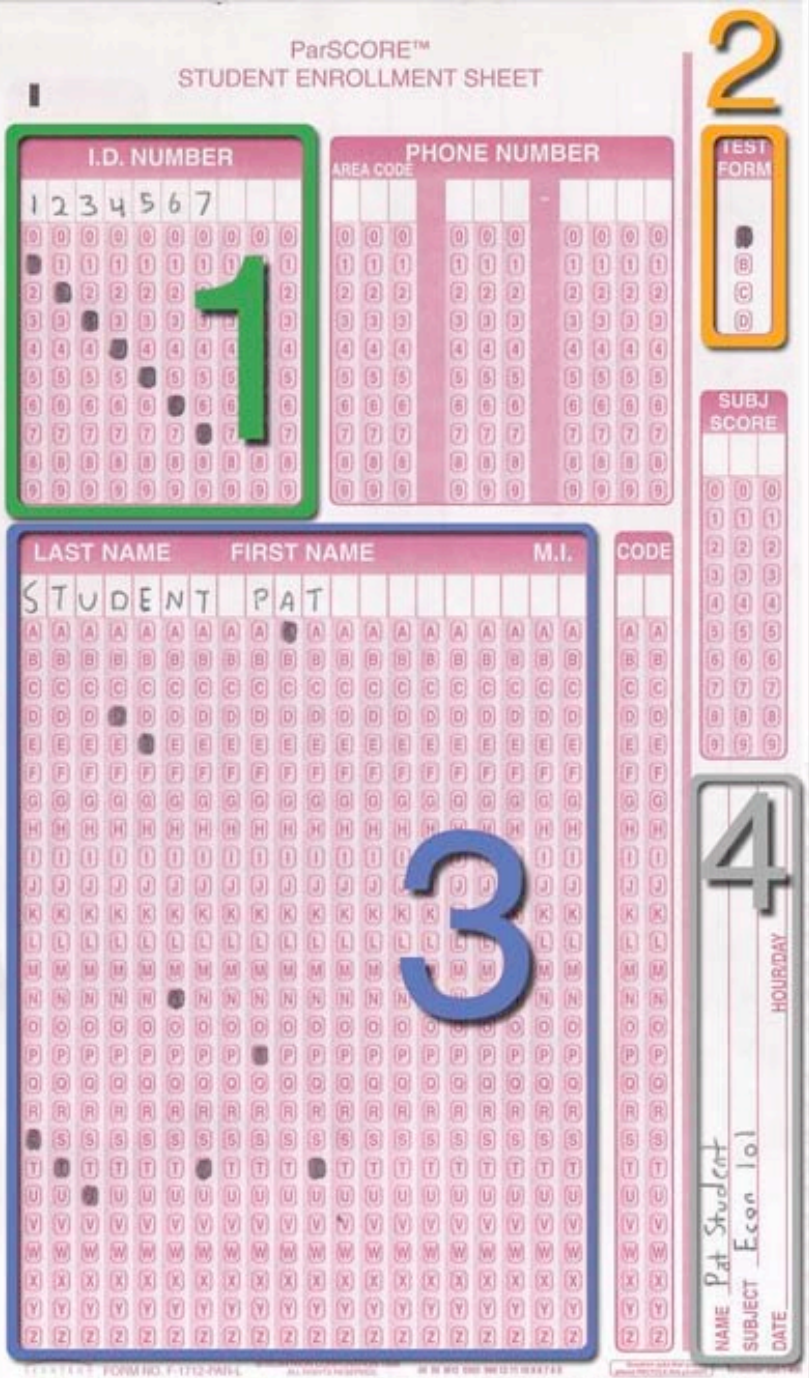
What I know today about the midterm

- Thursday, October 31st, 2-3:45 PM
  - Same time, same place
- 75 multiple choice questions
- Closed book and closed note
- No smartphones allowed
- Calculators of any kind are permitted, but the math can be readily done without them
- Equation Sheet Provided
- **Bring a #2 pencil!**
- **Know your Student ID**

What I know today about your midterm

- Chris and Emily will proctor the Exam
- It is 30% of your quarter grade
- Emily and Chris both will have office hours in the Center from Adaptive Optics from 4-6 this afternoon
- Emily will have office hours from 11:30-12:30 on Wednesday in ISB 356.
- The second review session is **tonight** with Chris at **7:30 in Thimann 1.**
- Scantrons will be provided on Thursday



1

- Your ID number is the most important piece of information on this form. Without it we cannot scan your exam.
- Please write AND bubble in your 7-digit Student ID number.
- DO NOT add 0's to fill the boxes. 7 digits only, please.
- Your ID number can be found on the right side of your ID card, between the two hyphens.

ID Number

2

- If your instructor is giving multiple versions of your exam, it is imperative that you mark which version you are taking.
- If you neglect to mark this field correctly, we cannot scan your exam, and your instructor may not give you credit!
- If there is only one version of the exam, bubble in Test Form A.

Test Form

3

- Write and bubble in your last name, followed by a space, followed by your first name, followed by another space and your middle initial.
- If your last name normally contains a hyphen or space, omit it. Otherwise, the scanner will recognize the second word of your last name as your first name.

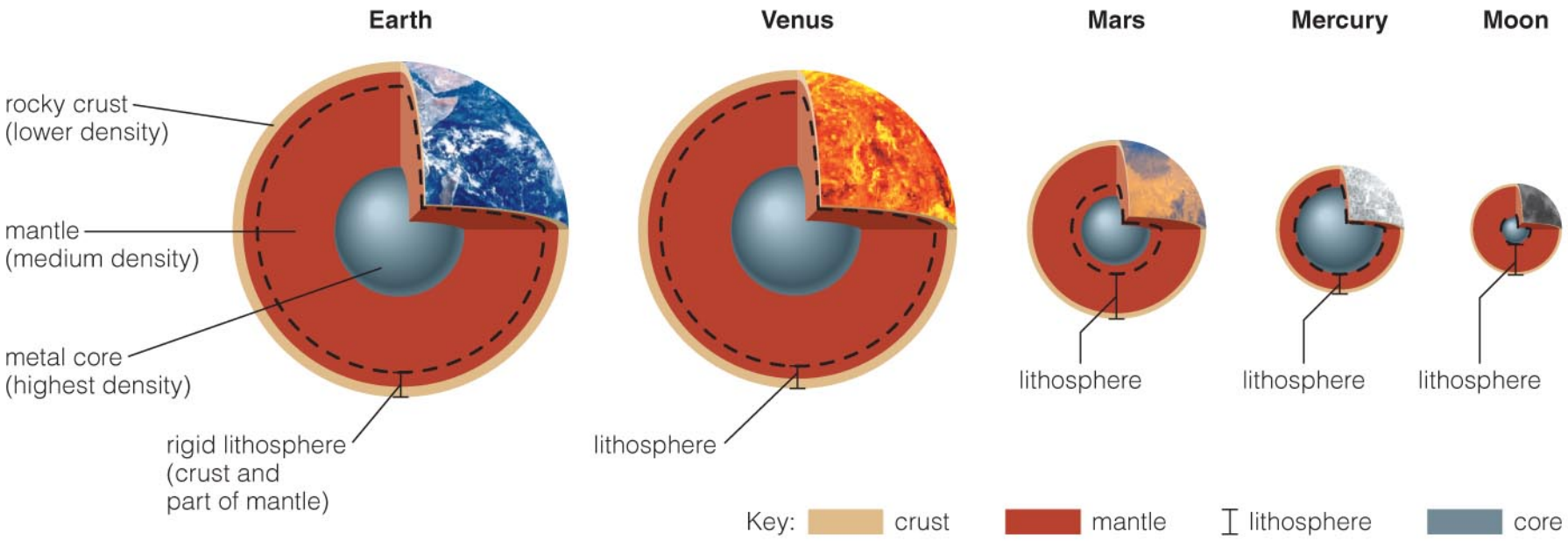
Name

4

- REMEMBER: Machines read bubbles. People read letters. By writing in this information, you can ensure that the person grading your exam can manually enter any information the machine cannot read.

Written Information

Role of Size



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

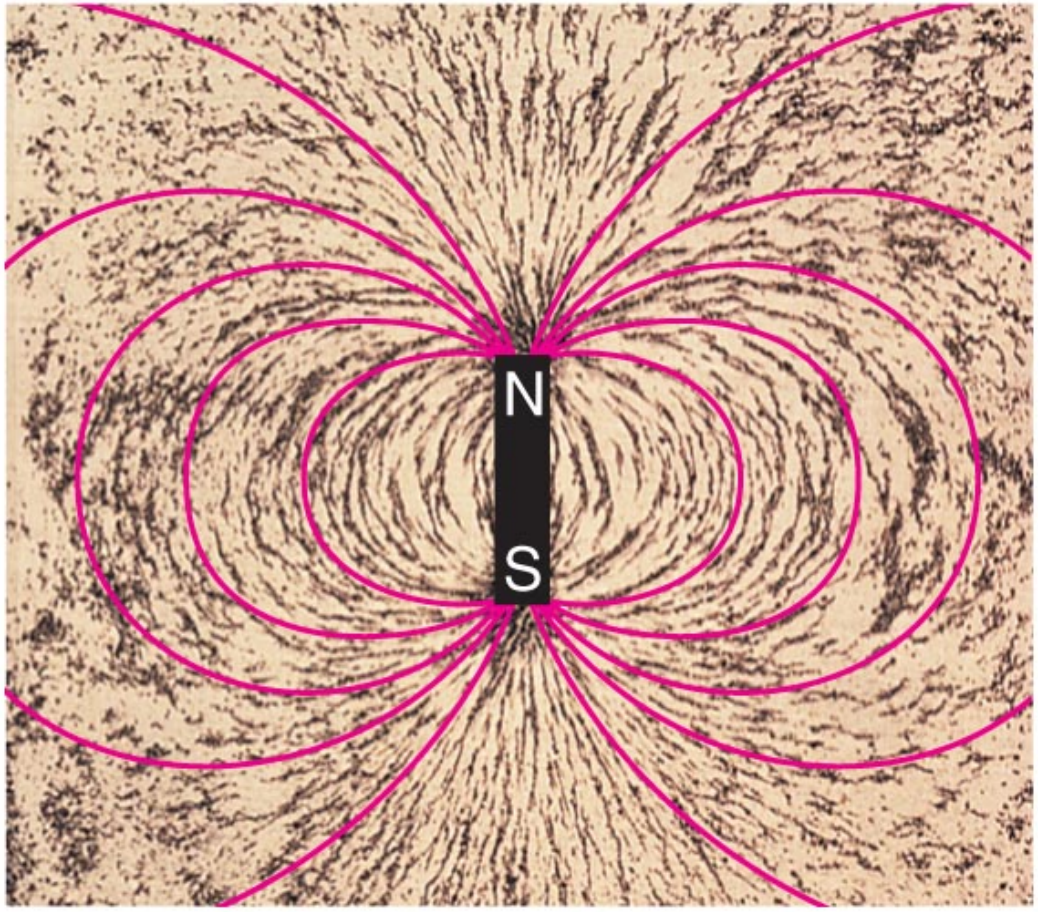
Surface Area–to–Volume Ratio

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

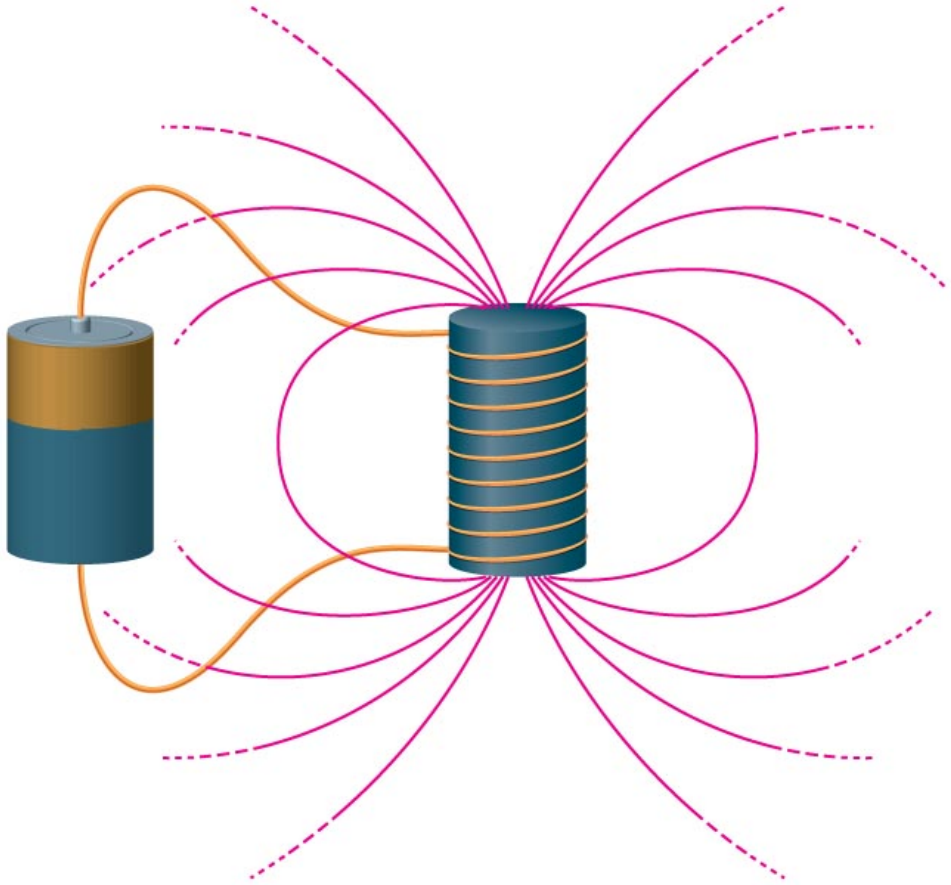
$$\text{Surface area–to–volume ratio} = \frac{4\pi r^2}{\frac{4}{3}\pi r^3} = \frac{3}{r}$$

- Larger objects have a smaller ratio and cool more slowly.

Why do some planetary interiors create magnetic fields?

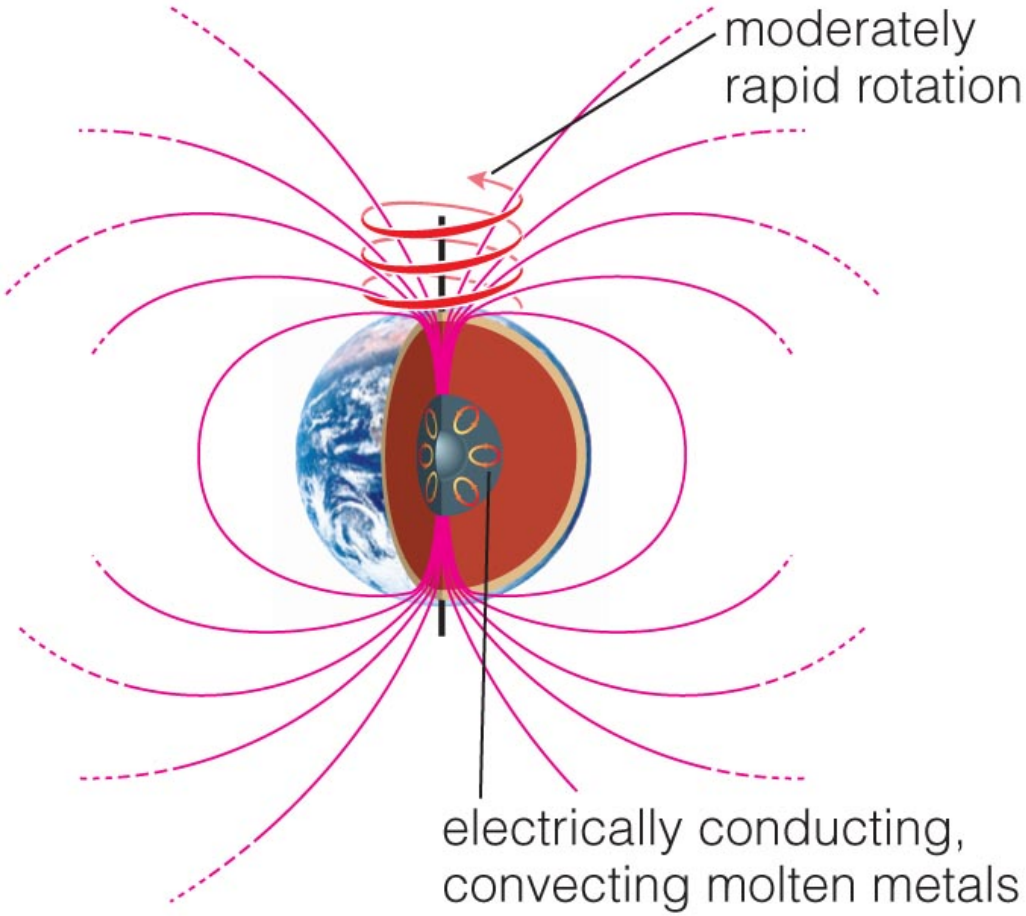


Sources of Magnetic Fields



- Motions of charged particles are what create magnetic fields.

Sources of Magnetic Fields



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

What have we learned?

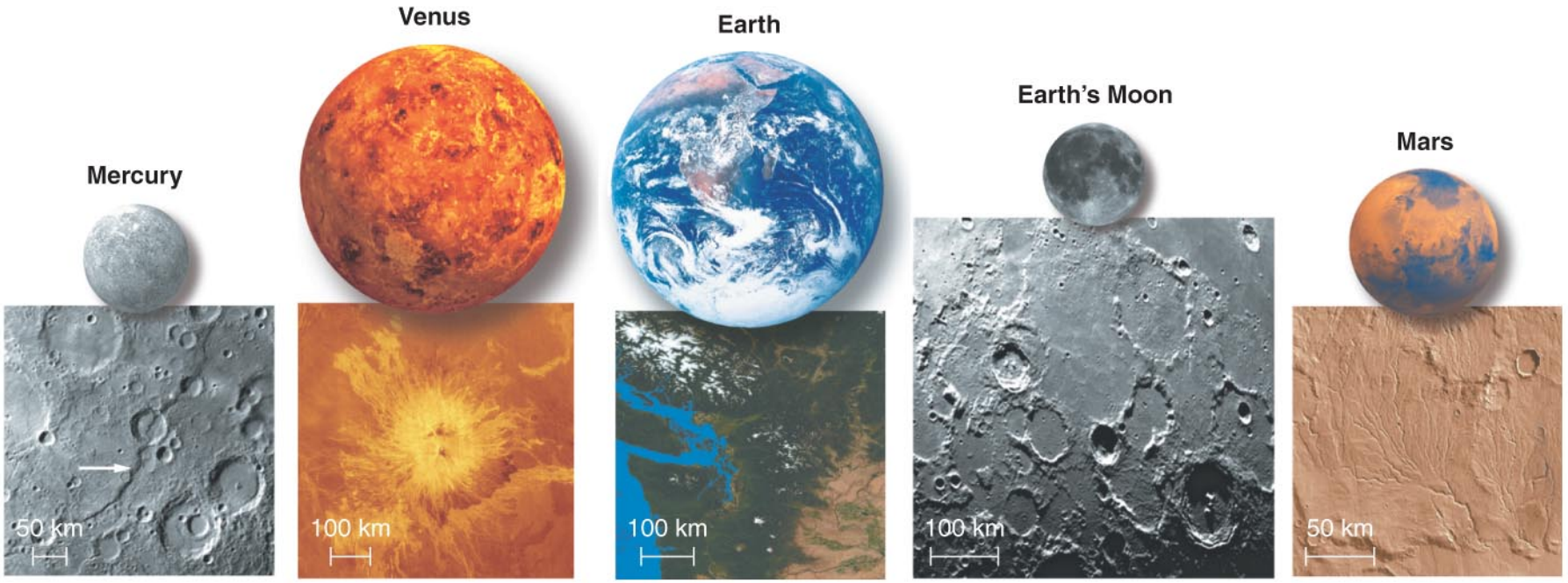
- What are terrestrial planets like on the inside?
  - All terrestrial worlds have a core, mantle, and crust.
  - Denser material is found deeper inside.
- What causes geological activity?
  - Interior heat drives geological activity.
  - Radioactive decay is currently main heat source.
- Why do some planetary interiors create magnetic fields?
  - Requires motion of charged particles inside a planet

9.2 Shaping Planetary Surfaces

Our goals for learning:

- What processes shape planetary surfaces?
- How do impact craters reveal a surface's geological age?
- Why do the terrestrial planets have different geological histories?

