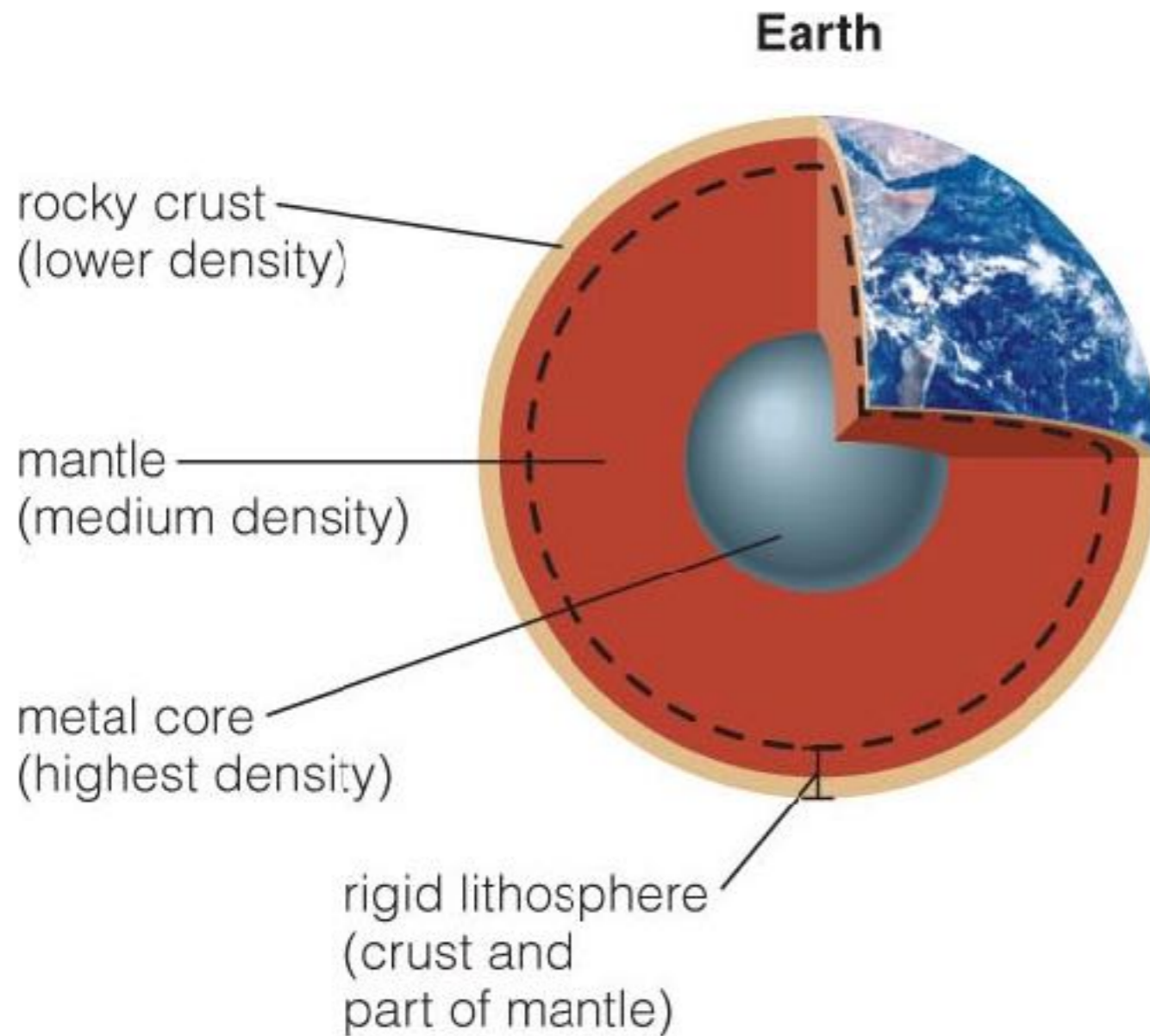
Today

- Terrestrial Planet Geology

Events

- Fall break next week
- no class Tuesday

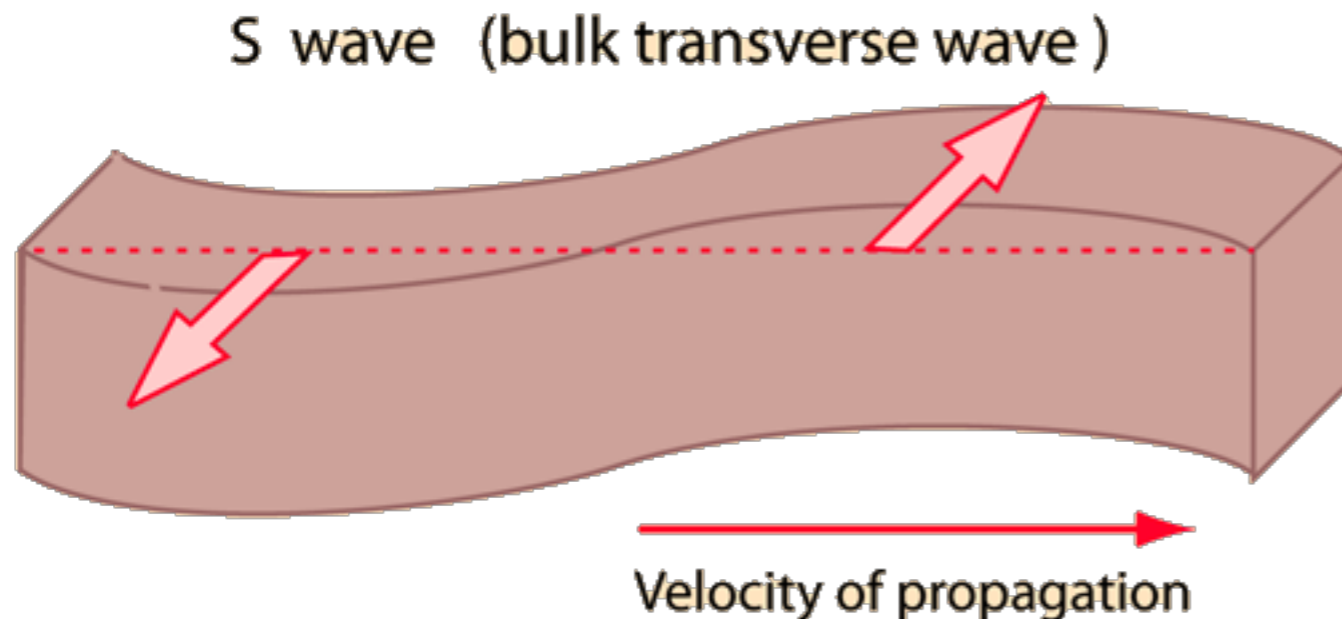
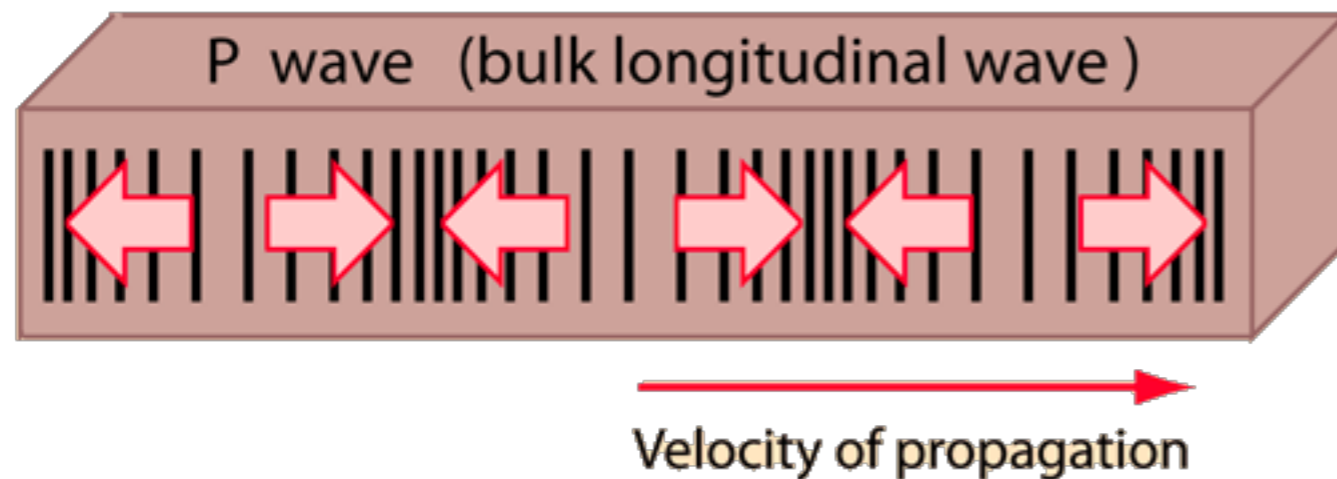
Lithosphere



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

Seismic waves

How do we know what's inside Earth?



- **P waves** (primary) compressional.
 - fast propagation
 - traverse all material
- **S waves** (secondary) transverse shear.
 - slower propagation
 - do not travel through liquid or gas

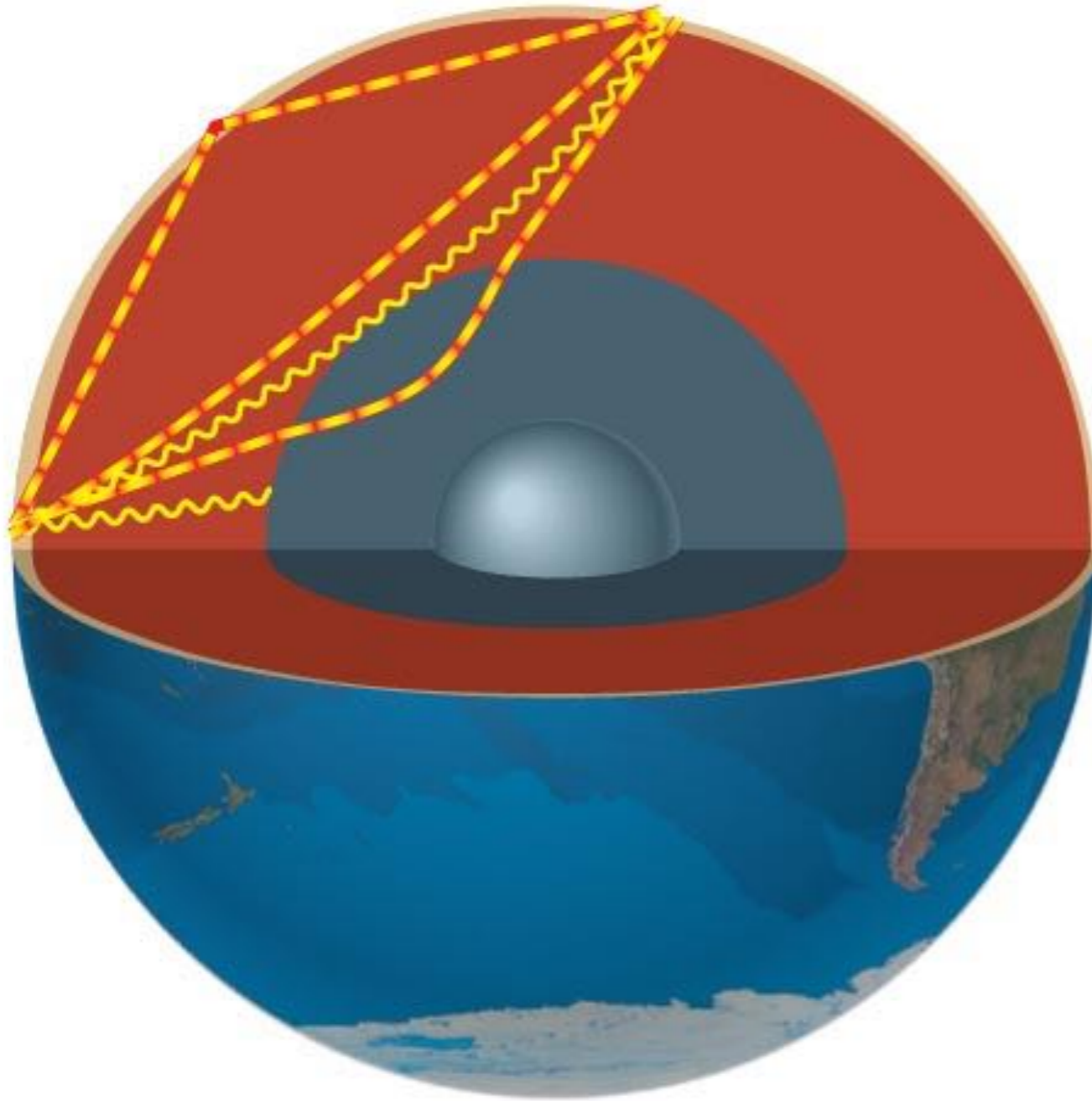
4 September 2010 mag. 7.1 Canterbury earthquake
in New Zealand.