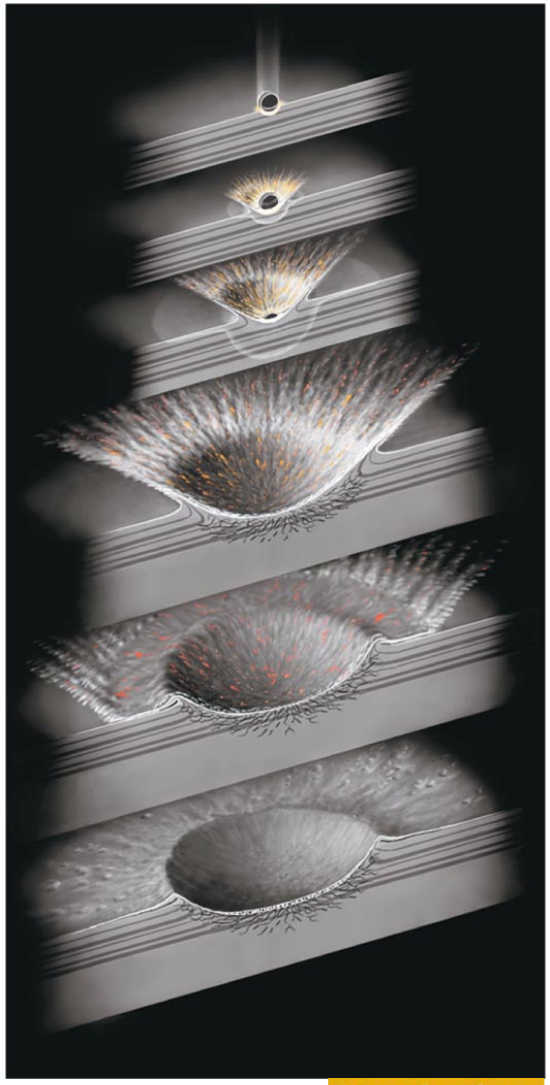
What processes shape planetary surfaces?



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



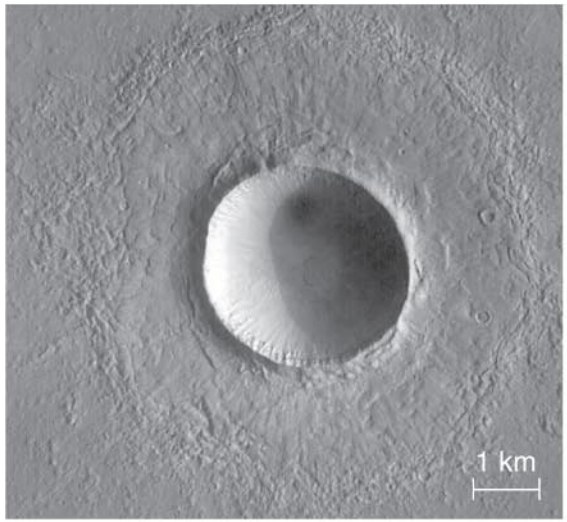
- Most cratering happened soon after the solar system formed.
- Craters are about 10 times wider than object that made them.
- Impact velocities are ~10-70 km/s
- Small craters greatly outnumber large ones.

Impact Craters

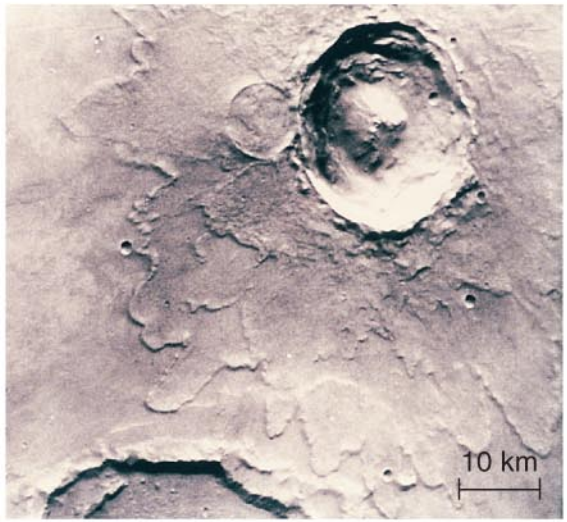
Meteor Crater (Arizona)

Tycho Crater (Moon)

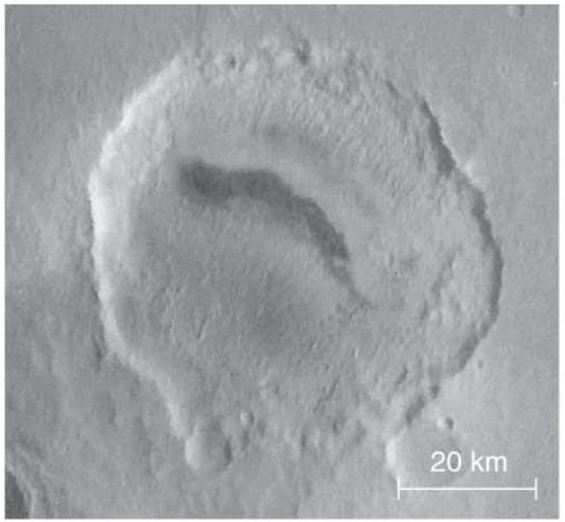
Impact Craters on Mars



"Standard" crater

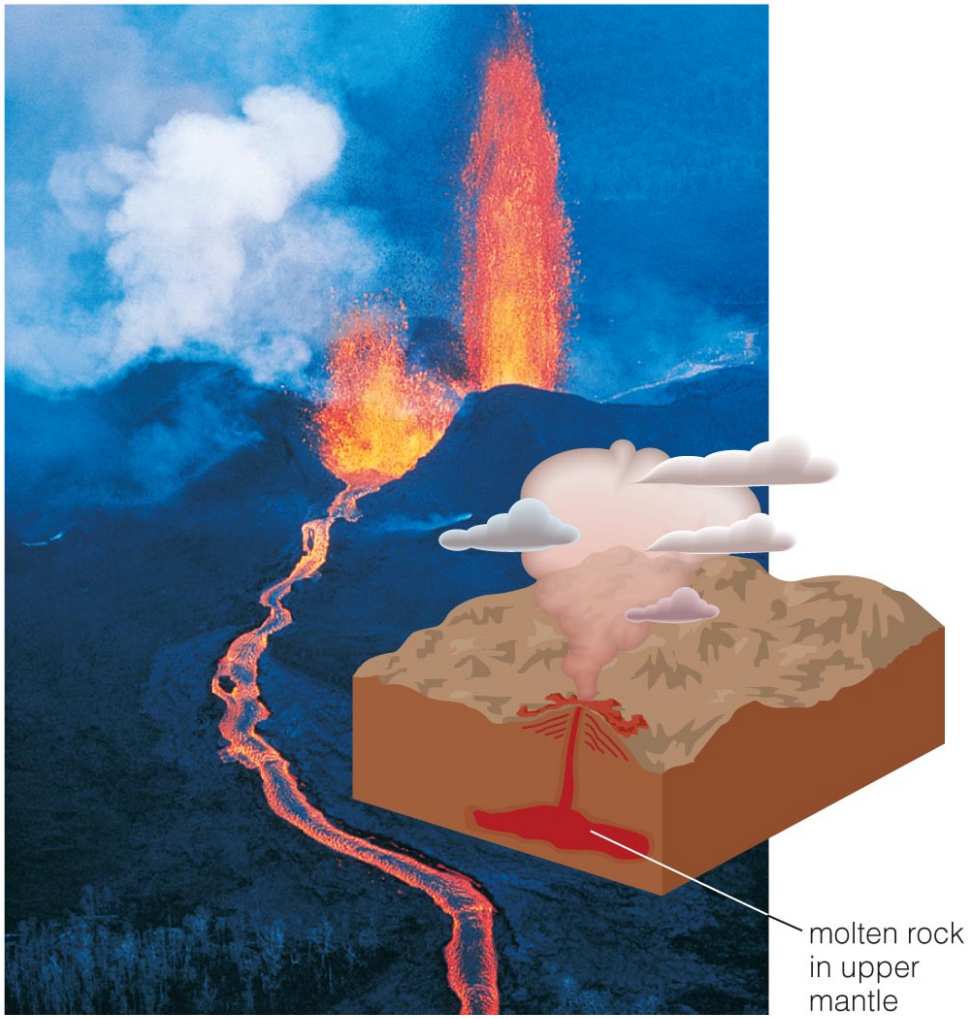


Impact into icy ground



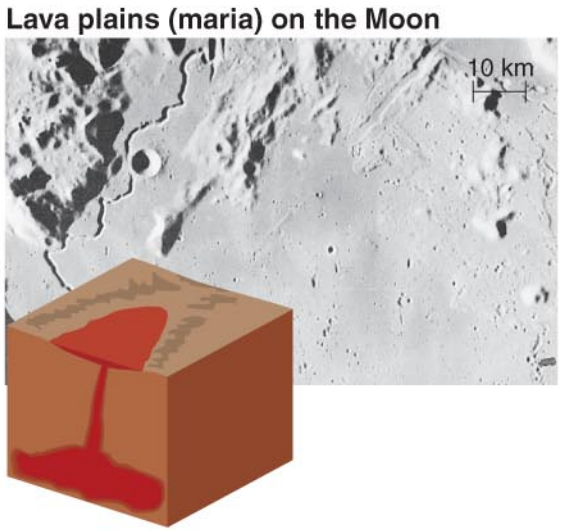
Eroded crater

Volcanism

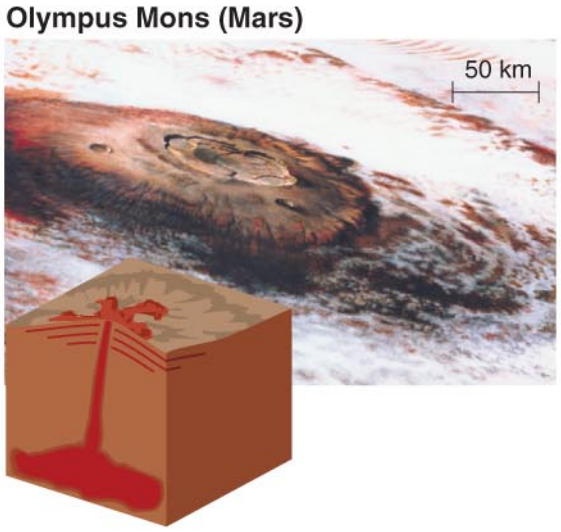


- Volcanism happens when molten rock (magma) finds a path through lithosphere to the surface.
- Molten rock is called *lava* after it reaches the surface.

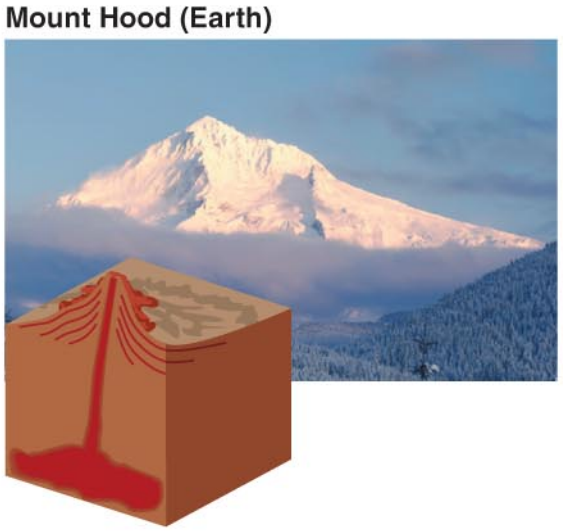
Lava and Volcanoes



Runny lava makes flat lava plains.



Slightly thicker lava makes broad *shield volcanoes*. (Hawaii, Olympus Mons)

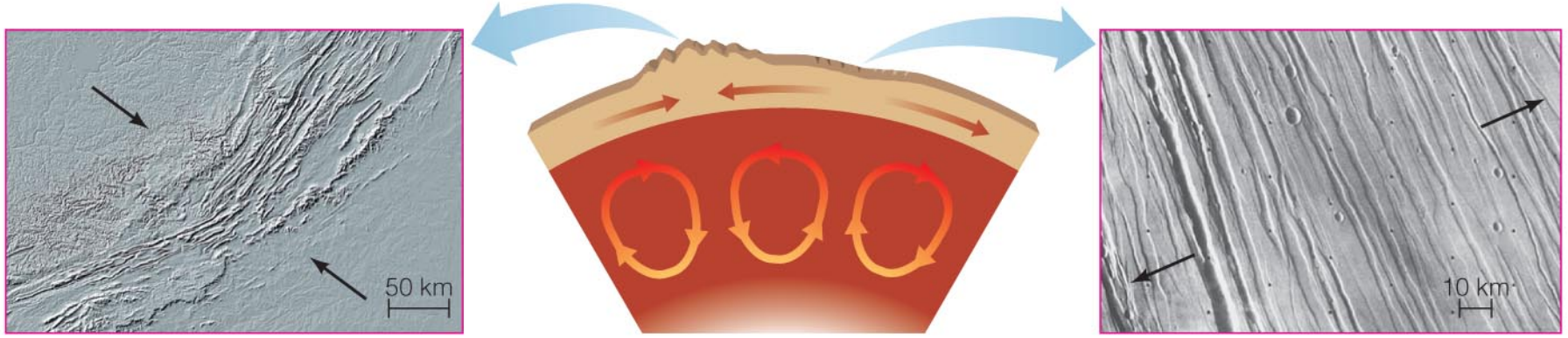


Thickest lava makes steep *stratovolcanoes*. (Mt. Fuji)

Outgassing

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

Tectonics



Appalachian Mountains in eastern United States

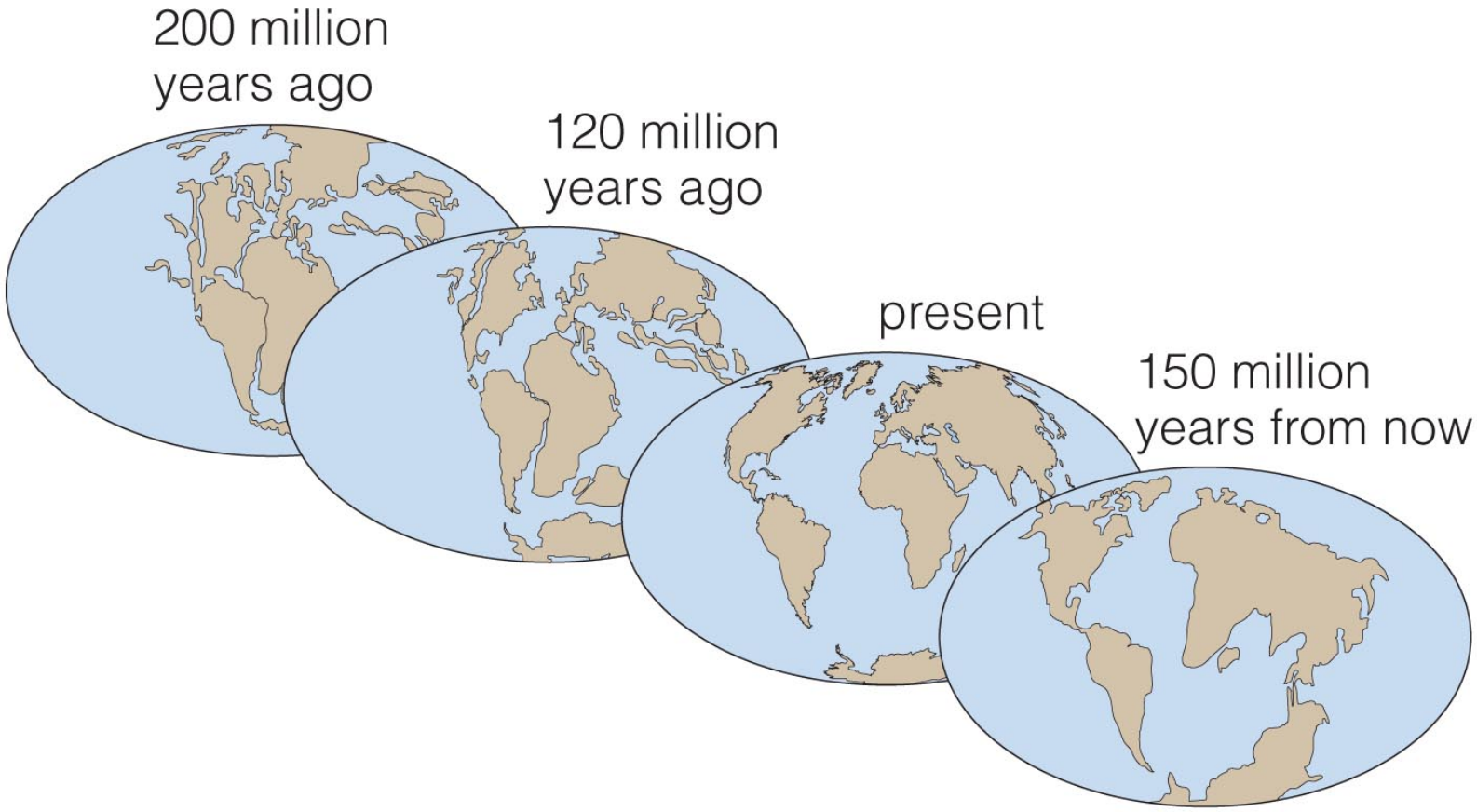
Ceraunius Valleys on Mars

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.
- Speed is only few cm per year



Clicker Question

How does the cooling of planets and potatoes vary with size?

a) Larger size makes it harder for heat from inside to escape.

b) Larger size means a bigger ratio of volume to surface area.

c) Larger size takes longer to cool.

d) all of the above

Clicker Question

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a) Larger size makes it harder for heat from inside to escape.

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d) all of the above

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 Grand Canyon.

Erosion by Ice

- Glaciers carved the Yosemite Valley.

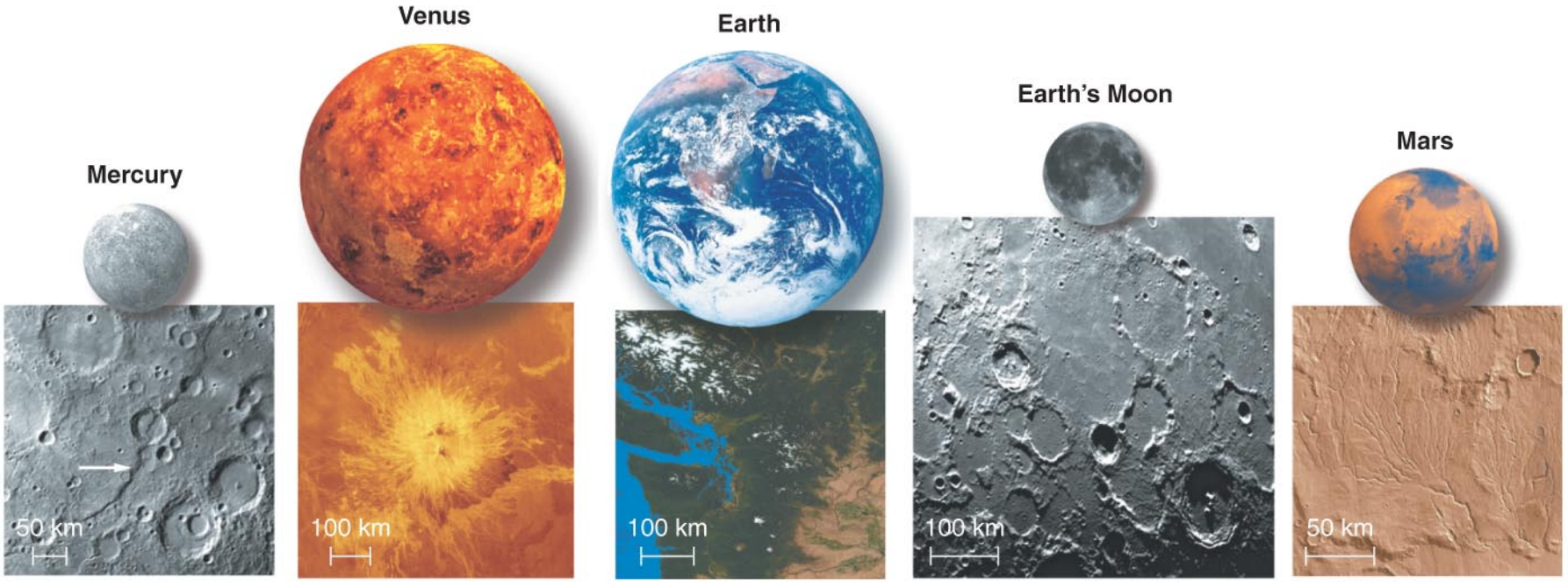
Erosion by Wind

- Wind wears away rock and builds up sand dunes.

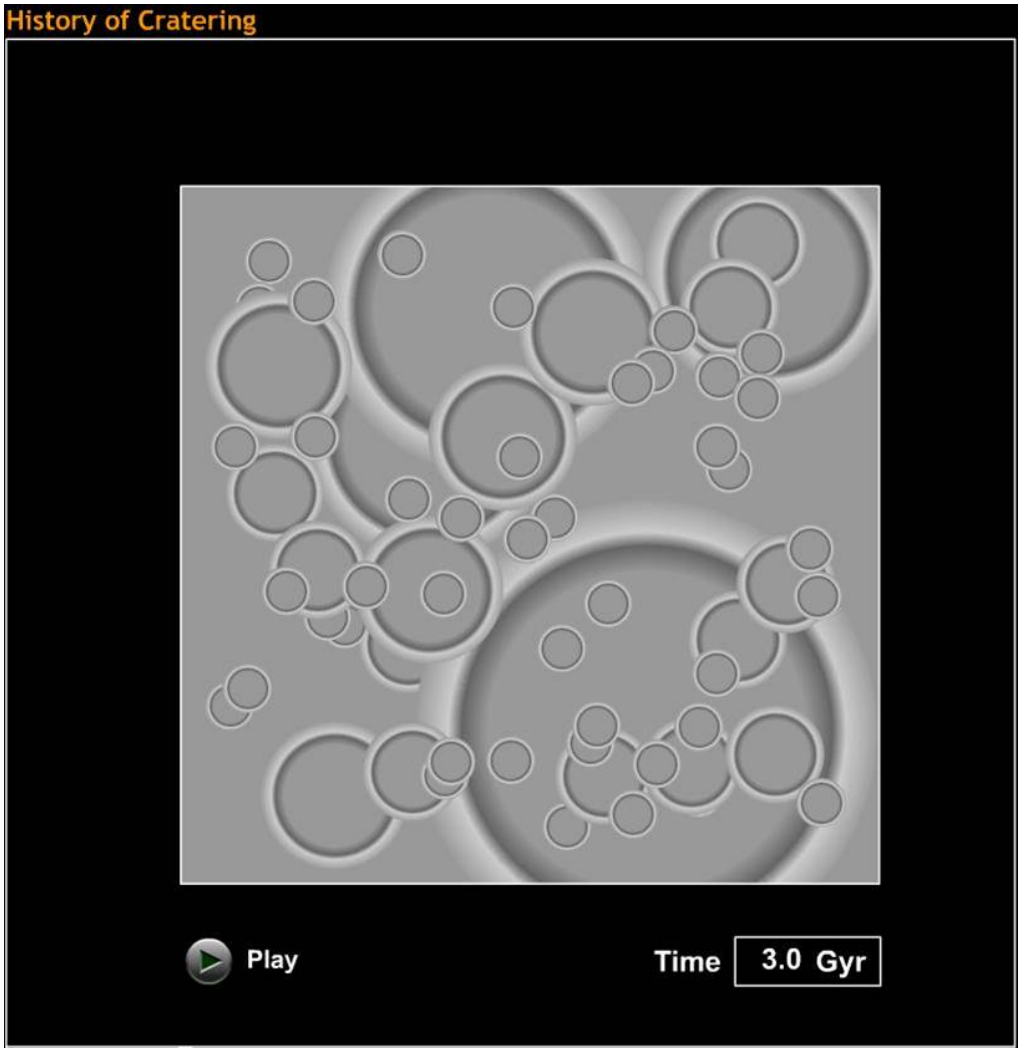
Erosional Debris

- Erosion can create new features such as deltas by depositing debris.
- Earth has had so much erosion that sedimentary rock is now common than igneous (volcanic) rock

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

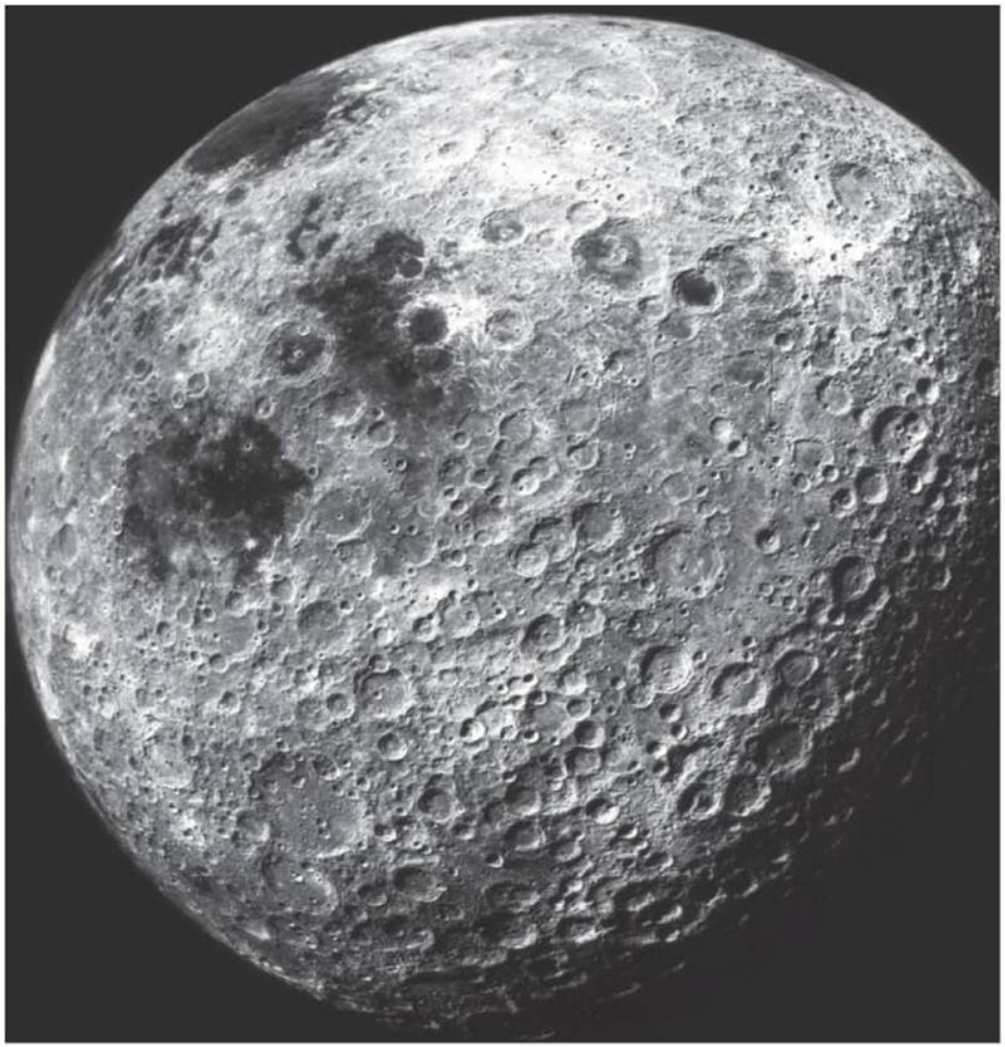


History of Cratering



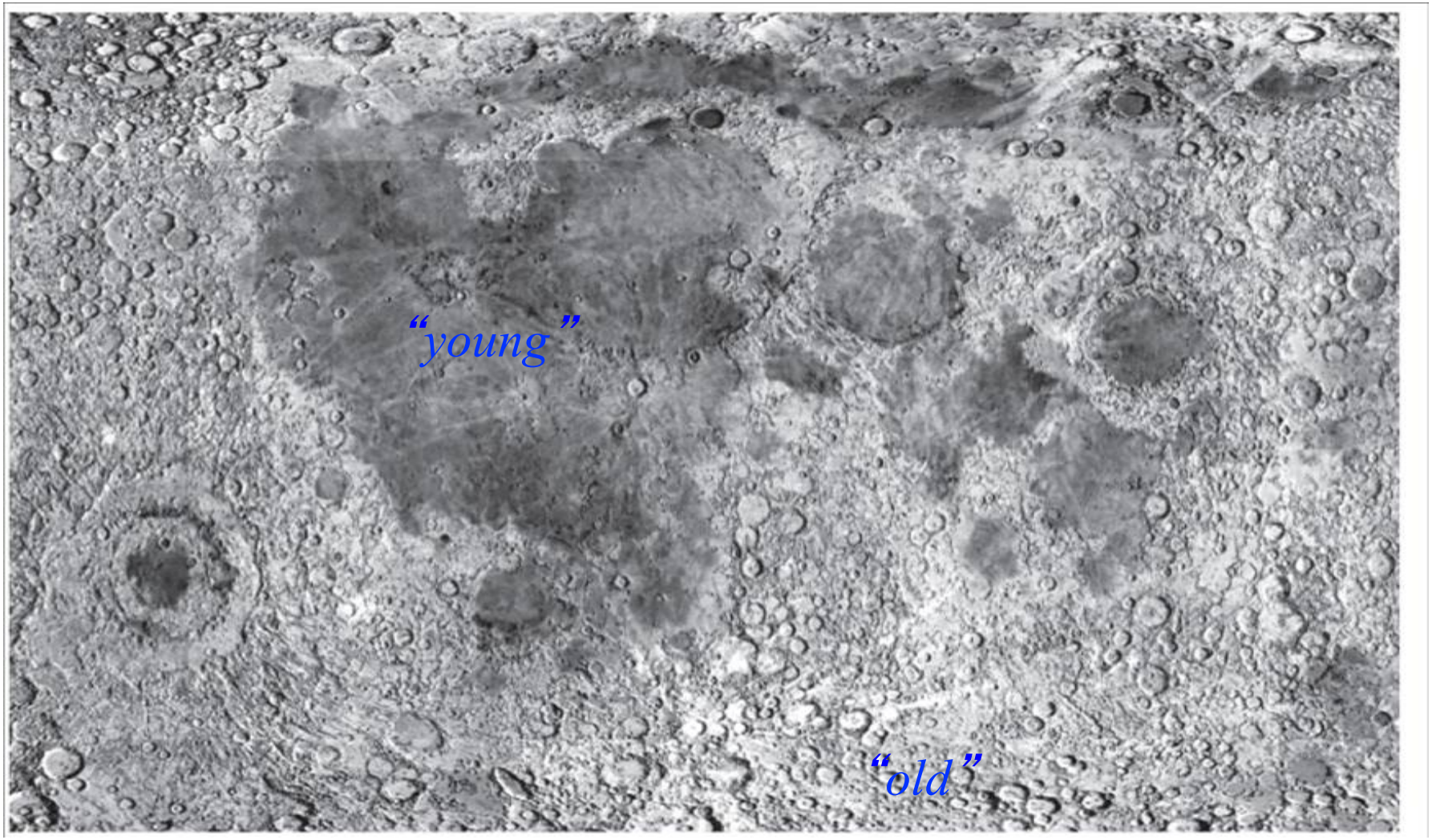
- Most cratering happened in the first billion years.
- A surface with many craters has not changed much in 3 billion years.

Cratering of Moon



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

Cratering of Moon



Cratering map of the Moon's entire surface

What are the 4 basic processes that shape planetary surfaces?

A. magnetic fields, impacts, volcanoes, erosion
B. magnetic fields, earthquakes, volcanoes, erosion
C. tectonics, impacts, volcanoes, erosion
D. magnetic fields, impacts, volcanoes, erosion
E. tectonics, impacts, erosion, magnetic fields

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A. magnetic fields, impacts, volcanoes, erosion
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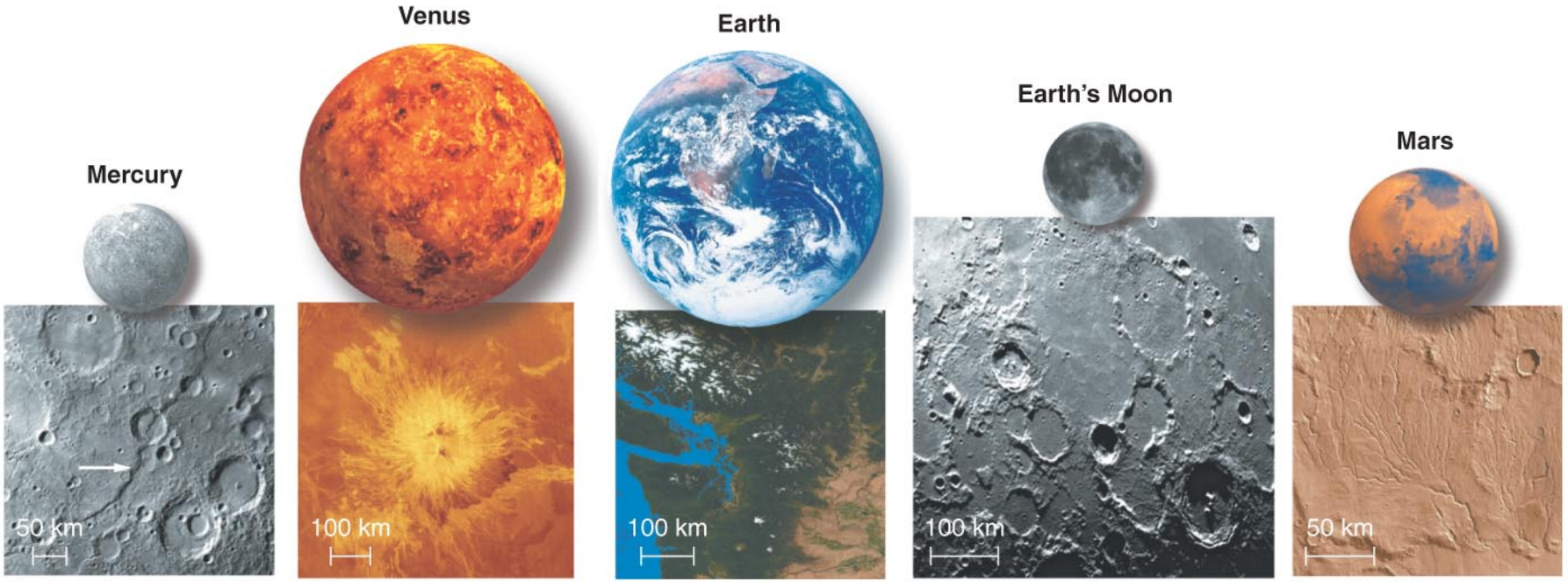
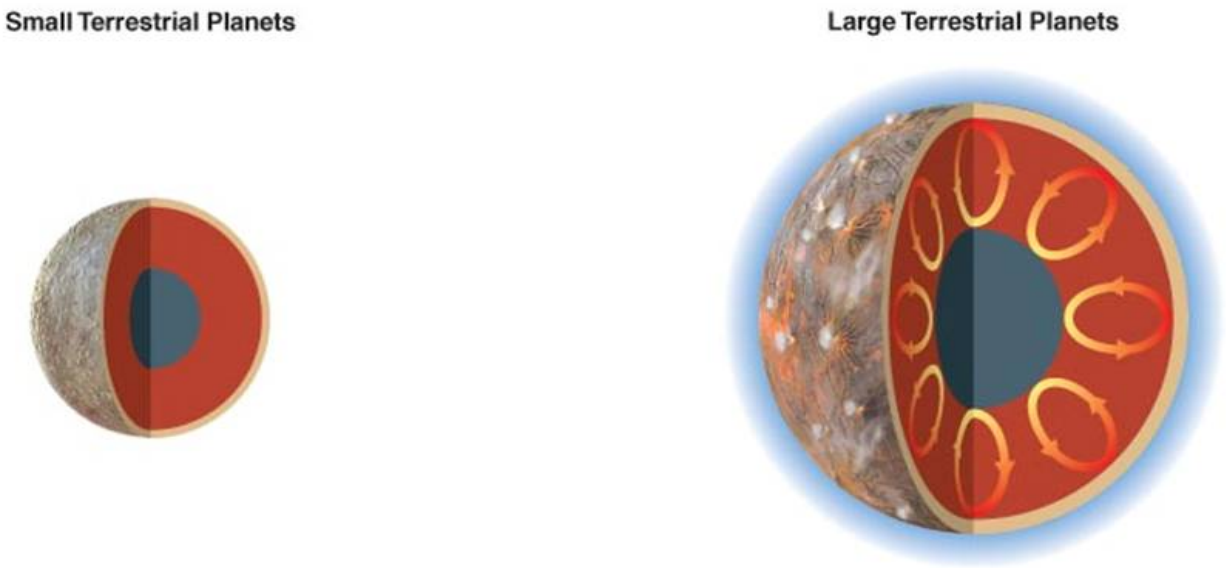
C. tectonics, impacts, volcanoes, erosion
D. magnetic fields, impacts, volcanoes, erosion
E. tectonics, impacts, erosion, magnetic fields

Why do the terrestrial planets have different geological histories?