Seismic waves

How do we know what's inside Earth?



- P waves go through Earth's core, but S waves do not.
- Earth's core has a liquid outer layer that reflects S waves & refracts P waves.

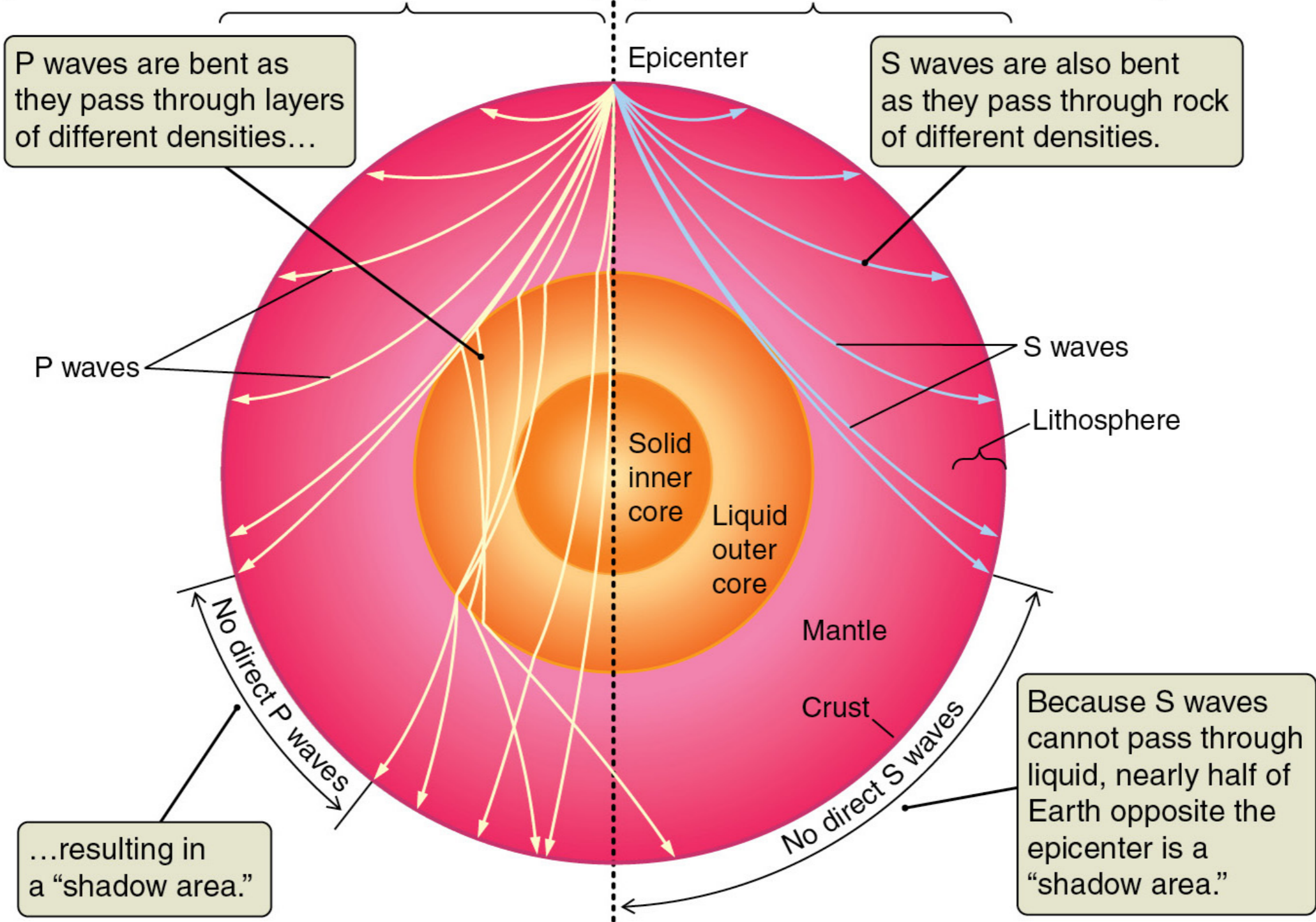
For clarity, each type of wave is shown on one-half of Earth.

Primary waves (P waves)
Longitudinal waves result from alternating compression and decompression, like a spring. They travel through solid and liquid.

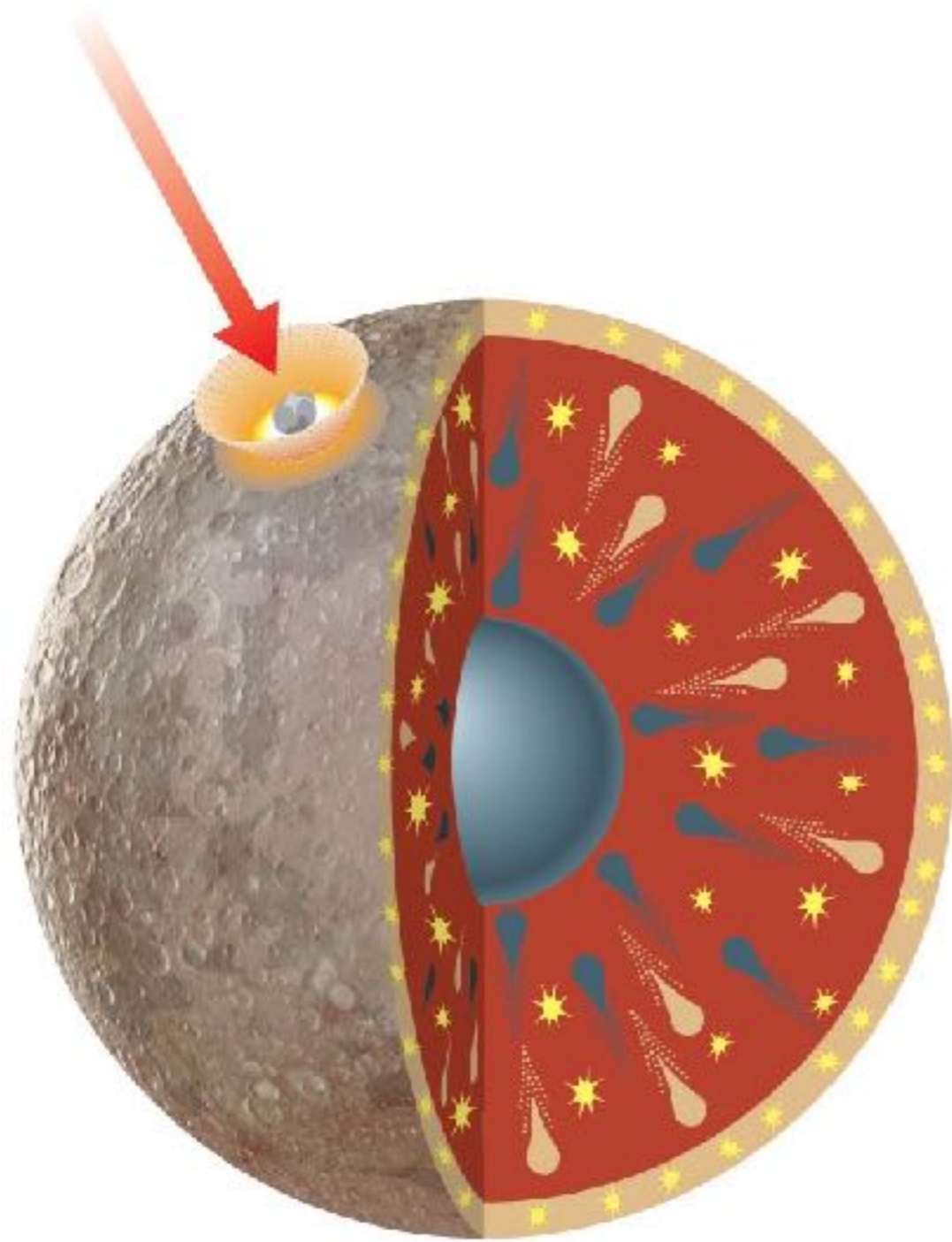
Secondary waves (S waves)
Transverse waves are like the waves that move along the length of a string. They cannot pass through liquids.

P waves are bent as they pass through layers of different densities...

S waves are also bent as they pass through rock of different densities.