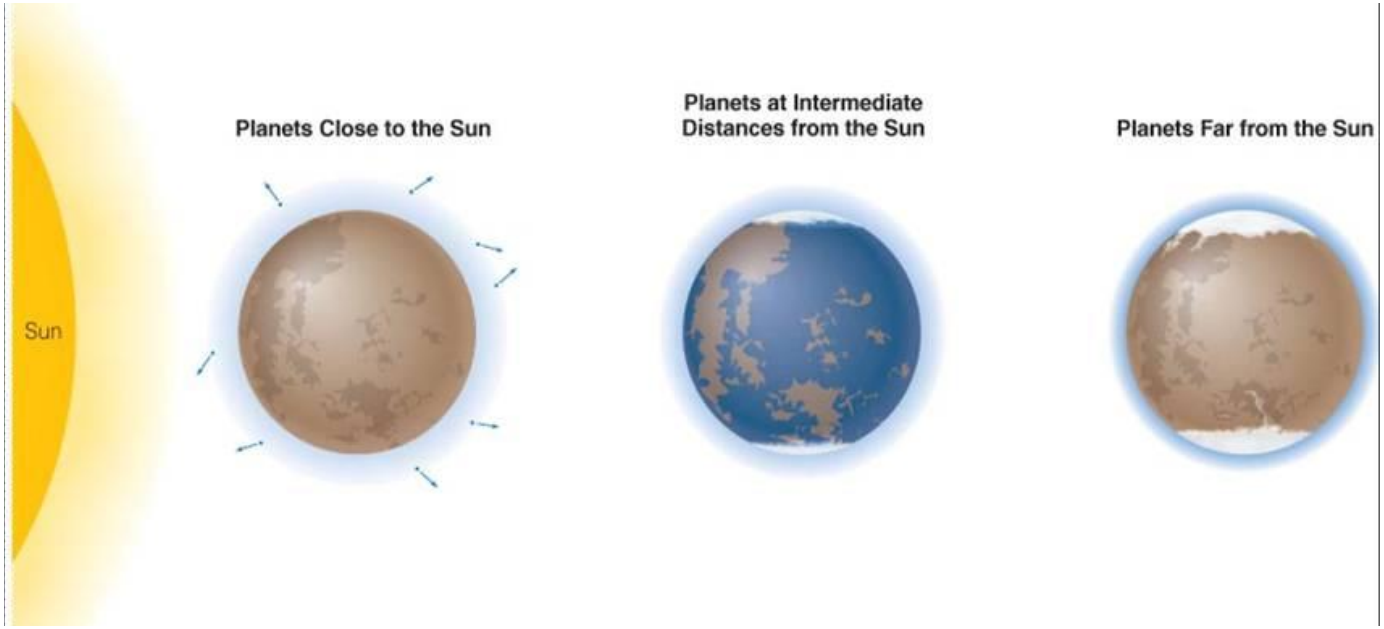


Role of Planetary Size



- Smaller worlds cool off faster and harden earlier.
- Larger worlds remain warm inside, promoting volcanism and tectonics.
- Larger worlds also have more erosion because their gravity retains an atmosphere.

Role of Distance from Sun



- Planets close to the Sun are too hot for rain, snow, ice and so have less erosion.
- Hot planets have more difficulty retaining an atmosphere.
- Planets far from the Sun are too cold for rain, limiting erosion.
- Planets with liquid water have the most erosion.

Role of Rotation

- Planets with slower rotation have less weather, less erosion, and a weak magnetic field.
- Planets with faster rotation have more weather, more erosion, and a stronger magnetic field.

What have we learned?

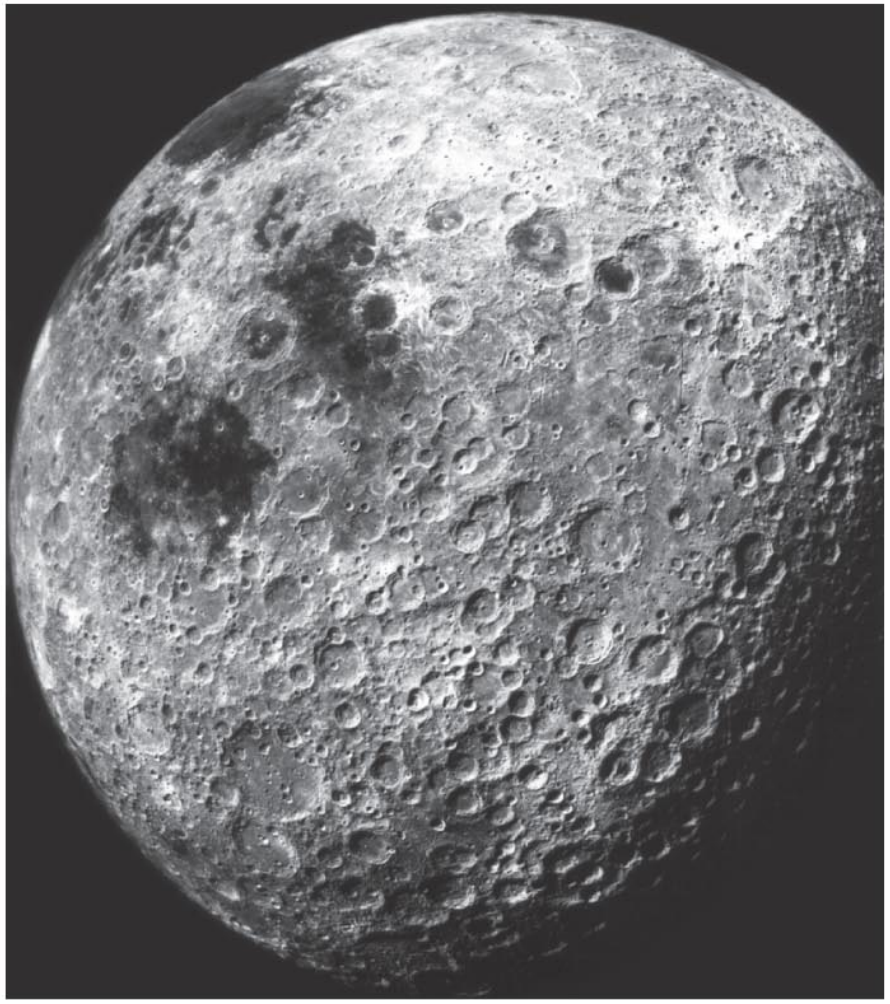
- What processes shape planetary surfaces?
  - Cratering, volcanism, tectonics, erosion
- How do impact craters reveal a surface's geological age?
  - The amount of cratering tells us how long ago a surface formed.
- Why do the terrestrial planets have different geological histories?
  - Differences arise because of planetary size, distance from Sun, and rotation rate.

9.3 Geology of the Moon and Mercury

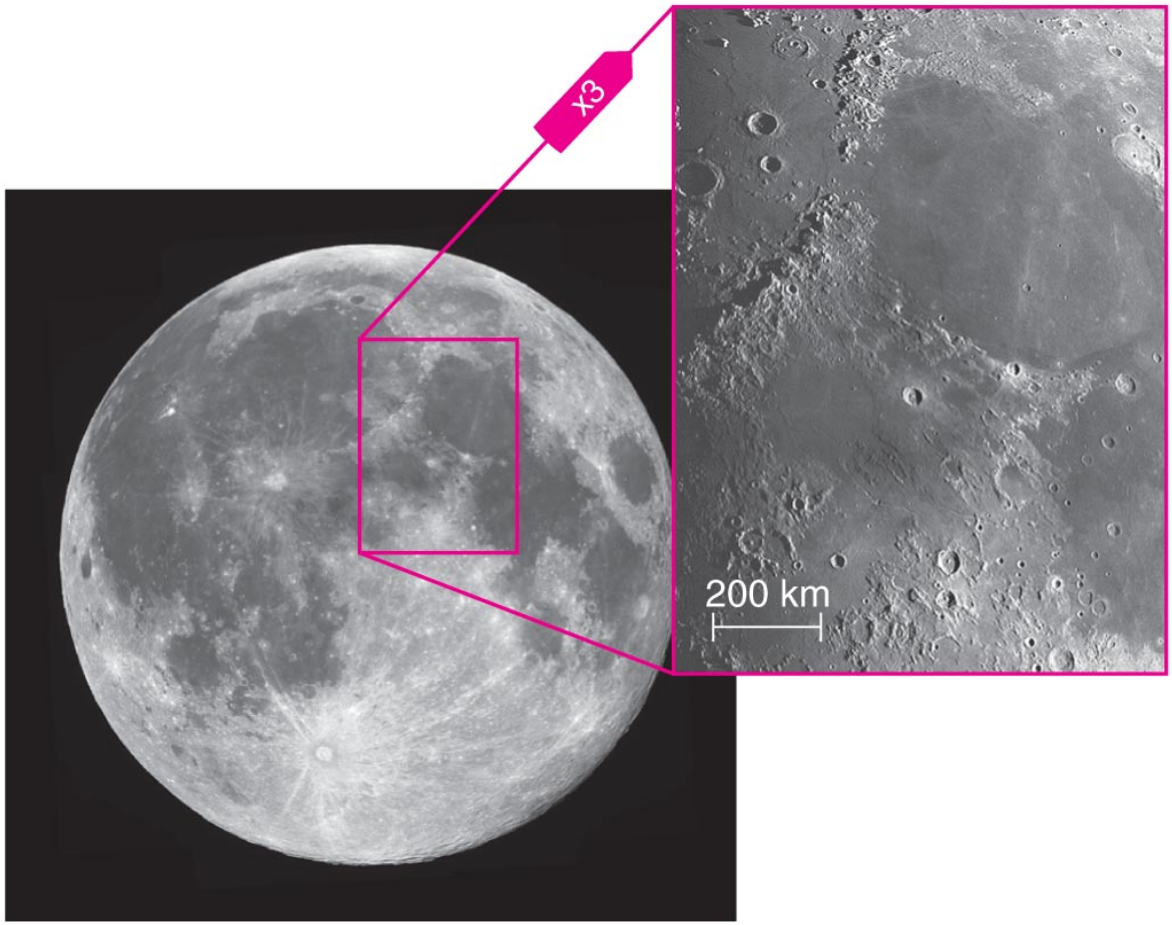
Our goals for learning:

- What geological processes shaped our Moon?
- What geological processes shaped Mercury?

What geological processes shaped our Moon?

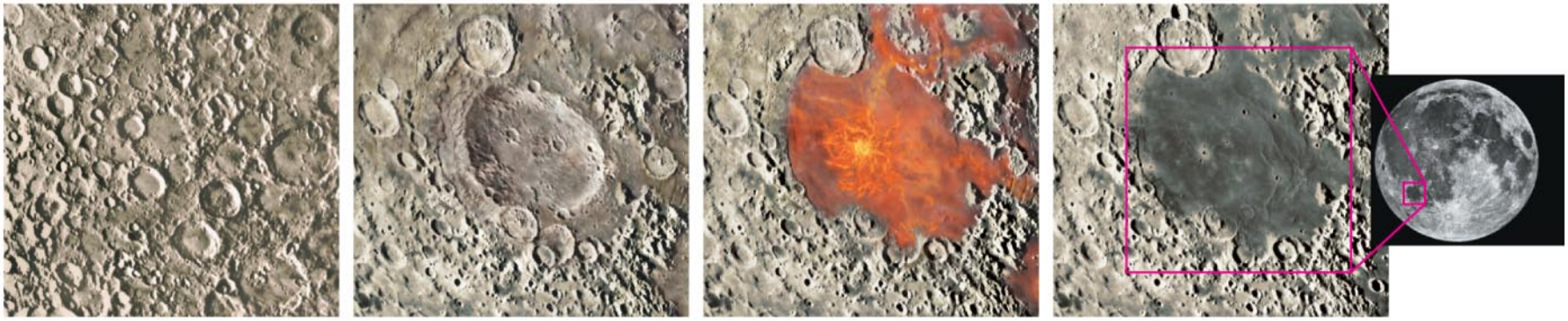


Lunar Maria



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

Formation of Lunar Maria



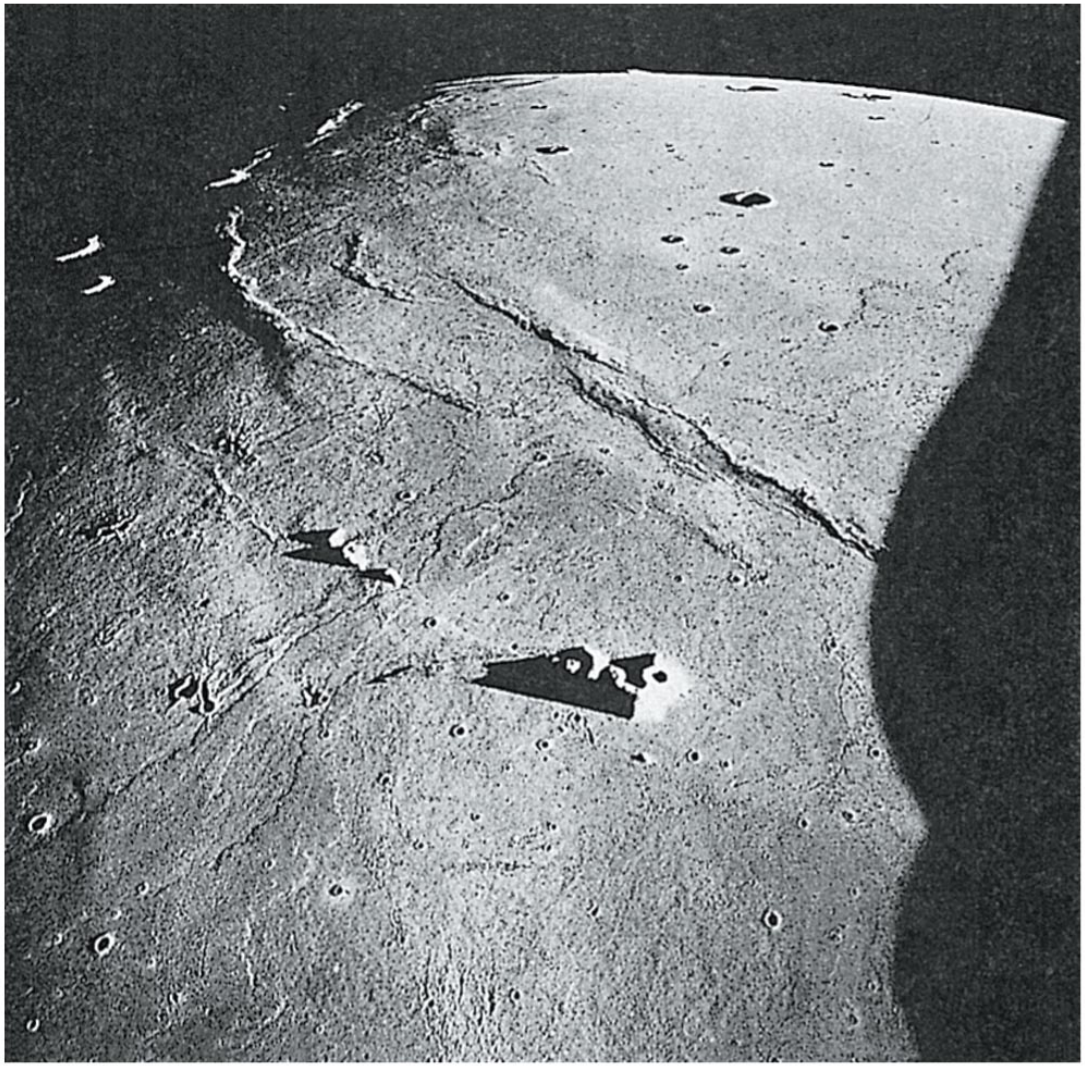
Early surface is covered with craters.

Large impact crater weakens crust.

Heat build-up allows lava to well up to surface.

Cooled lava is smoother and darker than surroundings.

Tectonic Features



- Wrinkles arise from cooling and the contraction of a lava flood.

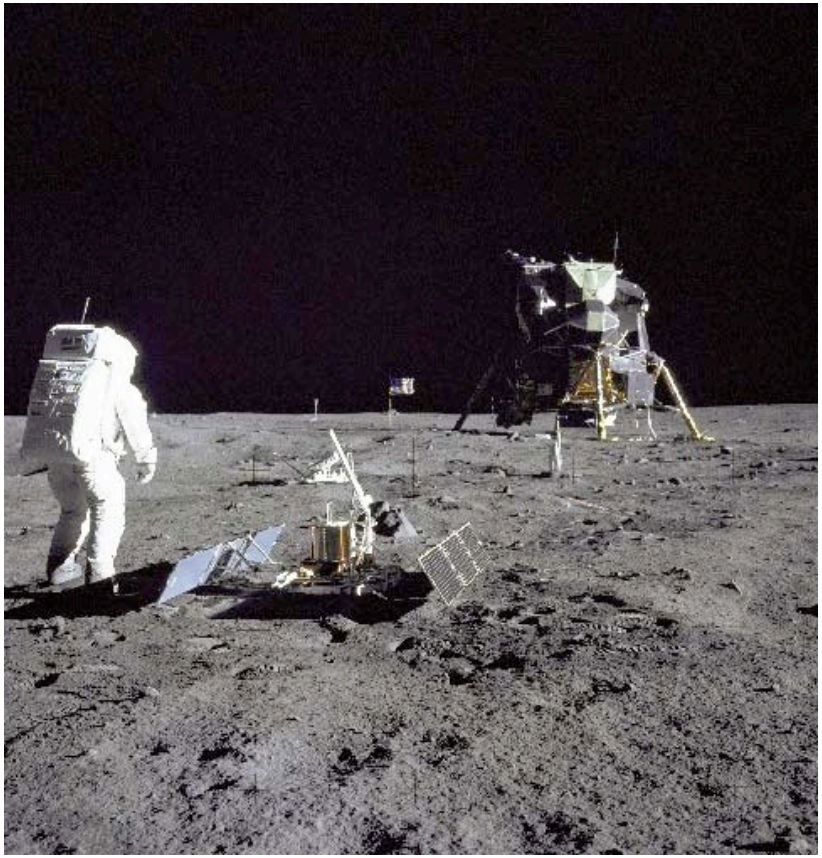
Surface "Gardening"

- Micrometeorites are not filtered by an atmospheres and constant pulverize the surface to a fine dust
- Large lander foot pads?

Geologically Dead

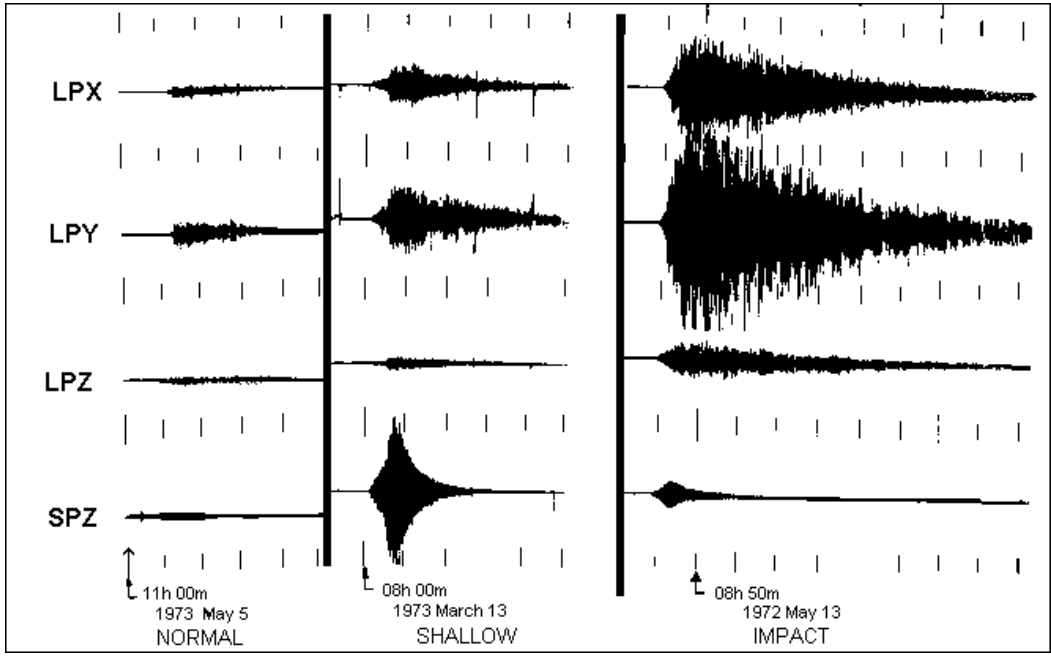
- Moon is considered geologically “dead” because geological processes have virtually stopped.
- Although….

Moonquakes

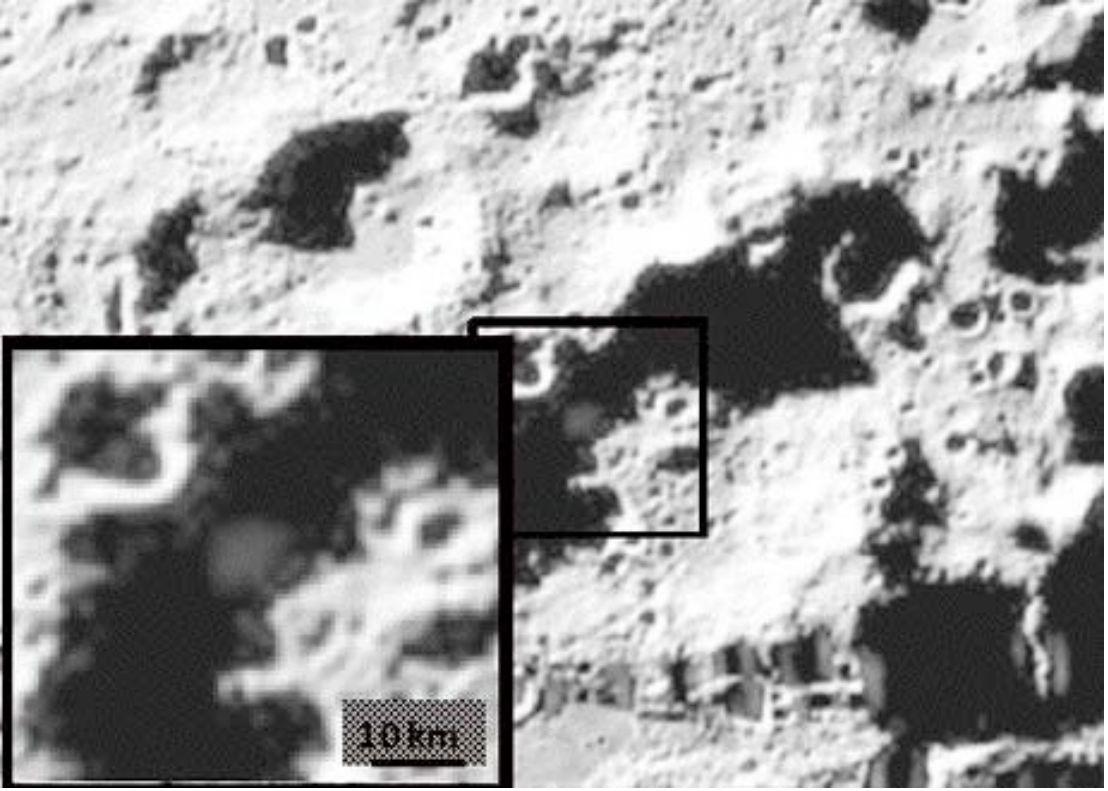


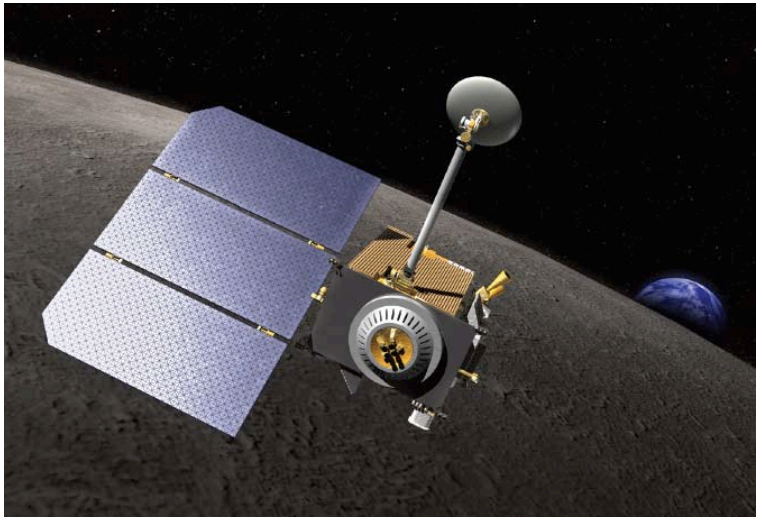
Buzz Aldrin next to the first seismometer on the moon, 1969. In the background is Eagle, Apollo's lunar lander.

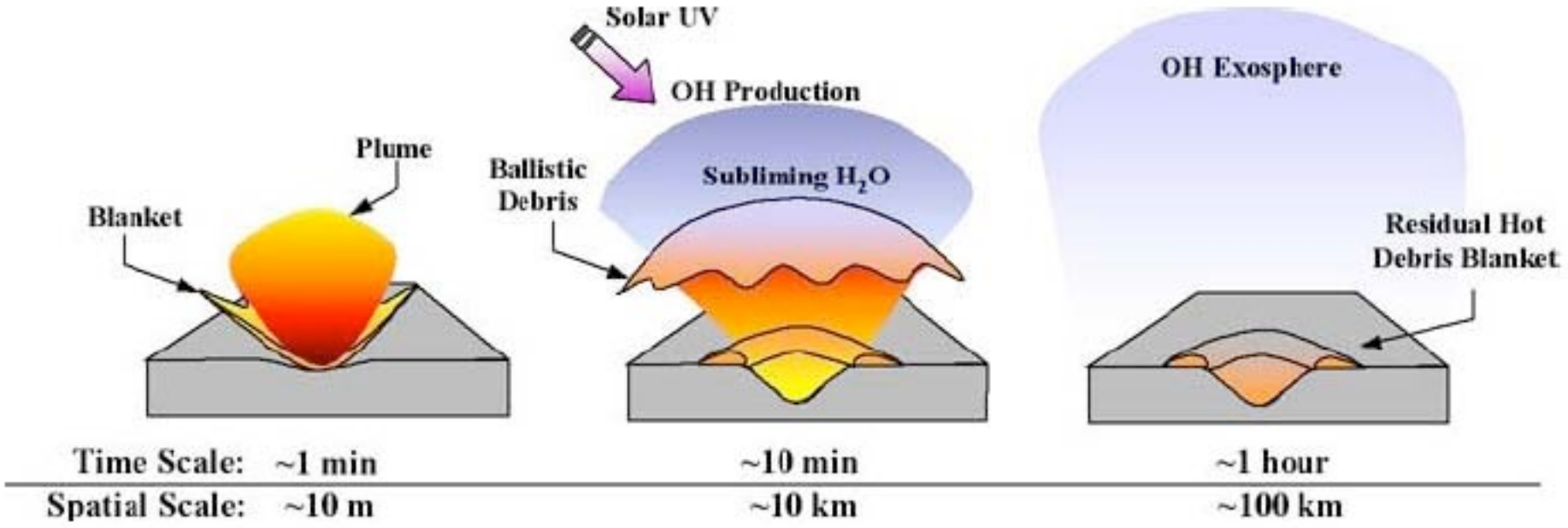
- Tidal flexing due to tides raised on moon by Earth (27 day pattern)
- Heating/cooling of crust due to night/ day (close to surface)
- Meteorite impacts onto surface
- Some up to magnitude 5
- Lunar bases must be Earthquake proof



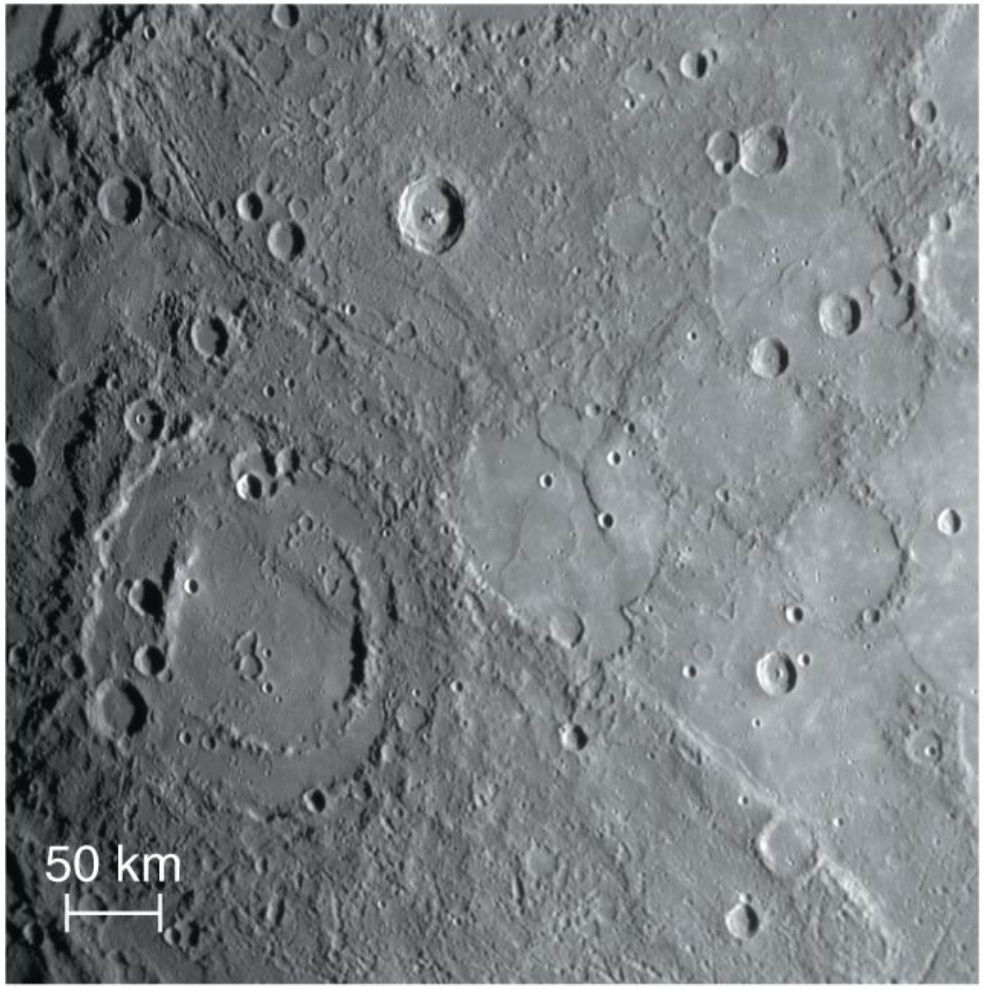
NASA's LCROSS



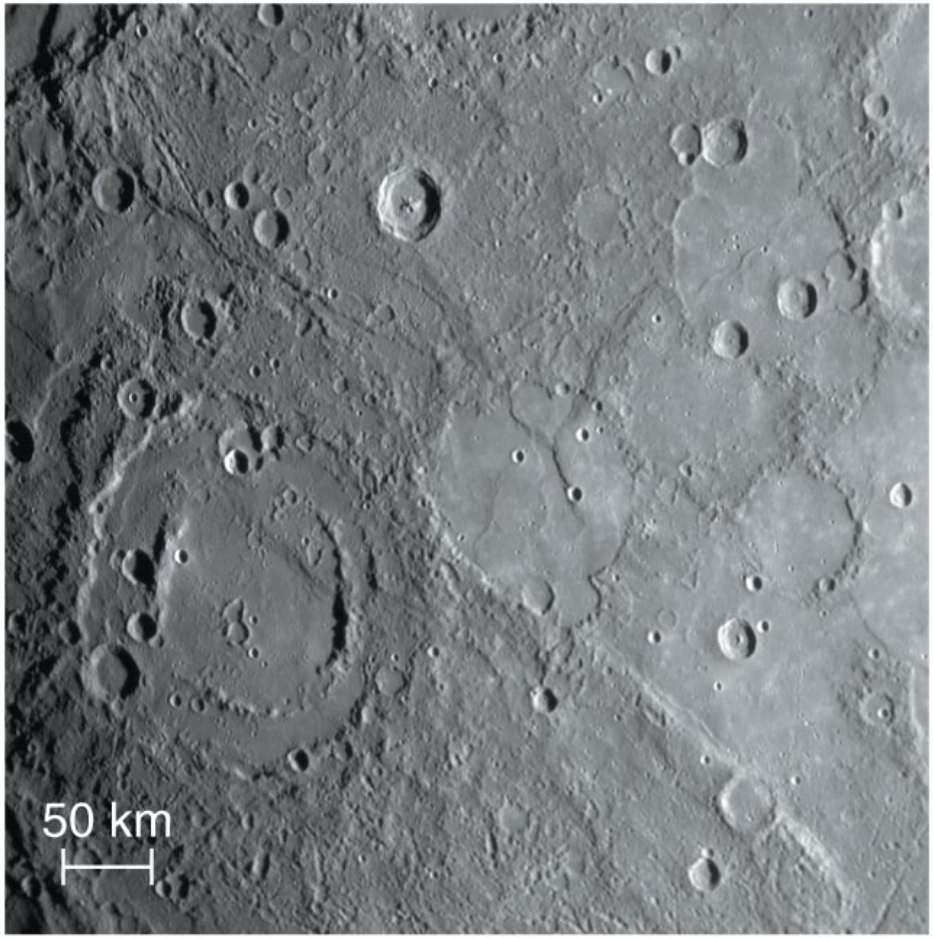




What geological processes shaped Mercury?