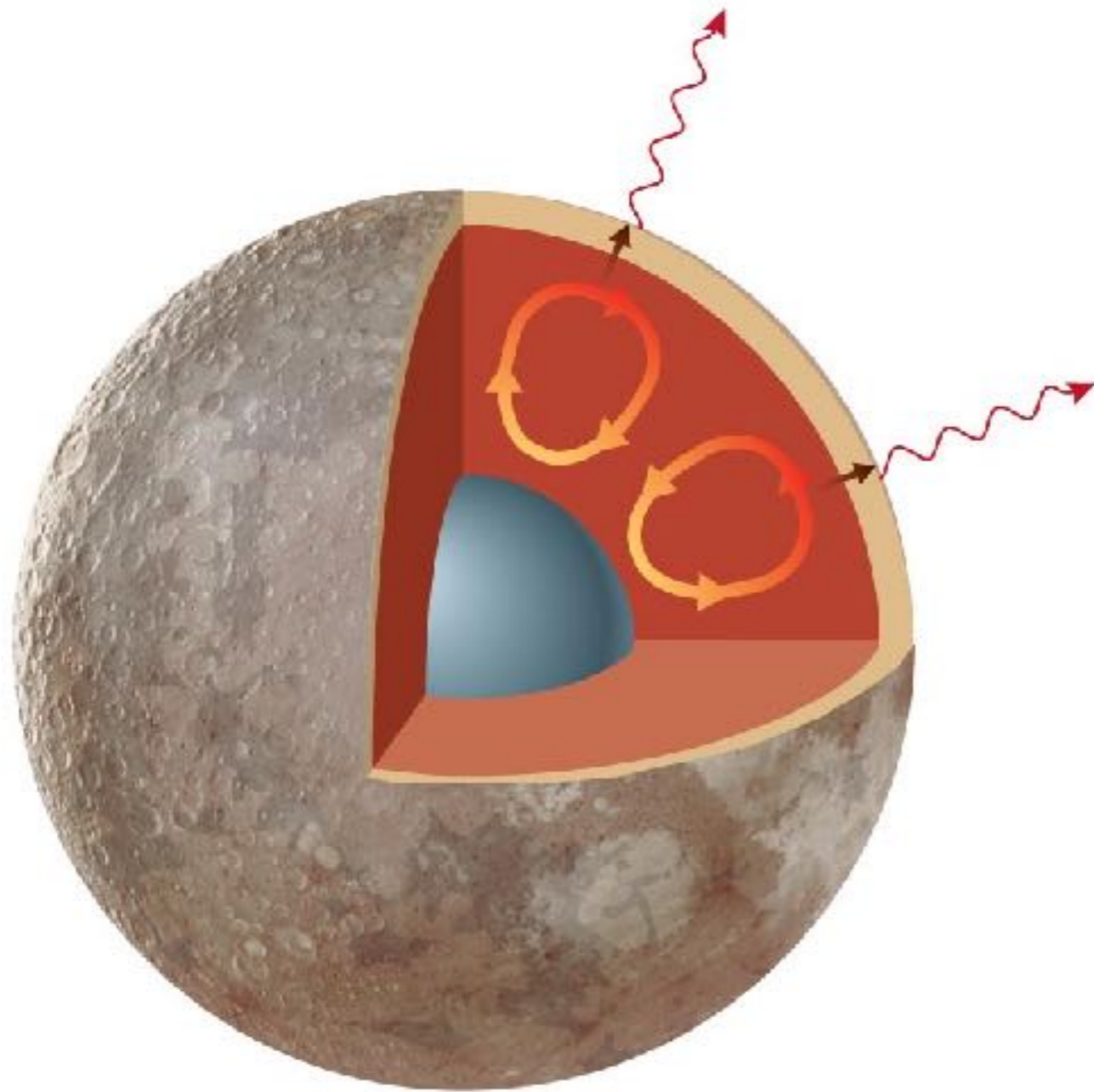
Heating of Planetary Interiors



- Accretion and differentiation when planets were young
 - Heat of formation
 - Differentiation releases gravitational energy as dense material sinks
- Radioactive decay is most important heat source today.
 - Long lasting energy source from trapped radioactive material

Heat drives geological activity

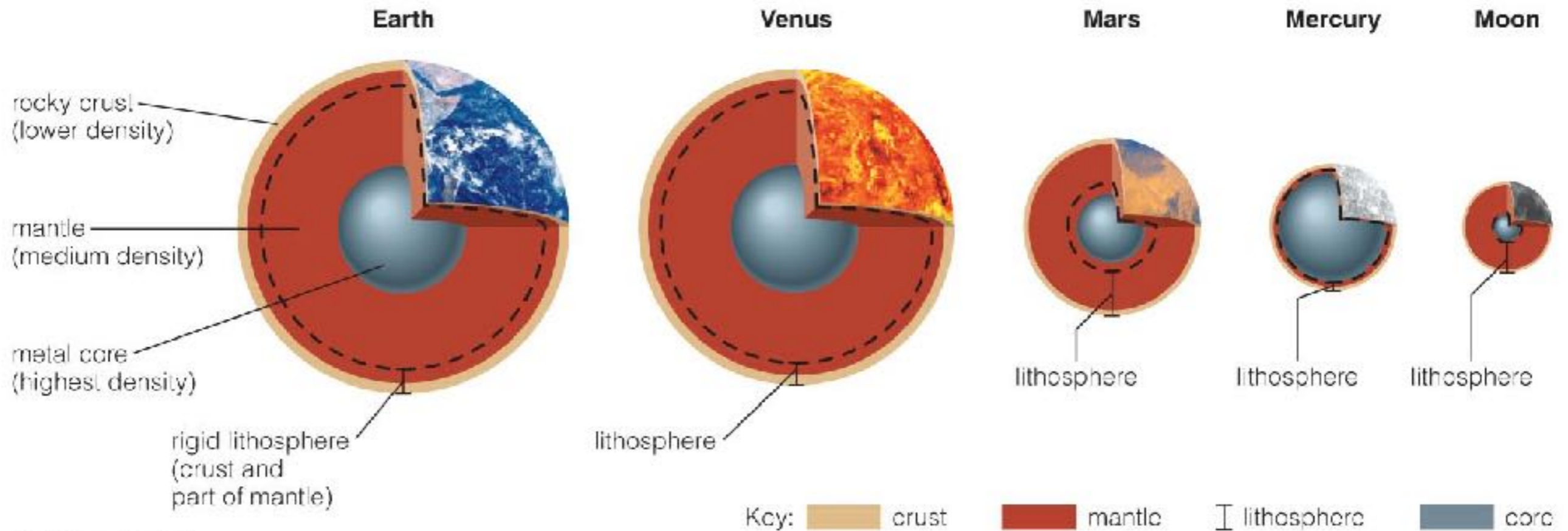
Cooling of Planetary Interiors



- 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.

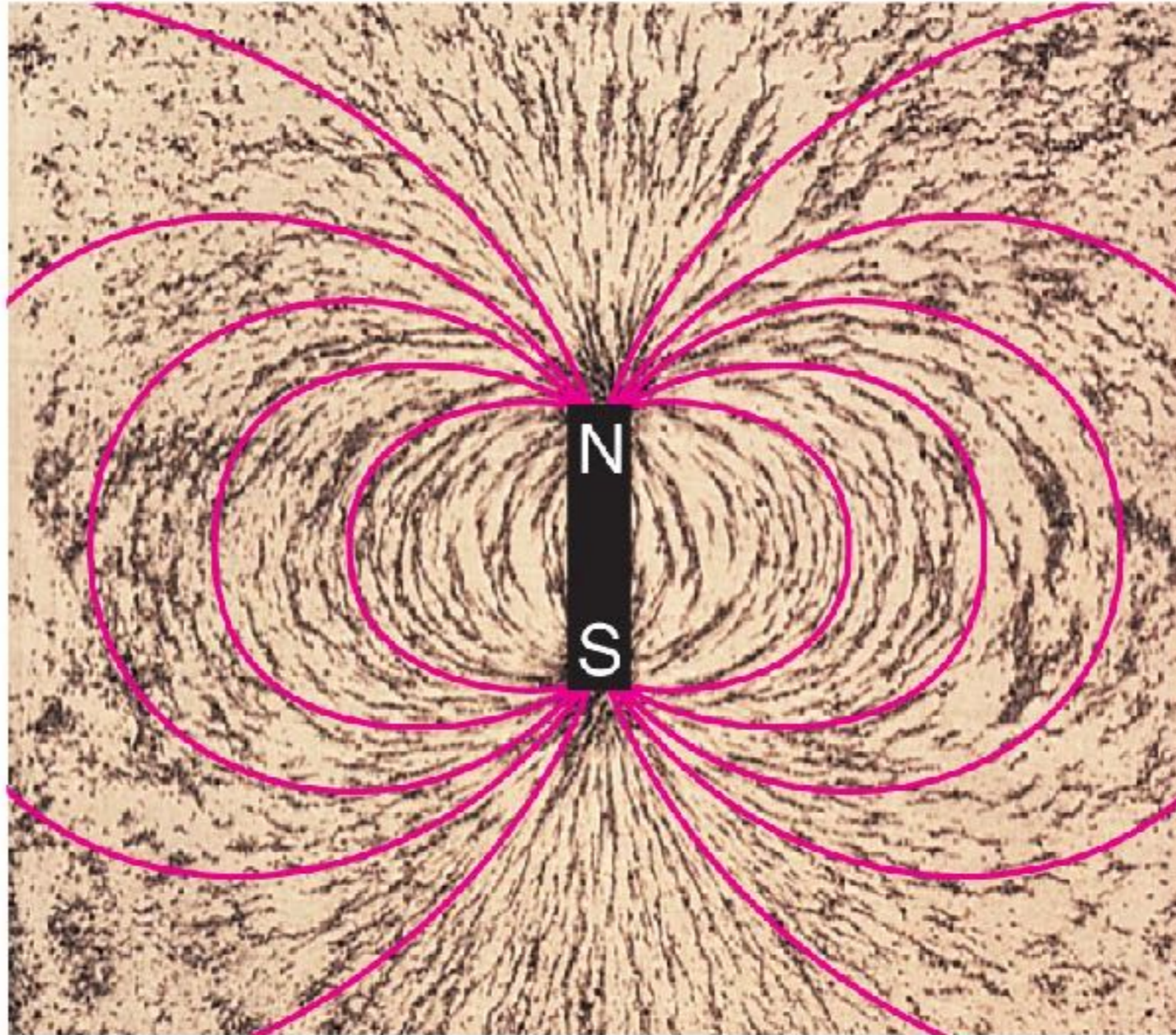
Heat drives geological activity

Role of Size

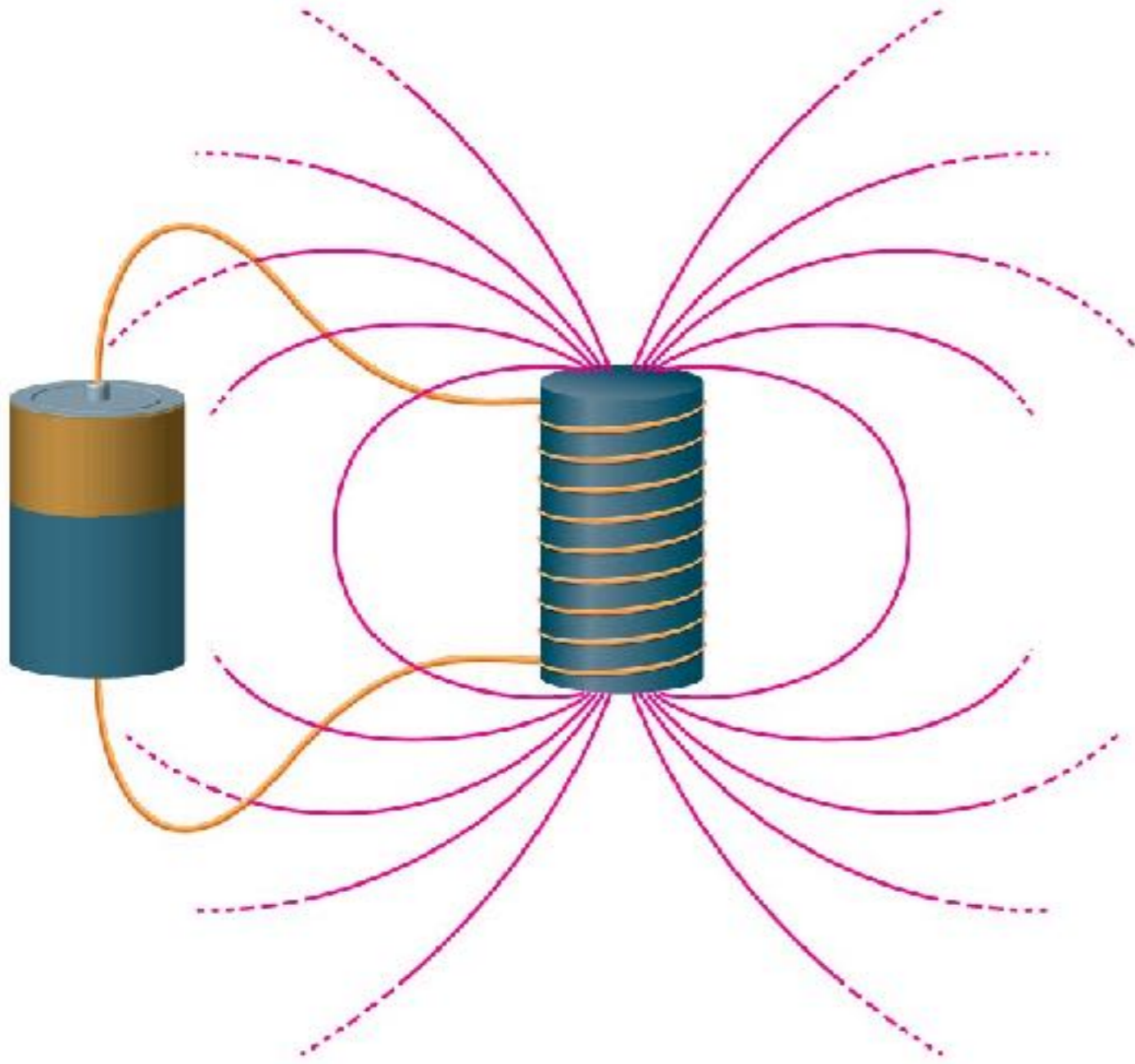


- Smaller worlds cool off faster and harden earlier.
 - cooling time depends on surface area/volume ratio
- The Moon and Mercury are now geologically "dead."