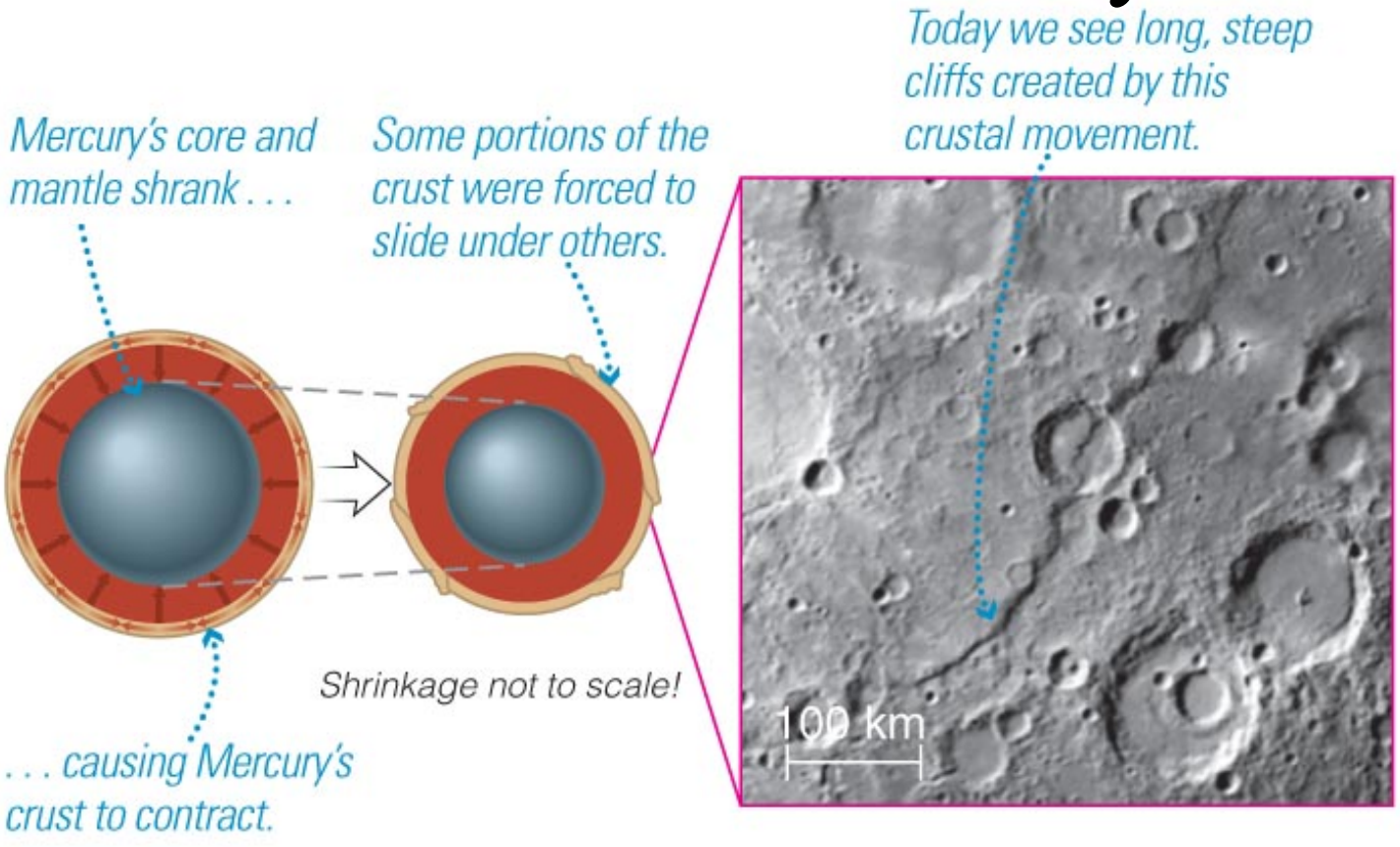


Cratering of Mercury



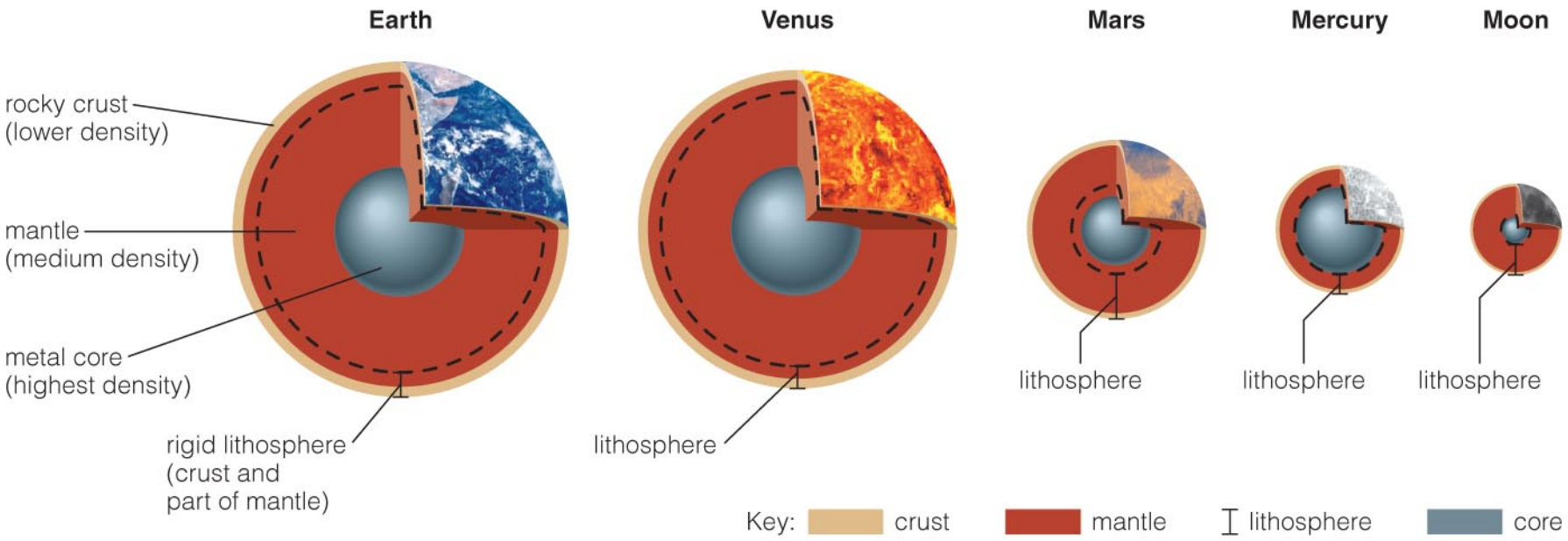
- Mercury has a mixture of heavily cratered and smooth regions like the Moon.
- Smooth regions are likely ancient lava flows.
- A bit less cratered that the Moon, indicating more geological activity during era of heavy bombardment

Tectonics on Mercury

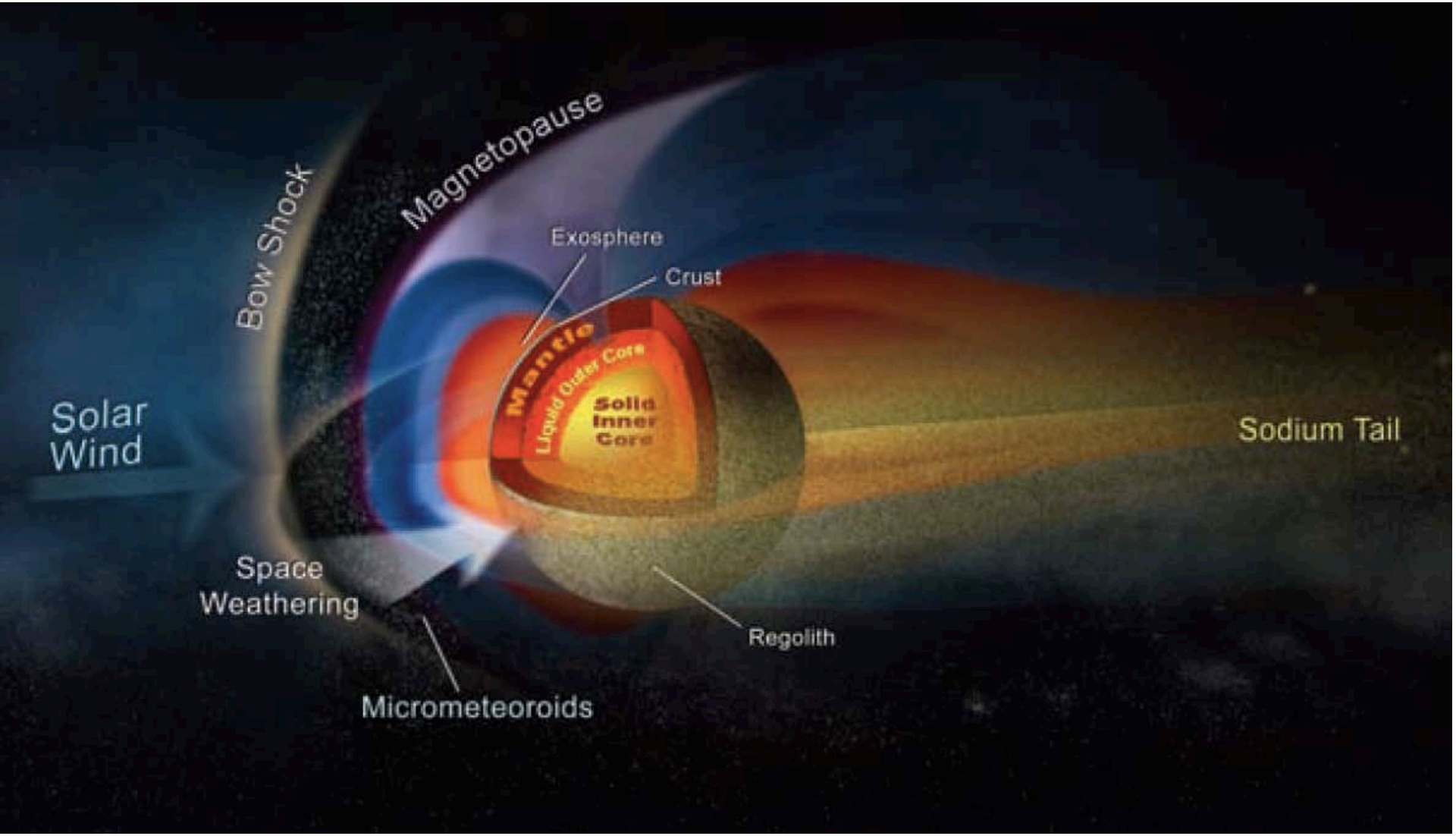


- Long cliffs indicate that Mercury shrank early in its history, probably 3 km (about 0.1% in radius)
- Cooling of metal core→ shrinking of metal core

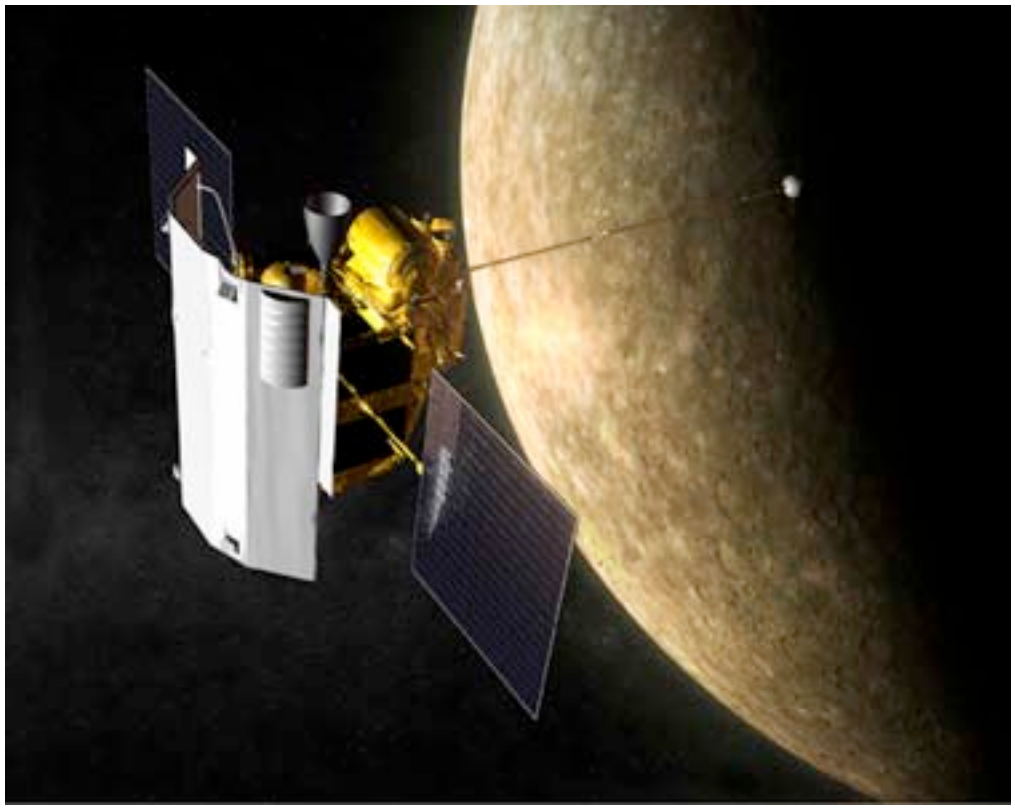
Impact on Mercury?



- Very large iron/rock ratio for Mercury may indicate that a giant impact ripped off much of its rock


Bow Shock
Magnetopause
Exosphere
Crust
Mantle
Liquid Outer Core
Solid Inner Core
Solar Wind
Sodium Tail
Space Weathering
Regolith
Micrometeoroids

NASA's Mercury Messenger



MErcury Surface, Space ENvironment, GEochemistry and Ranging (MESSENGER)

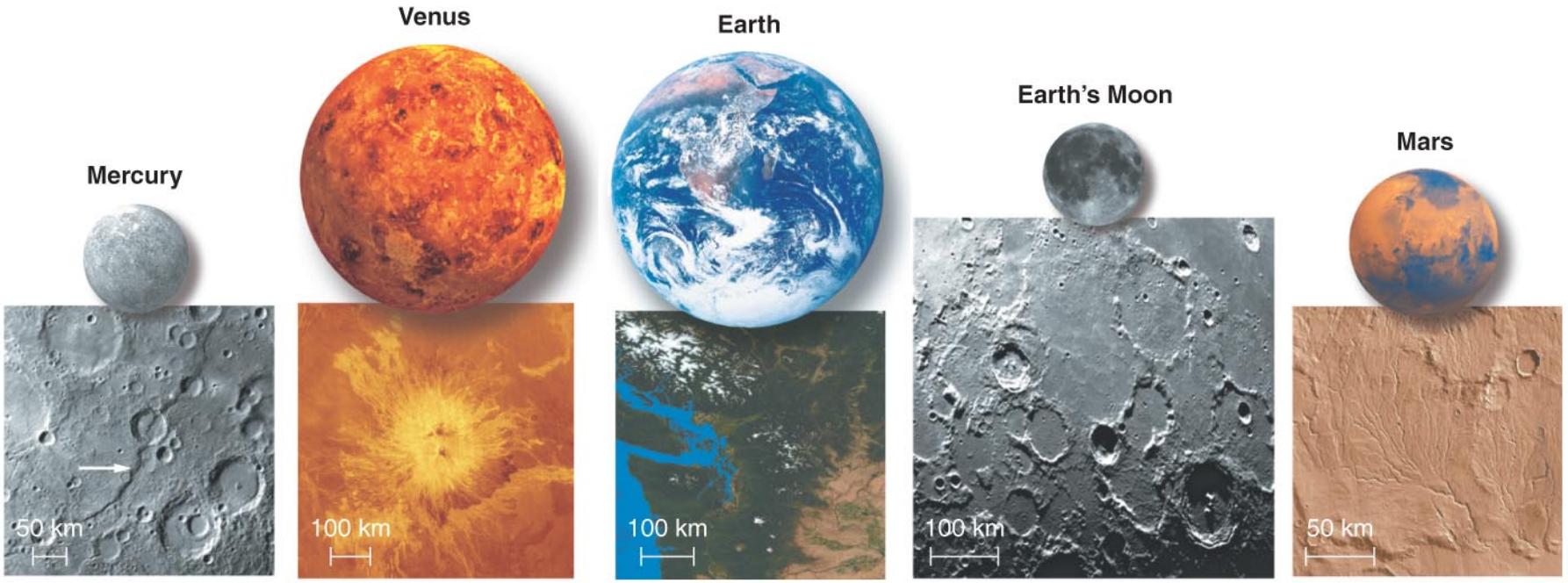
Orbit began in March, 2011

Has done some flybys already (show orbit movie)

What have we learned?

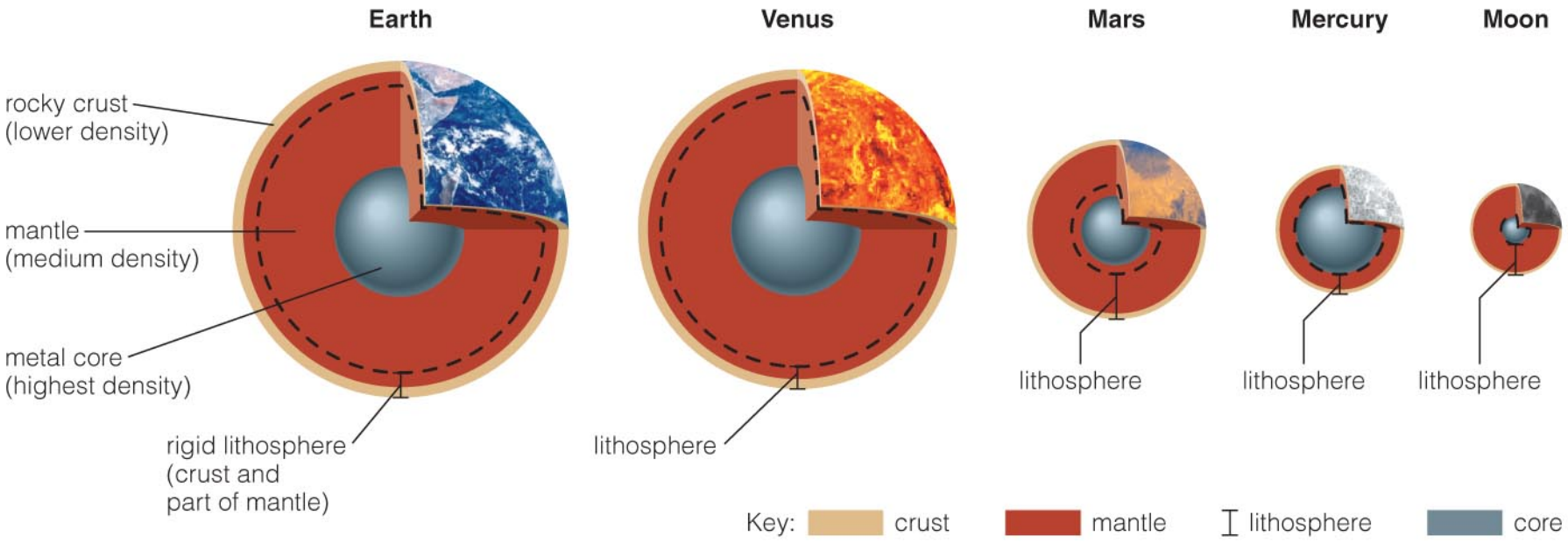
- What geological processes shaped our Moon?
  - Early cratering is still present.
  - Maria resulted from volcanism.
- What geological processes shaped Mercury?
  - Had cratering and volcanism similar to Moon
  - Tectonic features indicate early shrinkage.

What are terrestrial planets like on the inside?



- Planets are round because gravity overwhelms the strength of rock
- The same is not true for small objects like asteroids

Terrestrial Planet Interiors



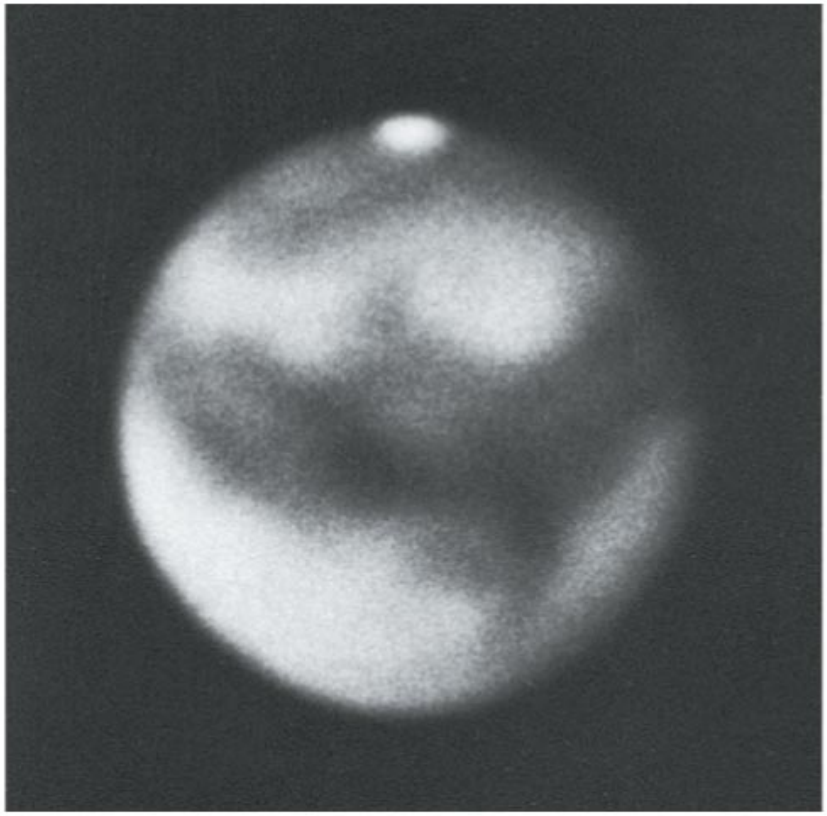
- Applying what we have learned about Earth's interior to other planets tells us what their interiors are probably like.