Planetary magnetic fields

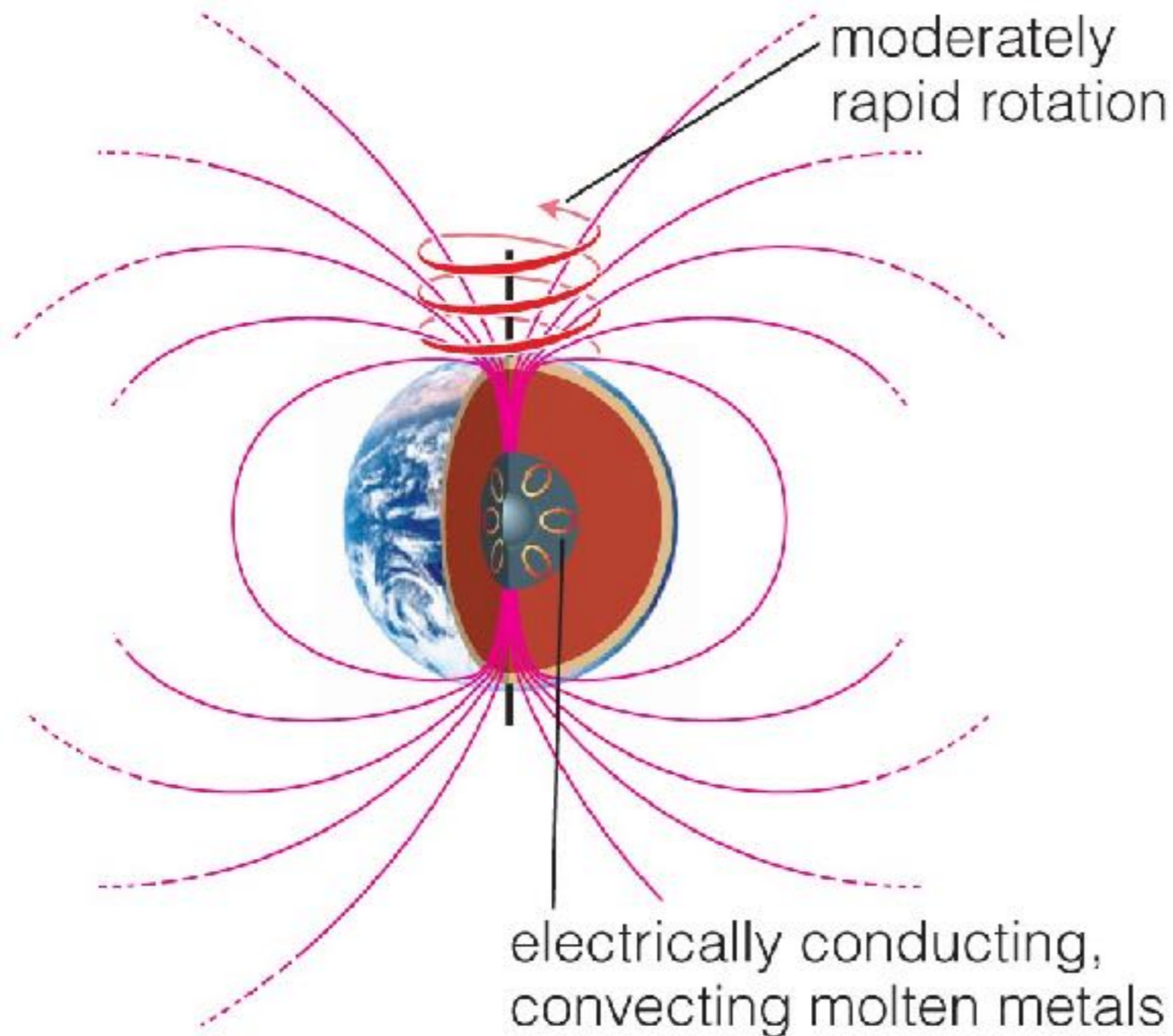


Sources of Magnetic Fields



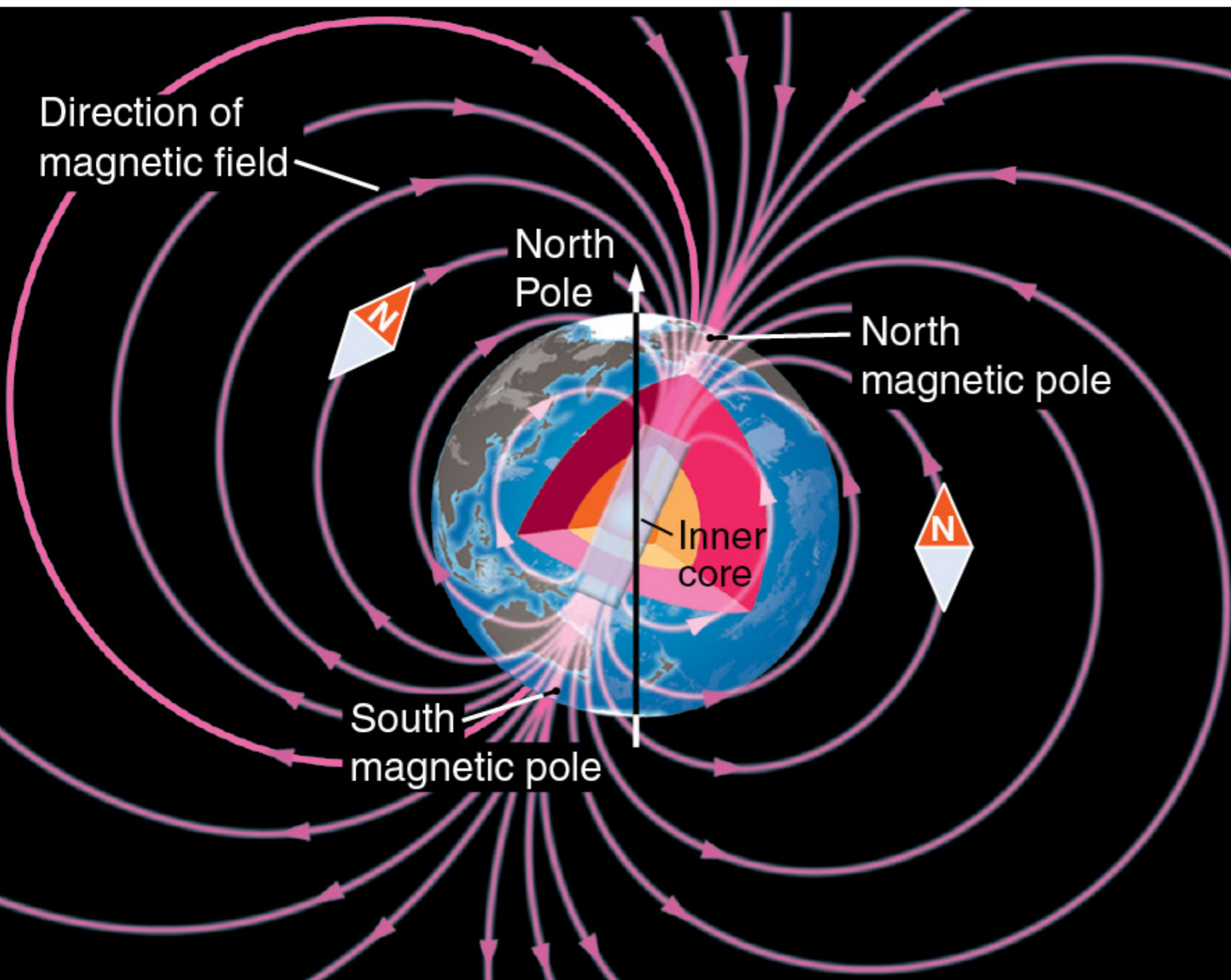
- Motions of charged particles create magnetic fields.

Sources of Magnetic Fields



- A planet can have a magnetic field if charged particles are moving inside.
- Three requirements:
 - Molten, electrically conducting interior
 - Convection
 - Moderately rapid rotation

Basically, gotta stir things up!



- Earth's magnetic field important to
 - shielding the surface from incoming charged particles (cosmic rays/solar storms)
 - protecting the atmosphere from the solar wind

What processes shape planetary surfaces?

Mercury



Heavily cratered Mercury has long steep cliffs (arrow).

Venus



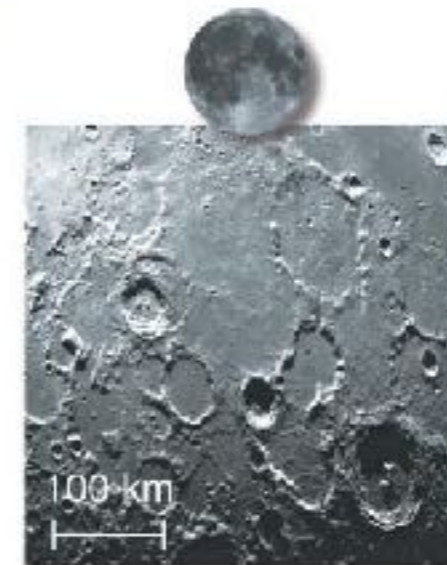
Cloud-penetrating radar revealed this twin-peaked volcano on Venus.

Earth



A portion of Earth's surface as it appears without clouds.

Earth's Moon



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

Mars

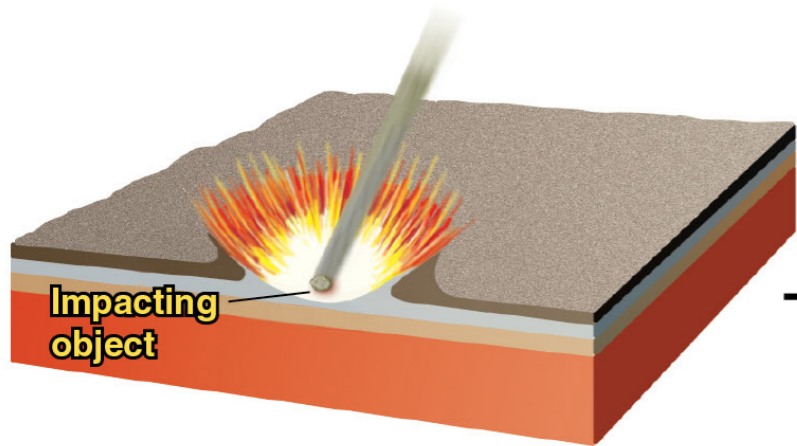


Mars has features that look like dry riverbeds; note the impact craters.

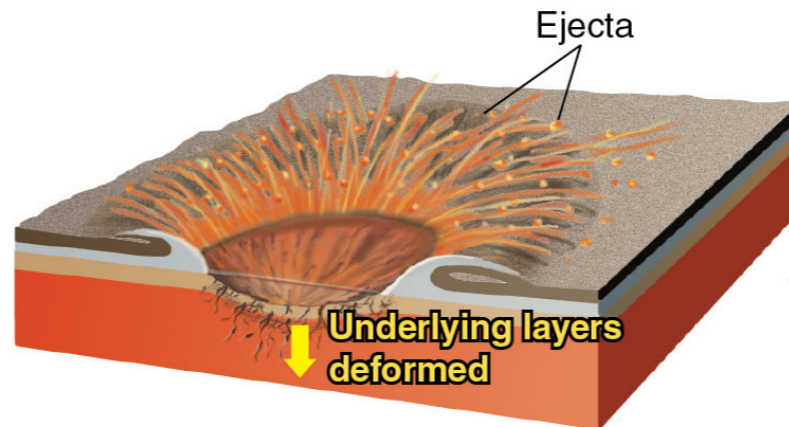
Processes That Shape Surfaces

- 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

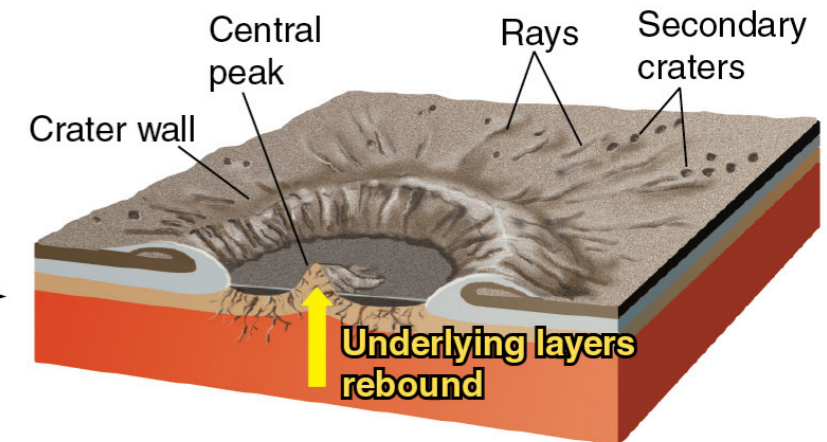
The impact of an object heats and compresses the surface it hits.



Material is thrown from the site of the impact. Ejecta lands around the crater, forming rays and secondary craters.



Rebound of the deformed surface may form a central peak in the crater, while melted rock pools in the crater floor, giving it a flat bottom.



- Most cratering happened soon after the solar system formed.
 - Late heavy bombardment 3.8 billion years ago
- Heavily cratered surfaces are old.
 - need active geology to erase craters
- Small craters greatly outnumber large ones.
 - small impactors more common than large ones

Impact Craters



a Meteor Crater in Arizona is more than a kilometer across and almost 200 meters deep. It was created around 50,000 years ago by the impact of a metallic asteroid about 50 meters across.

Meteor Crater (Arizona)



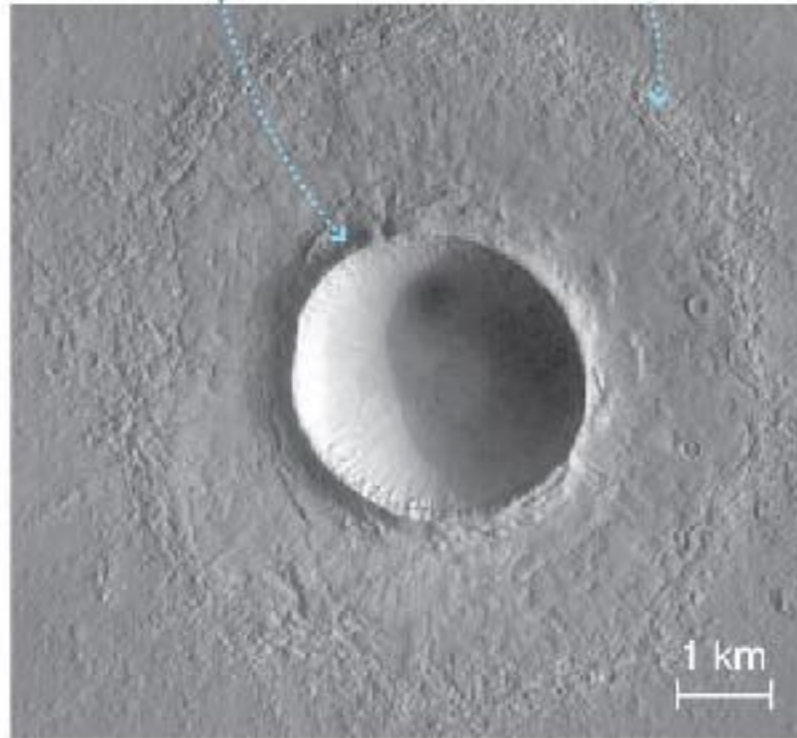
b This photo shows a crater, named Tycho, on the Moon. Note the classic shape and central peak.

Tycho Crater (Moon)

Impact Craters on Mars

A simple bowl-shaped crater, showing a sharp rim ...

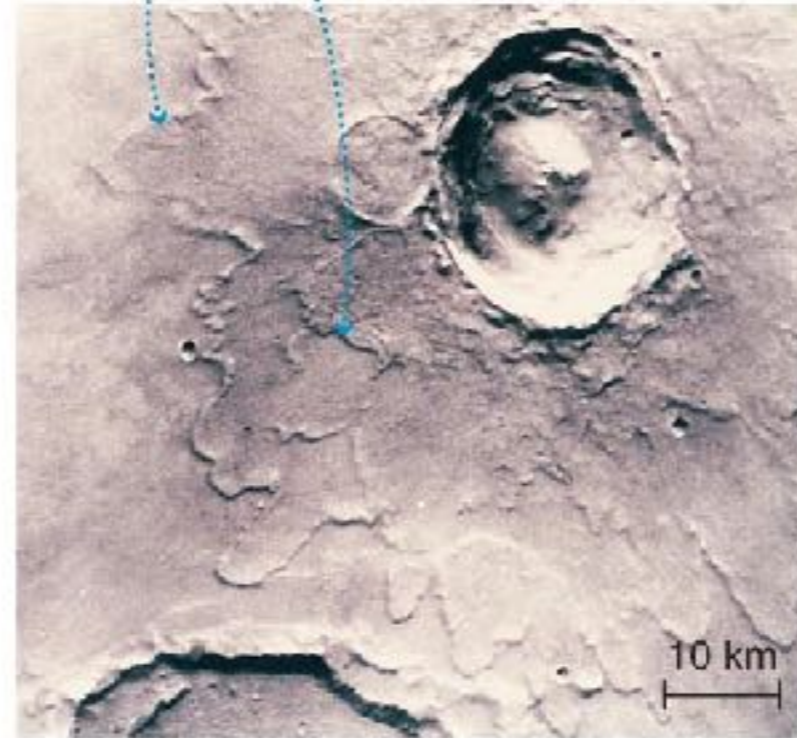
... and a ring of ejected debris.



a A crater with a typical bowl shape.

"Standard" crater

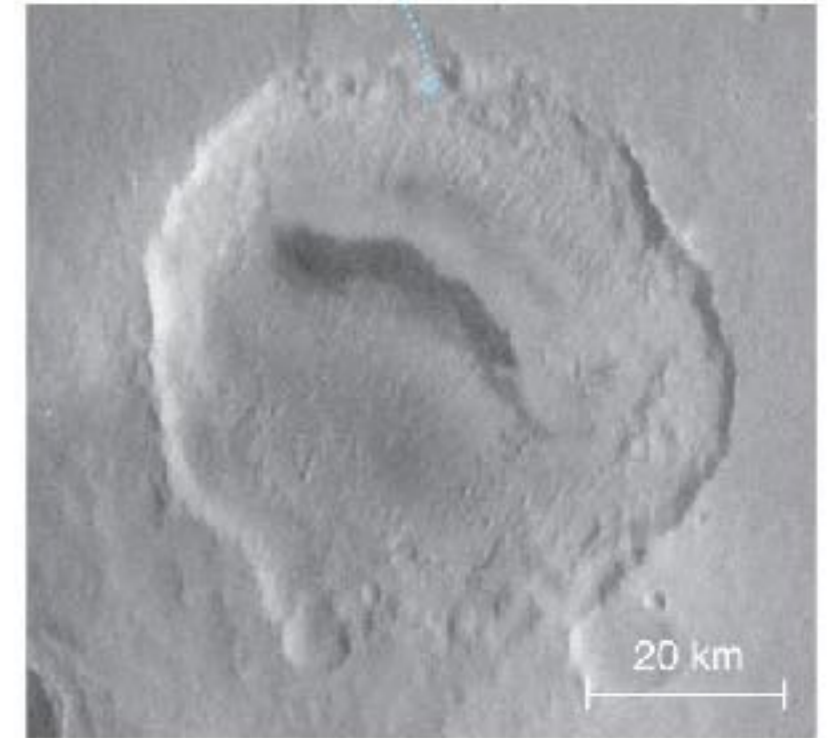
Unusual ridges suggest the impact debris was muddy.



b This crater was probably made by an impact into icy ground.