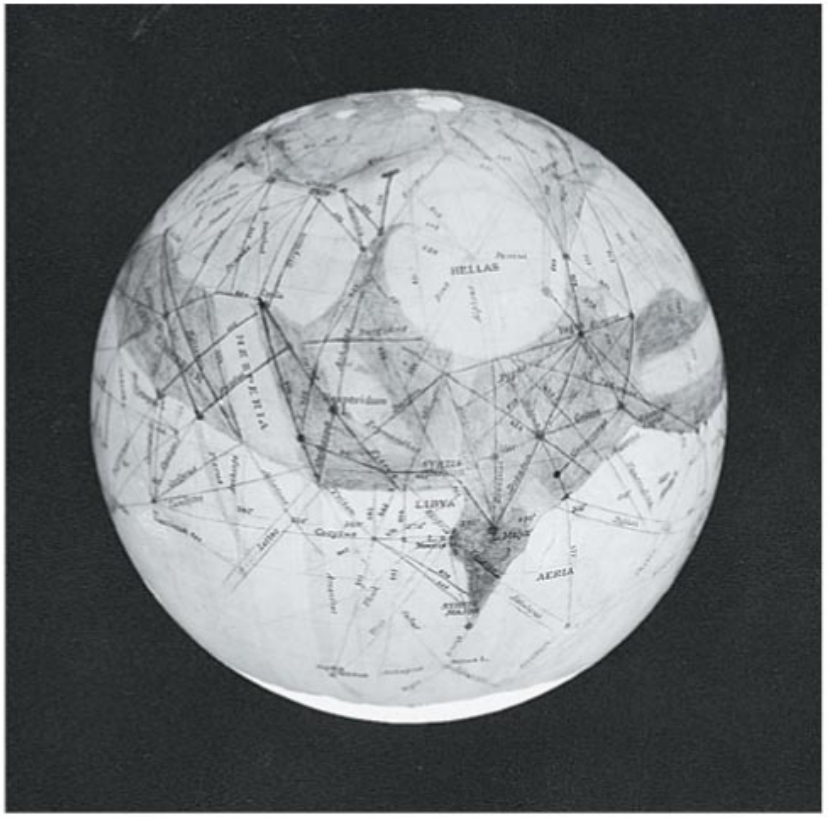
9.4 Geology of Mars

Our goals for learning:

- How did Martians invade popular culture?
- What are the major geological features of Mars?
- What geological evidence tells us that water once flowed on Mars?

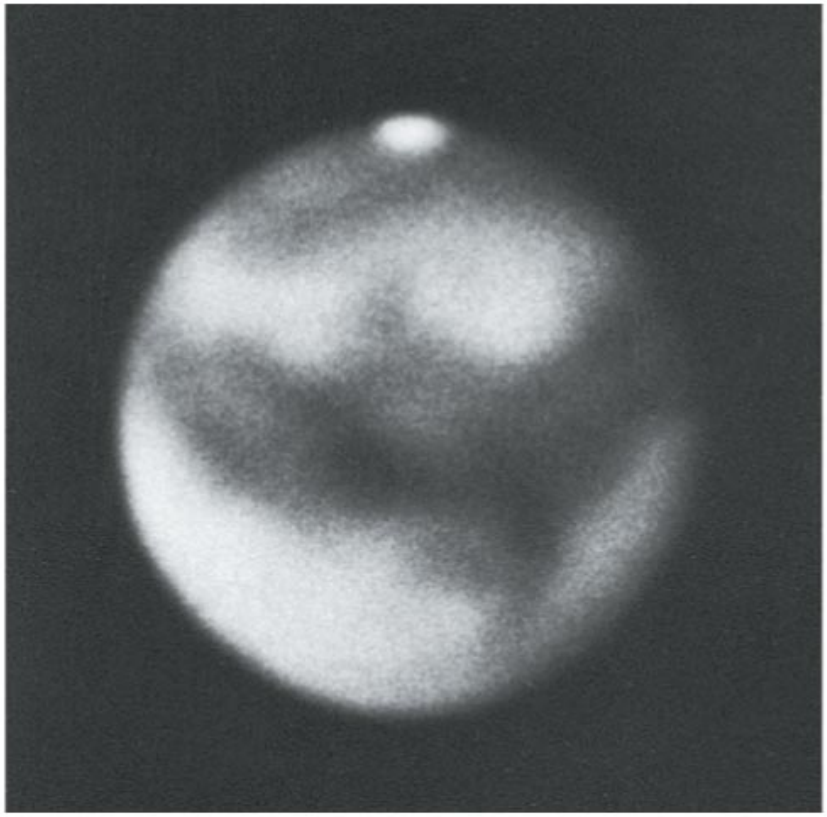
How did Martians invade popular culture?

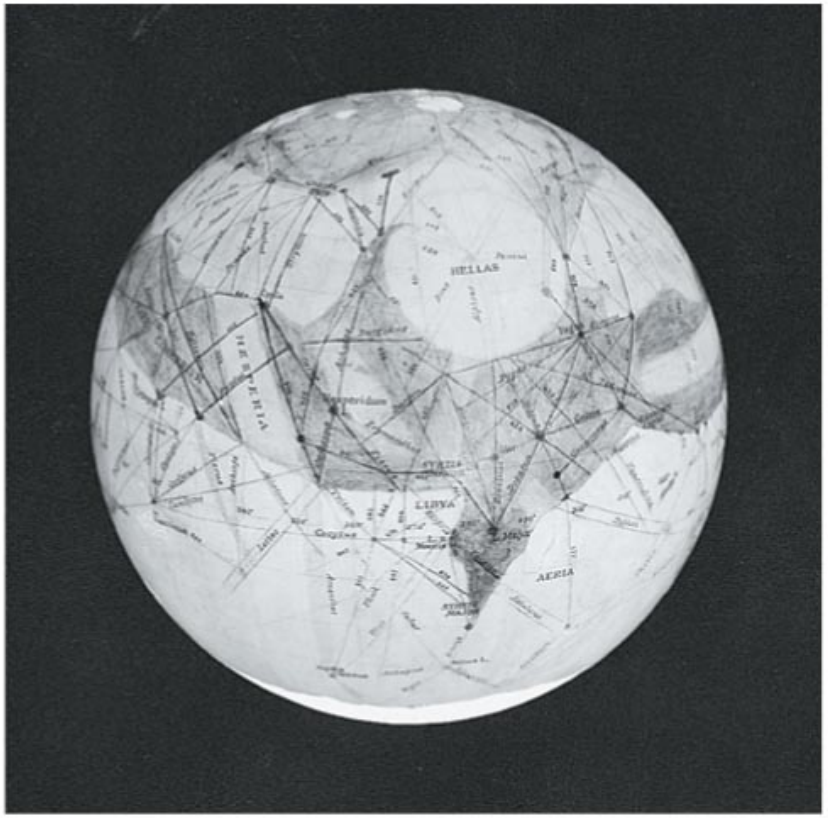




- Italian astronomer Giovanni Schiaperelli, 1879: Canali on Mars
- Canali means "channels" not canals. Oh well!
- 1894 Percival Lowell open observatory to study Martian Canals

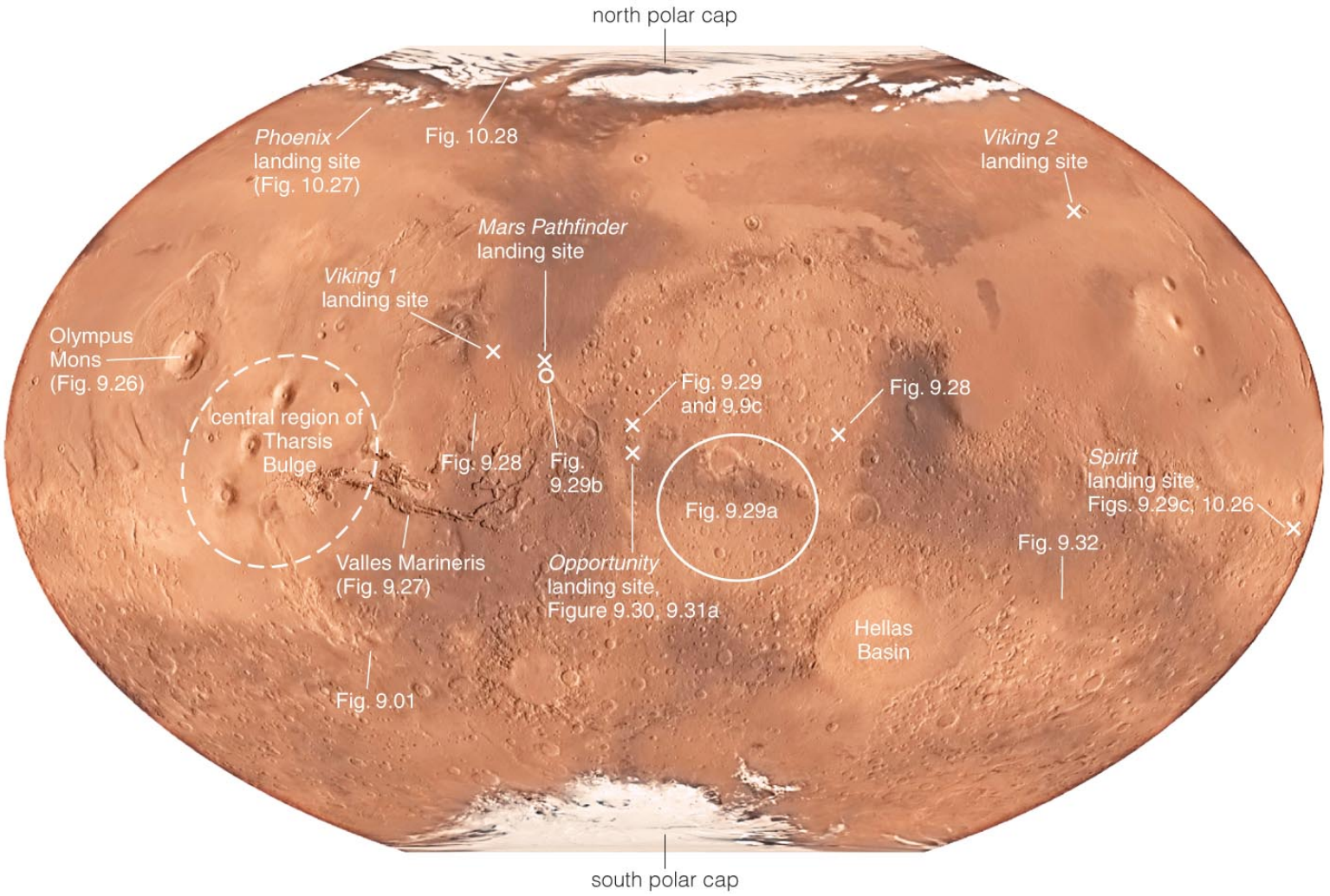
“Canals” on Mars





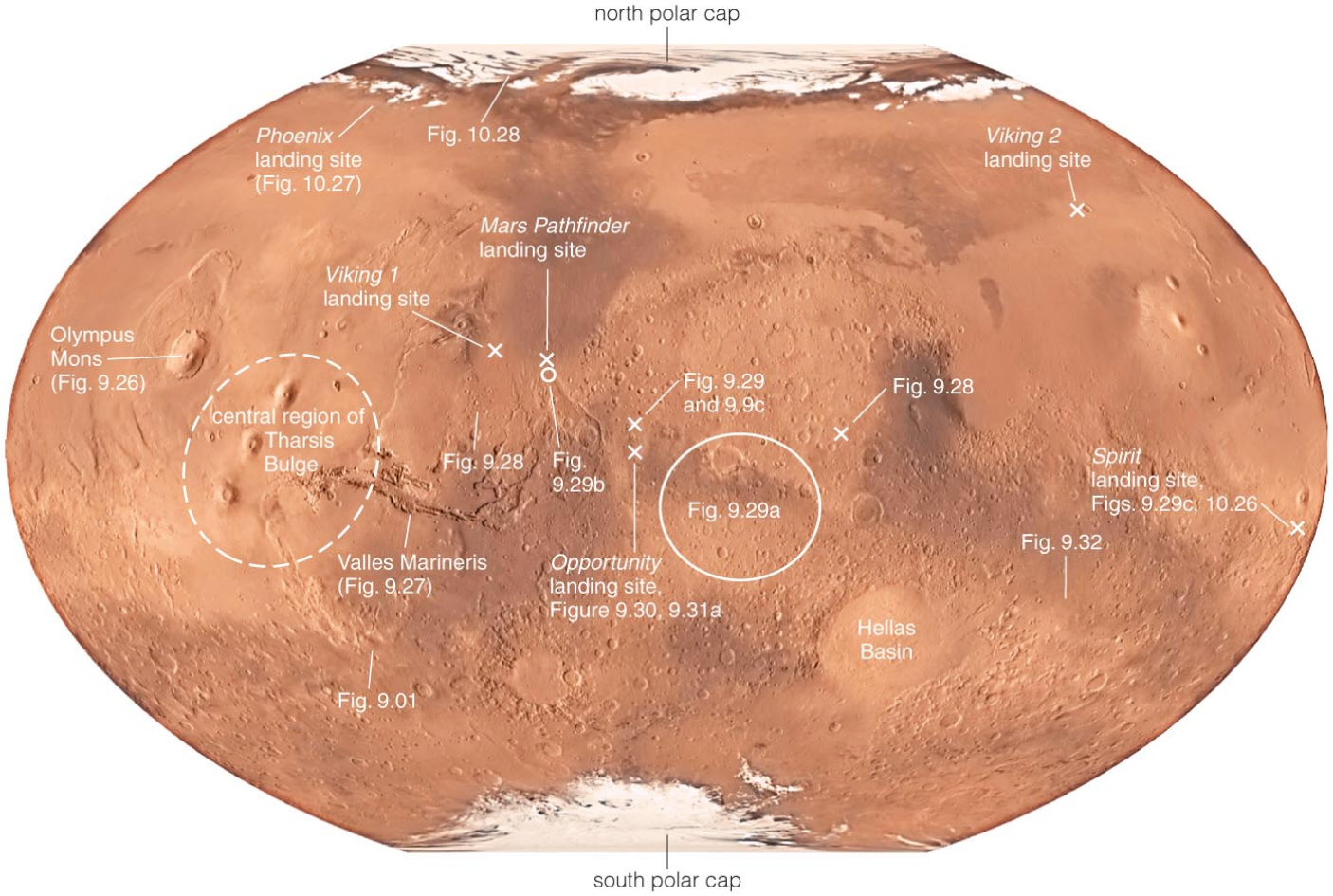
- Percival Lowell misinterpreted surface features seen in telescopic images of Mars.
- Led to H.G. Wells “War of the Worlds” in 1898….
- Settled in 1965 by NASA’s Mariner 4 spacecraft

What are the major geological features of Mars?



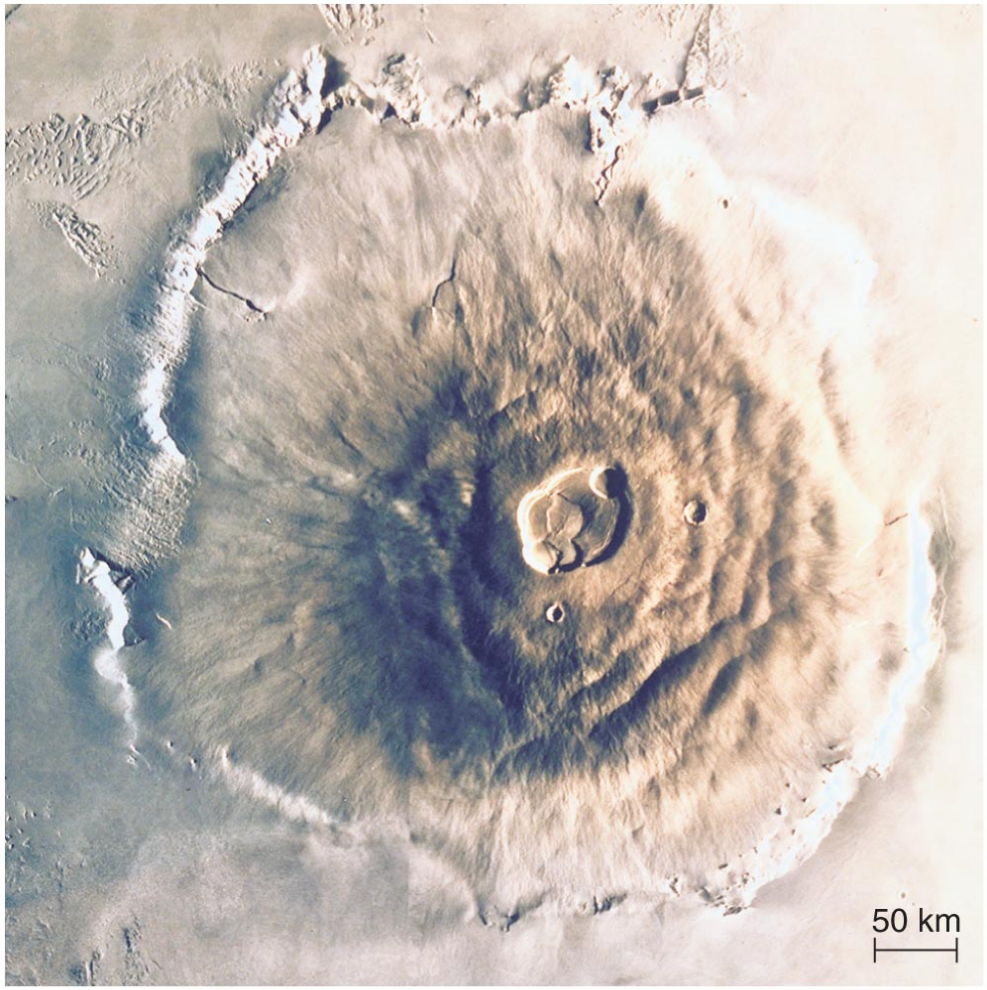
Martian *land area* is about the same size as Earth's land area

Cratering on Mars



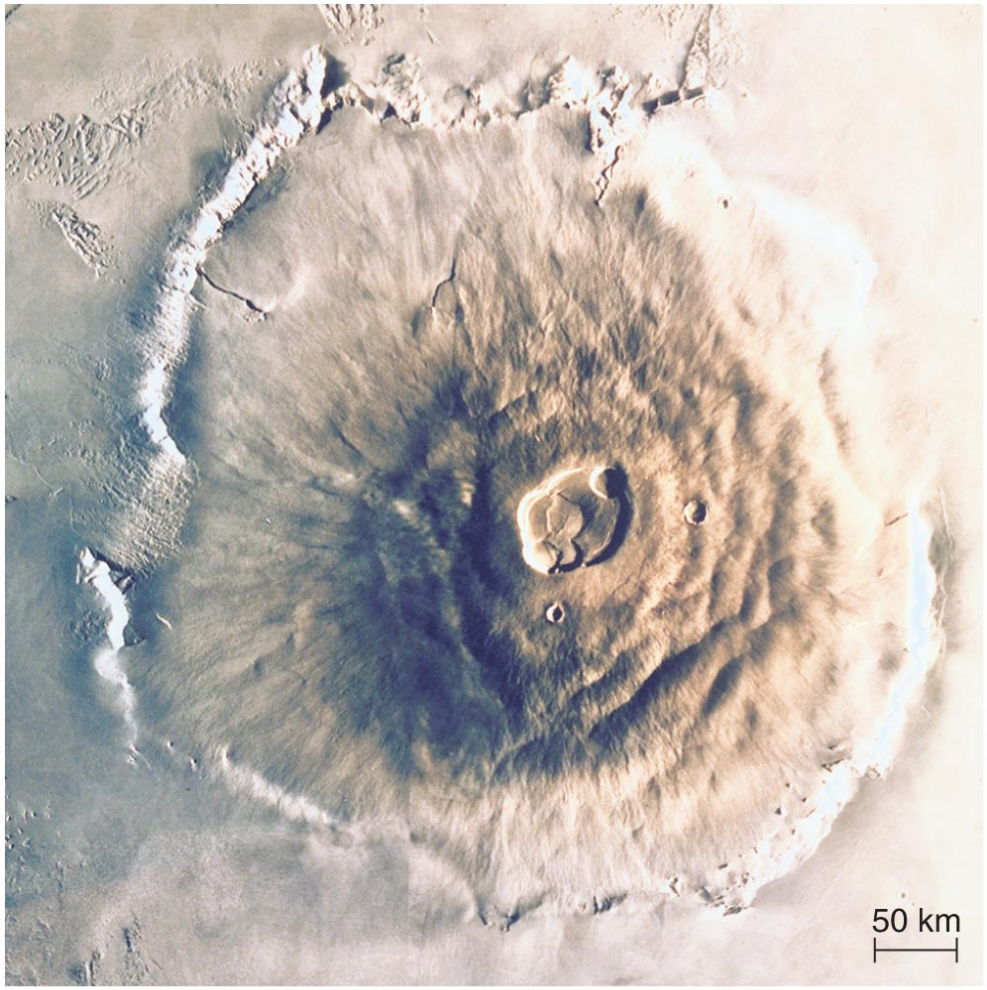
- The amount of cratering differs greatly across Mars's surface.
- Southern highlands are heavy cratered—northern plains are not
- Many early craters have been erased.