Impact into icy ground

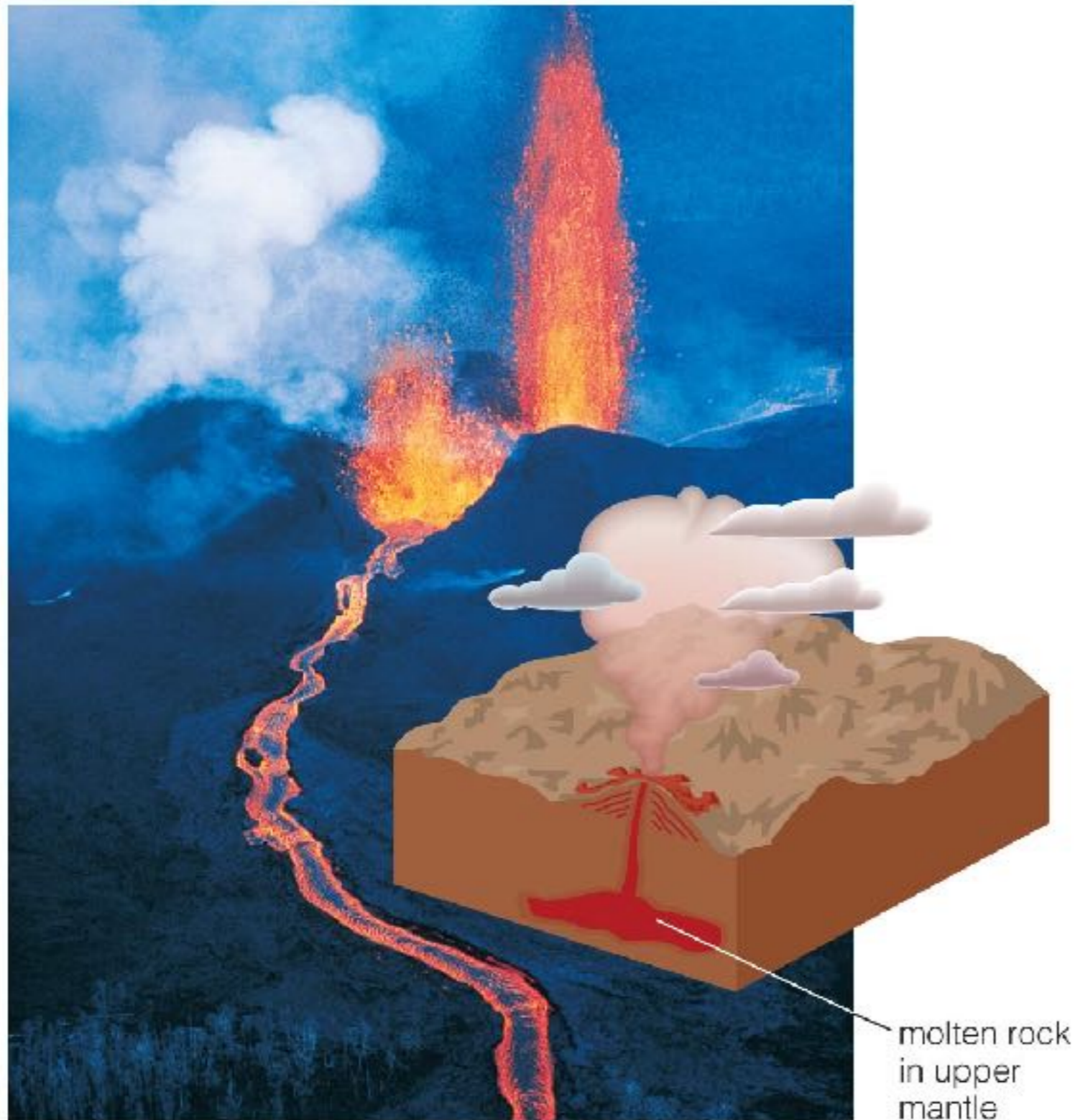
This crater rim looks like it was eroded by rainfall.



c This crater shows evidence of erosion.

Eroded crater

Volcanism

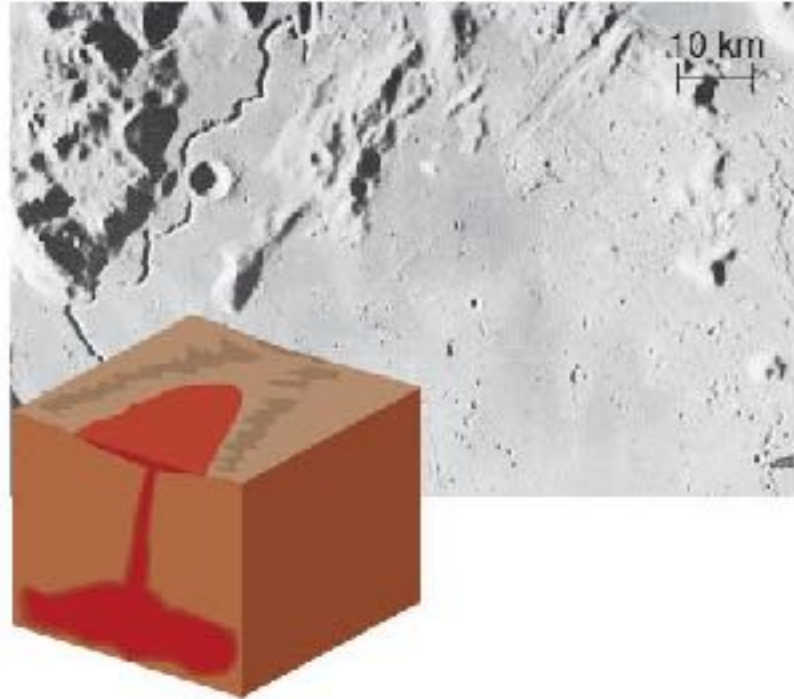


- Volcanism happens when molten rock (magma) finds a path through lithosphere to the surface.
- Molten rock is called lava after it reaches the surface.

Iceland's Bardarbunga eruption 2014/15

Lava and Volcanoes

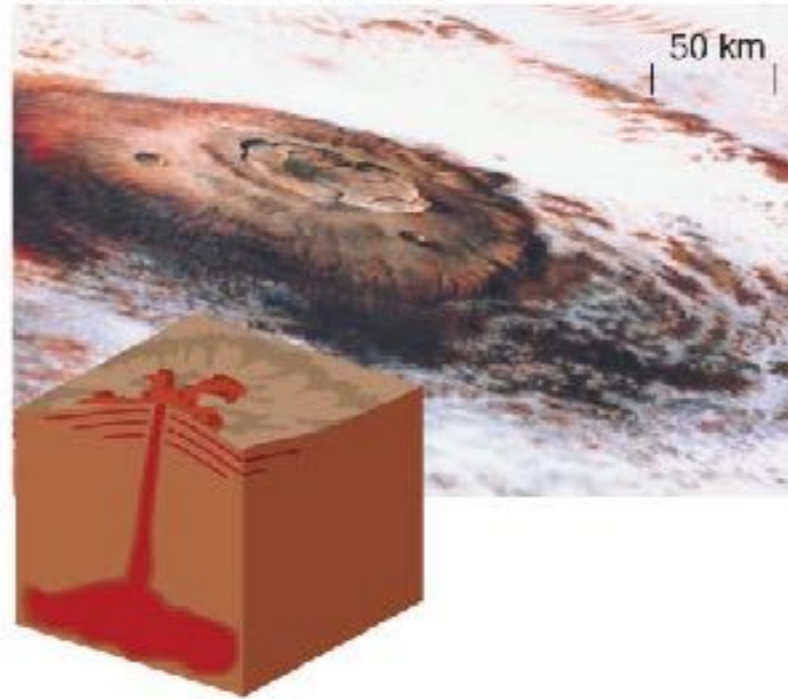
Lava plains (maria) on the Moon



a Very runny lava makes flat lava plains like these on the Moon. The long, winding channel near the upper left was made by a river of molten lava.

Runny lava makes flat lava plains.

Olympus Mons (Mars)



b Slightly thicker lava makes shallow-sloped shield volcanoes, such as Olympus Mons on Mars.

Slightly thicker lava makes broad shield volcanoes.

Mount Hood (Earth)



c The thickest lavas make steep-sloped stratovolcanoes like Oregon's Mount Hood.

Thickest lava makes steep stratovolcanoes.

Outgassing



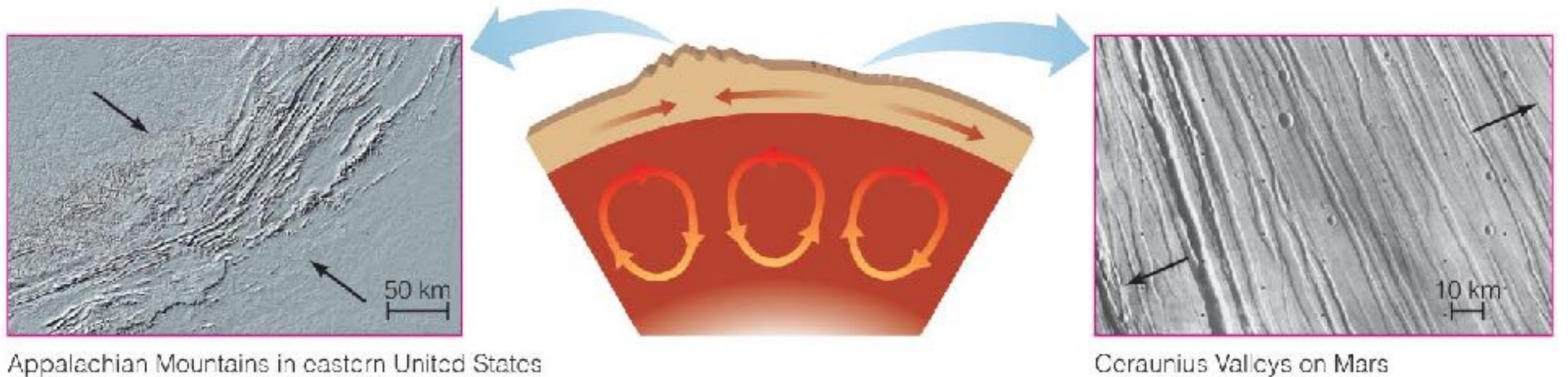
a The eruption of Mount St. Helens, May 18, 1980.



b More gradual outgassing from a volcanic vent in Volcanoes National Park, Hawaii.

- Volcanism releases gases from Earth's interior into the atmosphere.
- How planets get an atmosphere in the first place!

Tectonics

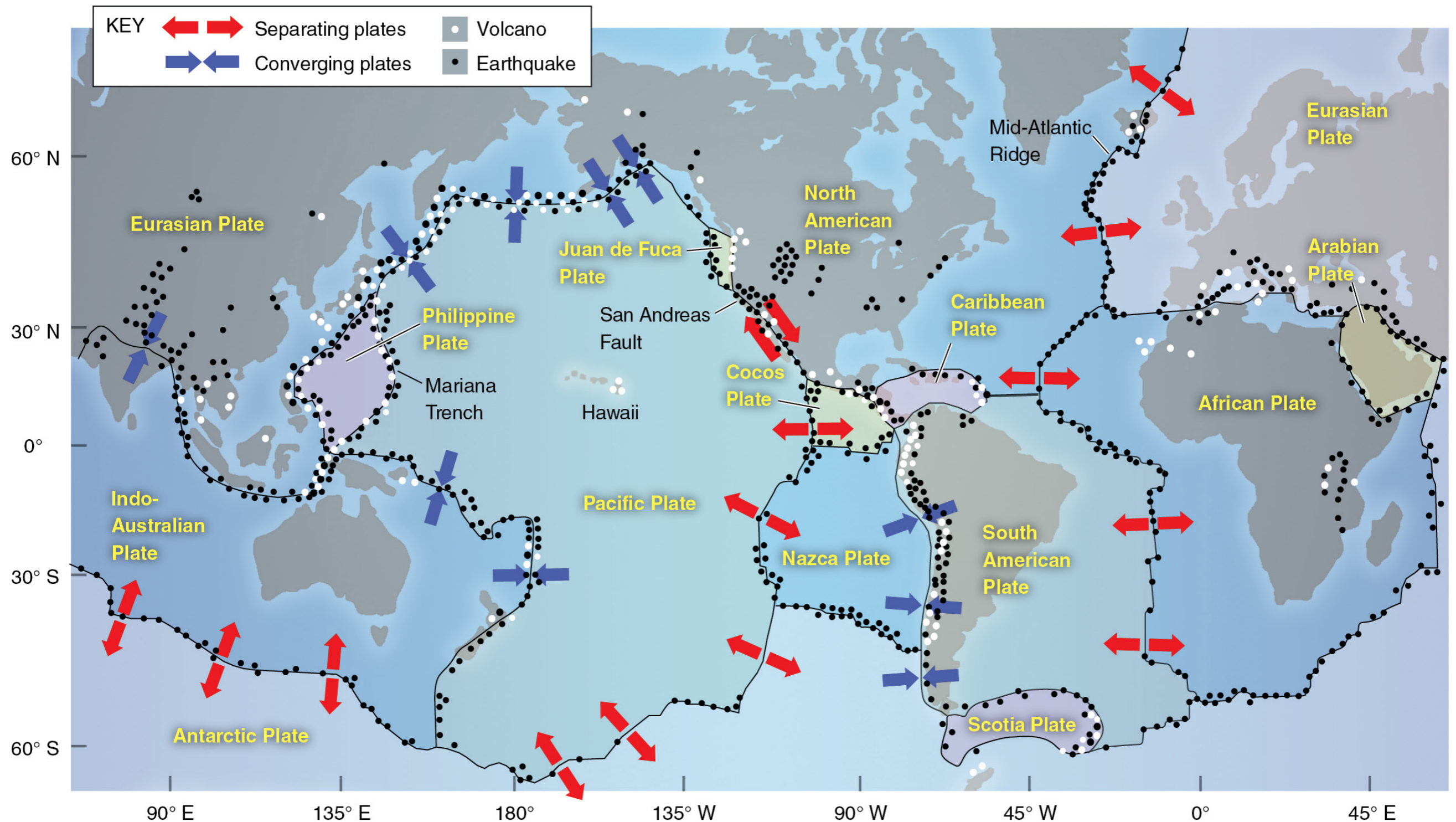


Interactive Figure 

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

Plate Tectonics on Earth

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



Erosion

- Erosion is a blanket term for weather-driven processes that break down or transport rock.
- Processes that cause erosion include:
 - glaciers
 - rivers, rain
 - wind
 - freeze/thaw

Erosion by Water



- The Colorado River continues to carve the Grand Canyon.

Local examples of Erosion

- freeze/thaw



Erosion by Ice



- Glaciers carved the Yosemite Valley.

Erosion by Wind



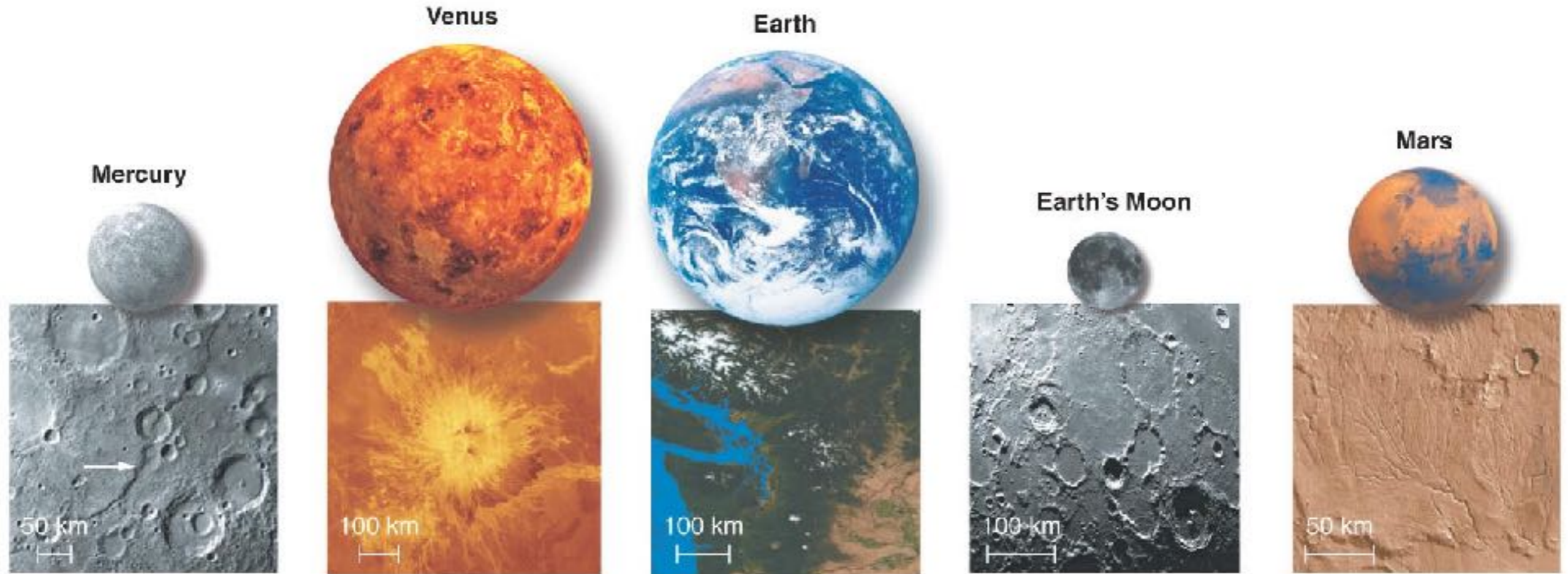
- Wind wears away rock and builds up sand dunes.
- Also active on Mars

Erosional Debris

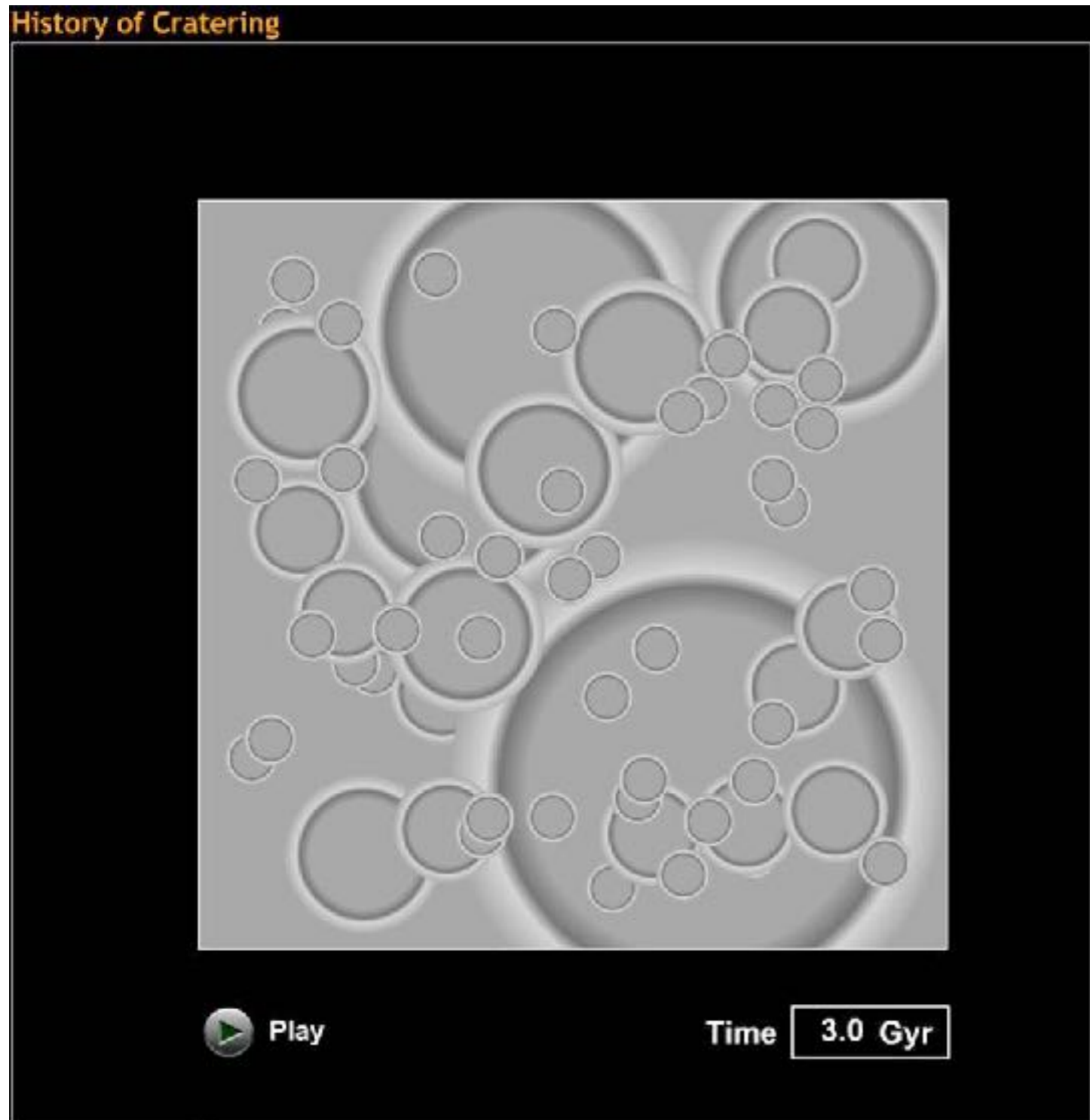


- Erosion can create new features such as deltas by depositing debris.

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



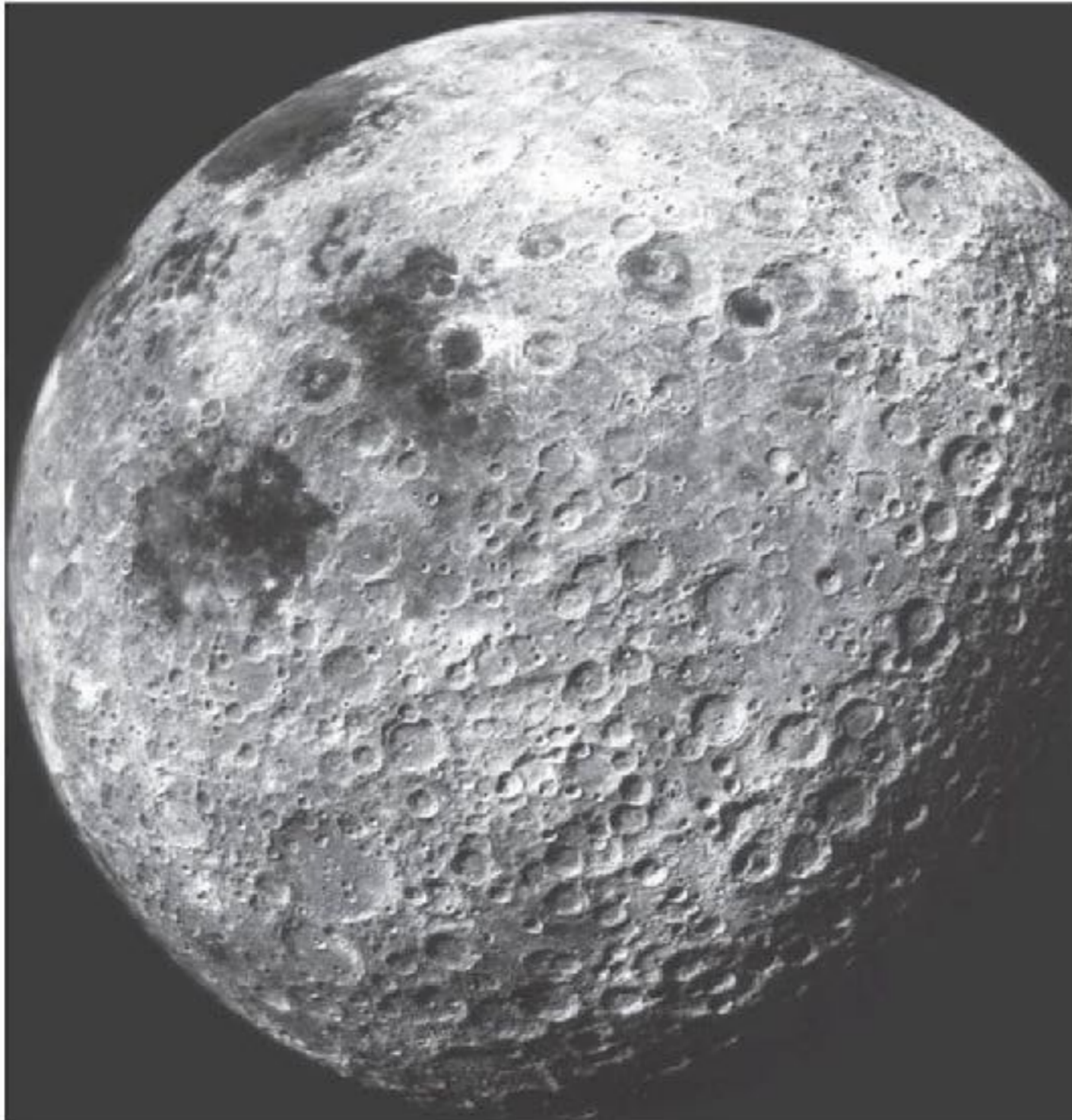
History of Cratering



Interactive Figure

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

Cratering of Moon

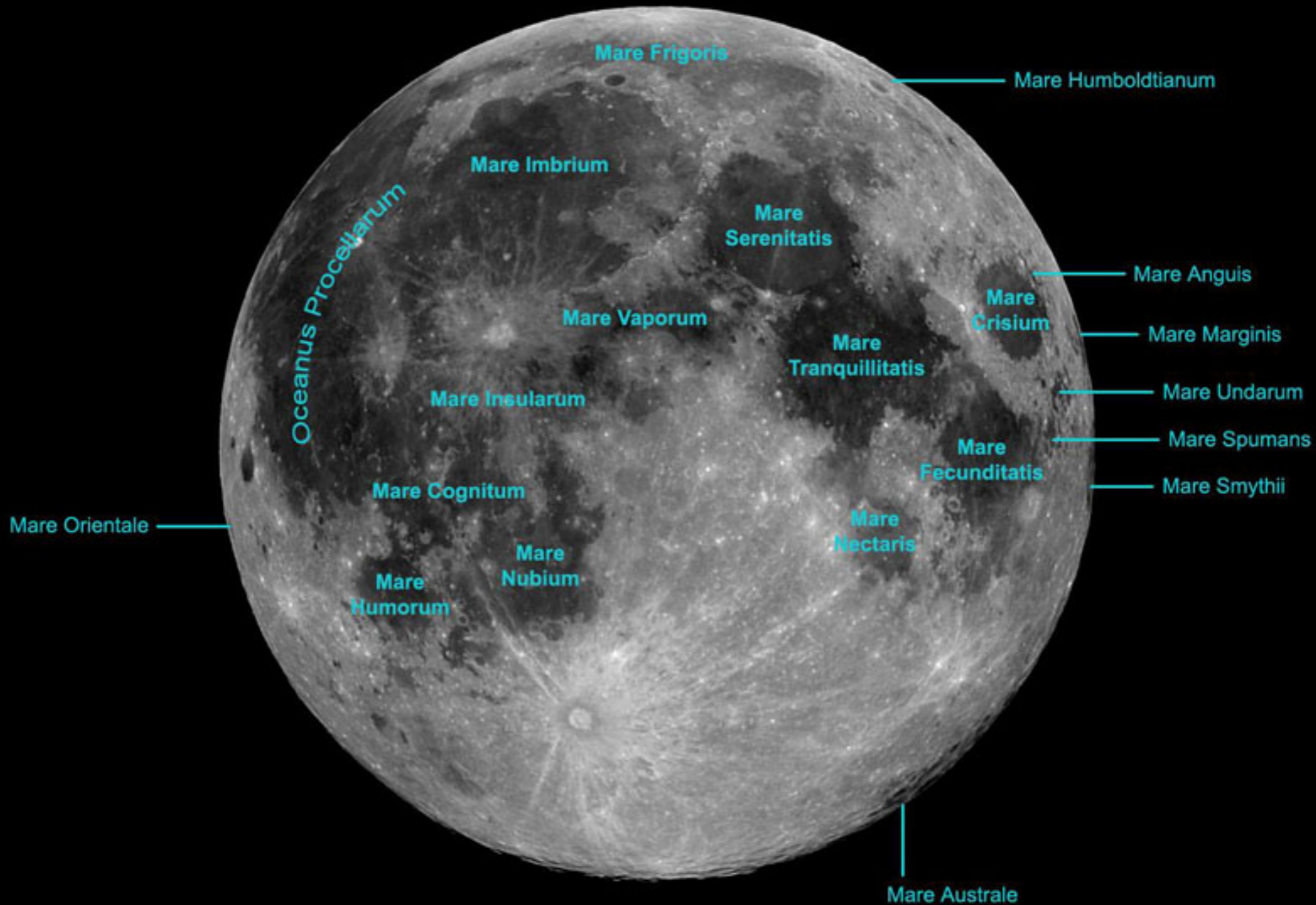


- Some areas of Moon are more heavily cratered than others.
- Younger regions were flooded by lava after most cratering.
 - mare

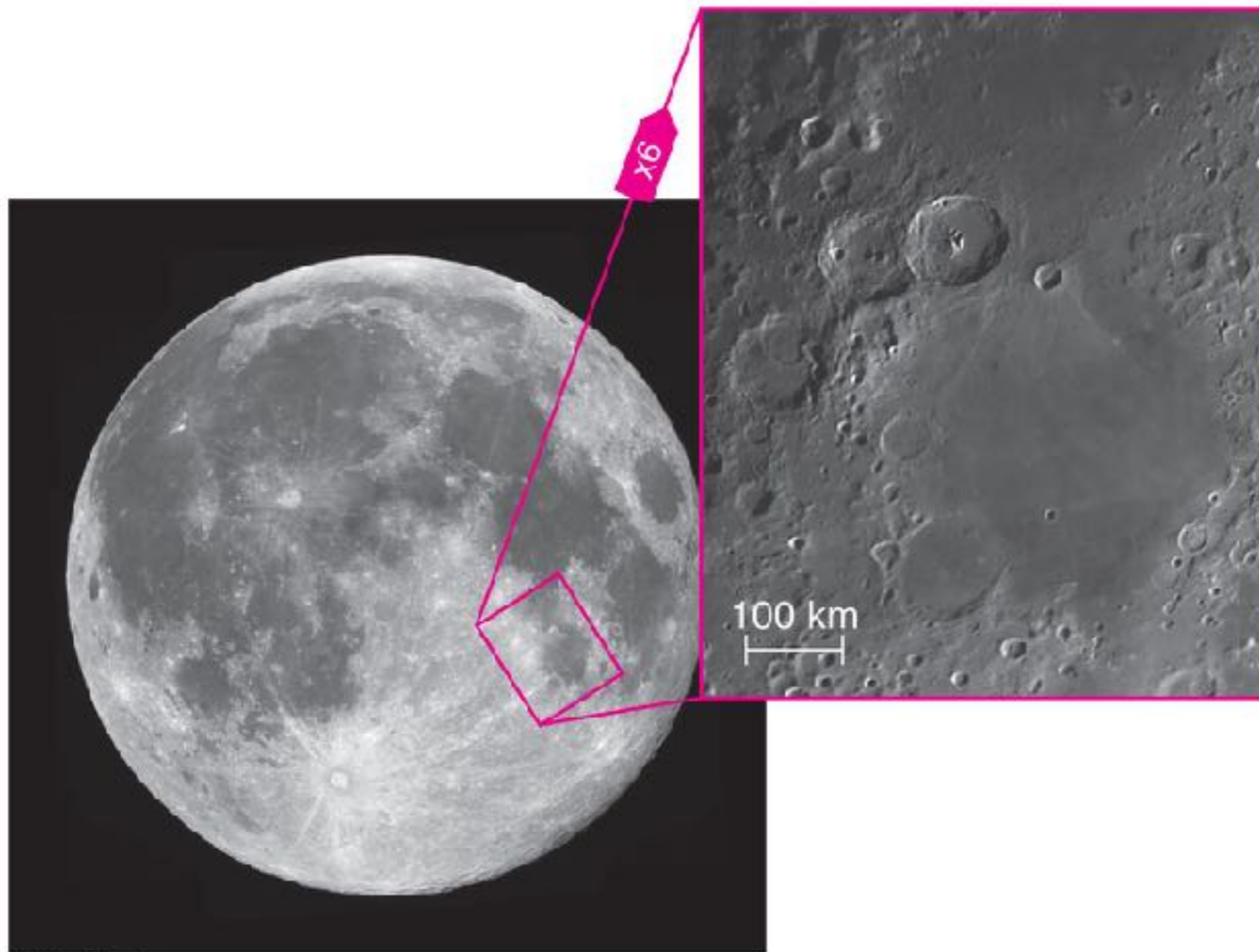
Cratering of Moon



Cratering map of the Moon's entire surface



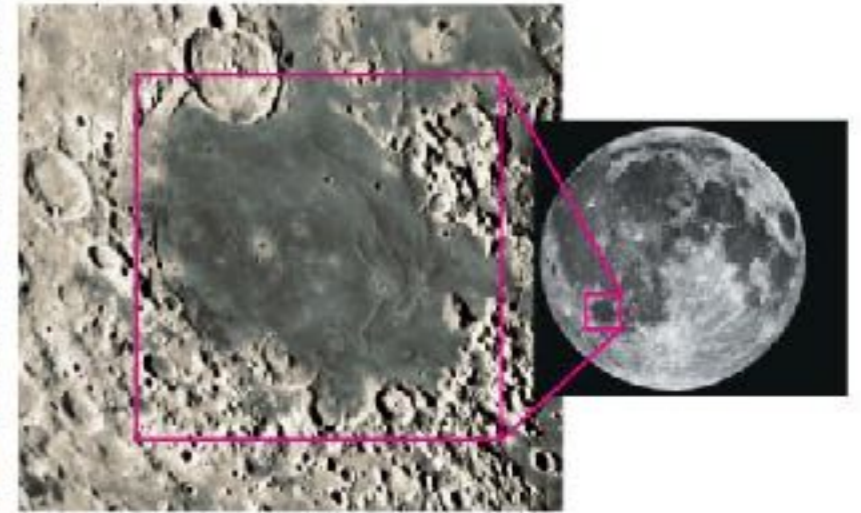
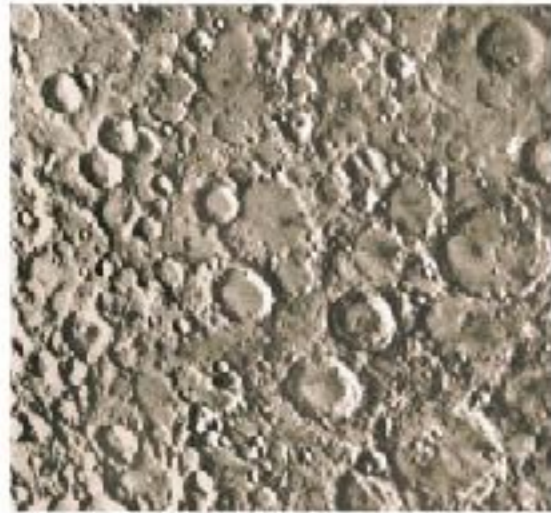
Lunar Maria



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

<https://www.youtube.com/watch?v=mIRPeYGKfic>

Formation of Lunar Maria



Early surface is 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.

Geologically Dead

- Moon is considered geologically "dead" because geological processes have virtually stopped.
- Cooling process essentially complete
 - no more geology because there isn't any interior heat to drive it