Volcanism on Mars



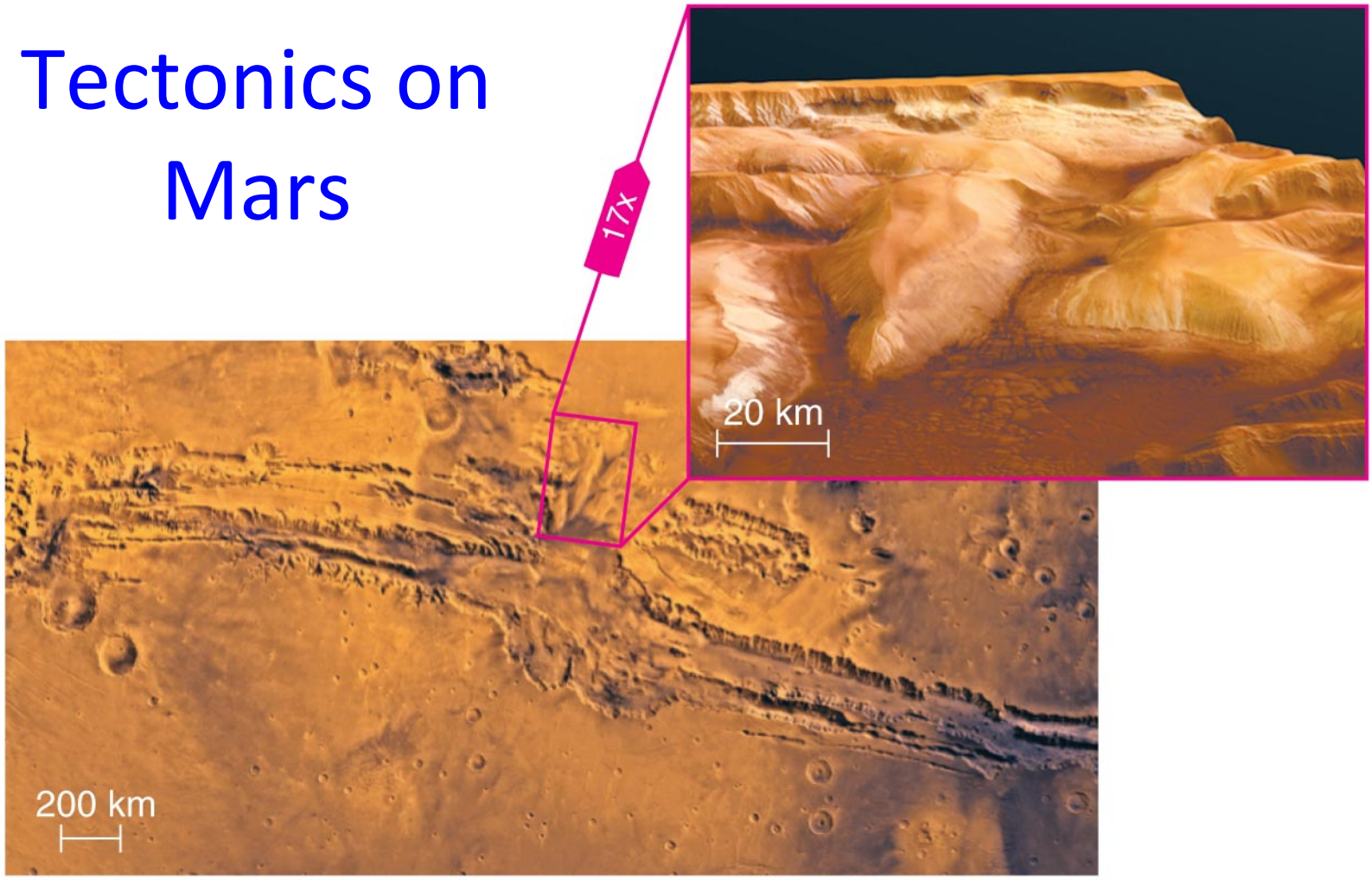
- Mars has many large shield volcanoes.
- Volcanism has been the planet's most important geological process
- No one knows why volcanism dominated the northern plains only
- Meteorites from Mars are as young at 180 Myr, so volcanoes may not be extinct
- Low gravity allows for taller mountains

Olympus Mons



- Area is the size of Arizona
- 26 km tall—3x higher than Everest
- Rim cliffs at top can be up to 6 km high

Tectonics on Mars

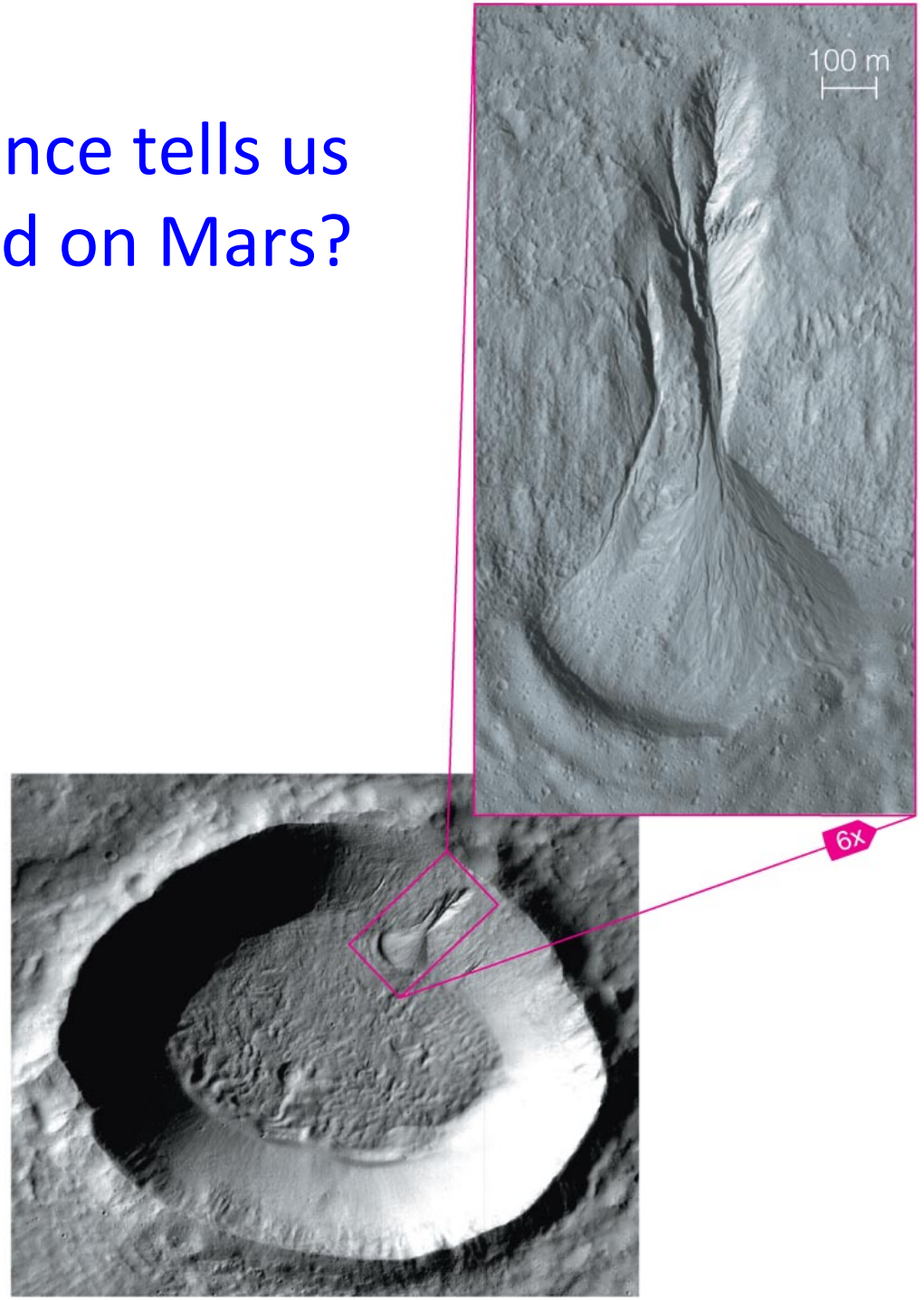


- The system of valleys known as Valles Marineris is thought to originate from tectonics.
- As long as the United States and 4 times deeper than the Grand Canyon

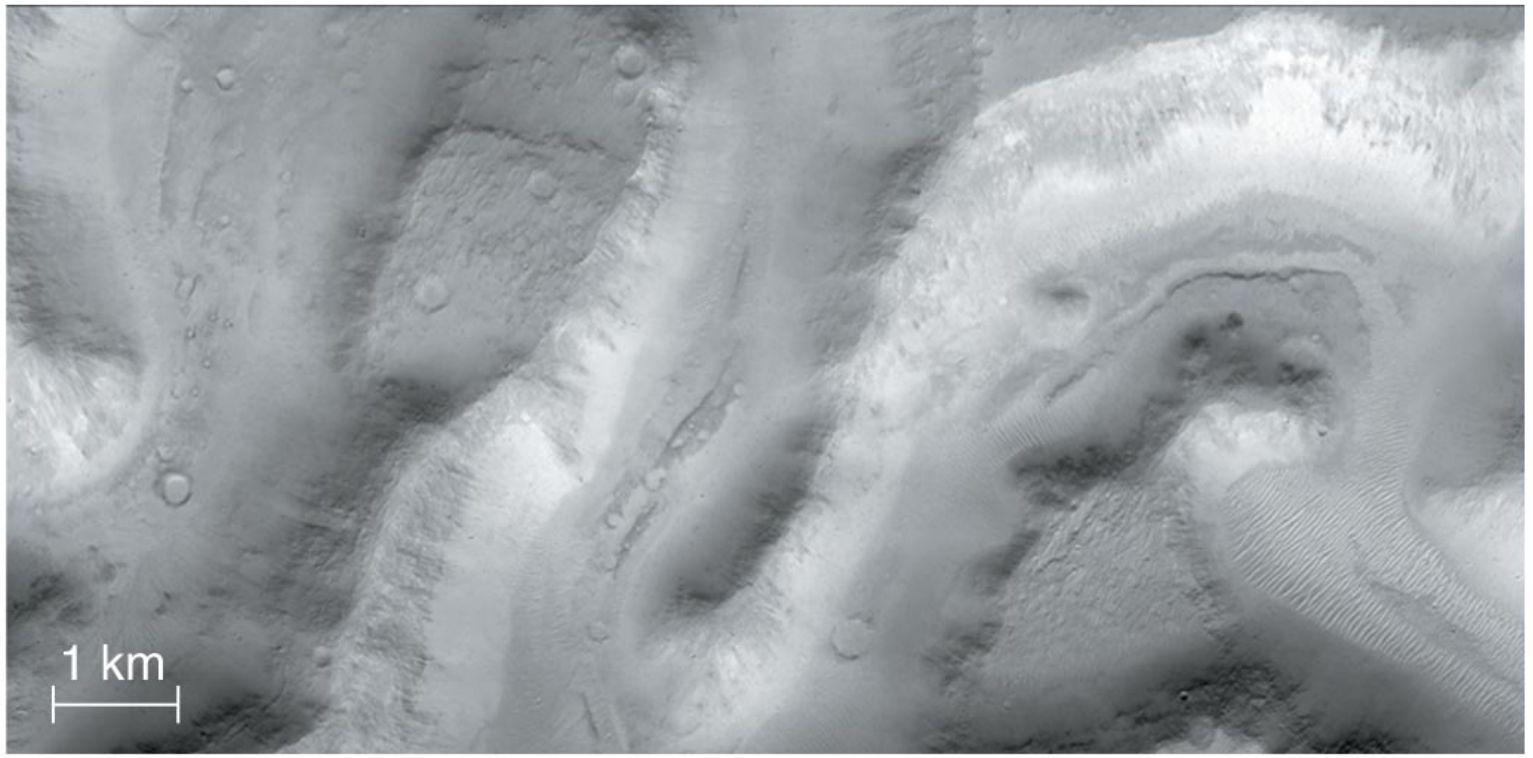
What geological evidence tells us that water once flowed on Mars?

<u>Current Mars:</u>
Liquid water would instantly freeze or evaporate, depending on the temperature

For liquid water, Mars MUST have been warmer, with a thicker atmosphere, in the past



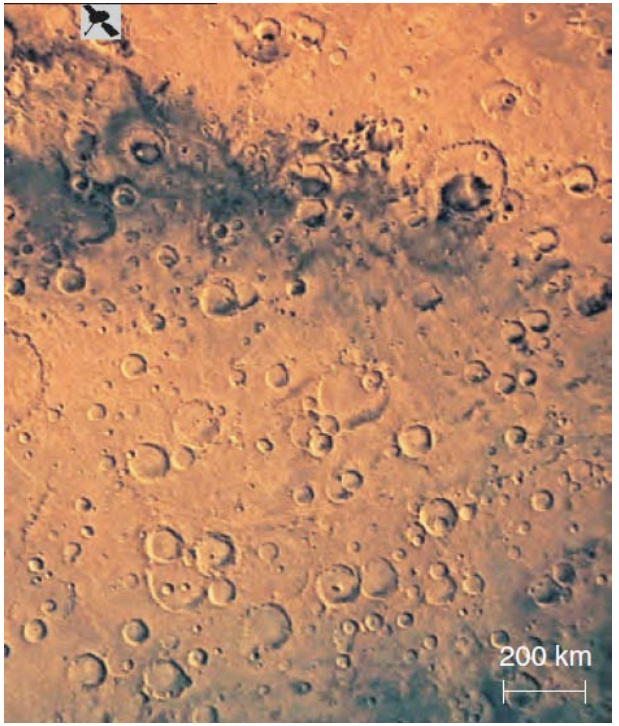
Dry Riverbeds?



- Close-up photos of Mars show what appear to be dried-up riverbeds.
- Cratering shows that these beds are around 3 Gyr old

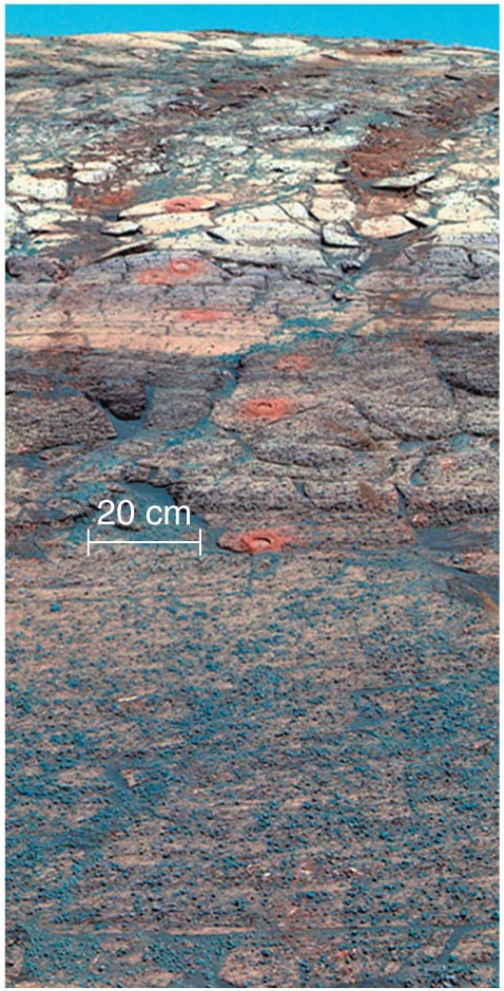
Erosion of Craters

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

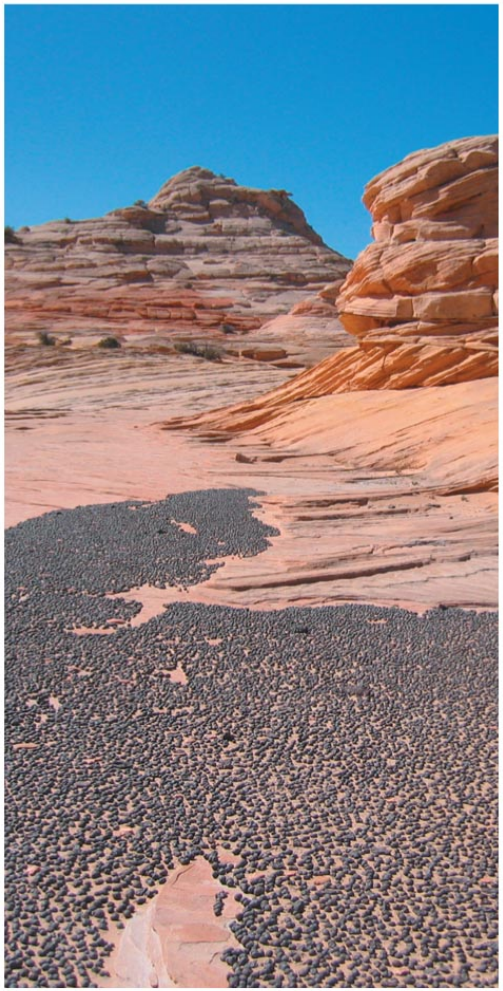


Martian Rocks

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



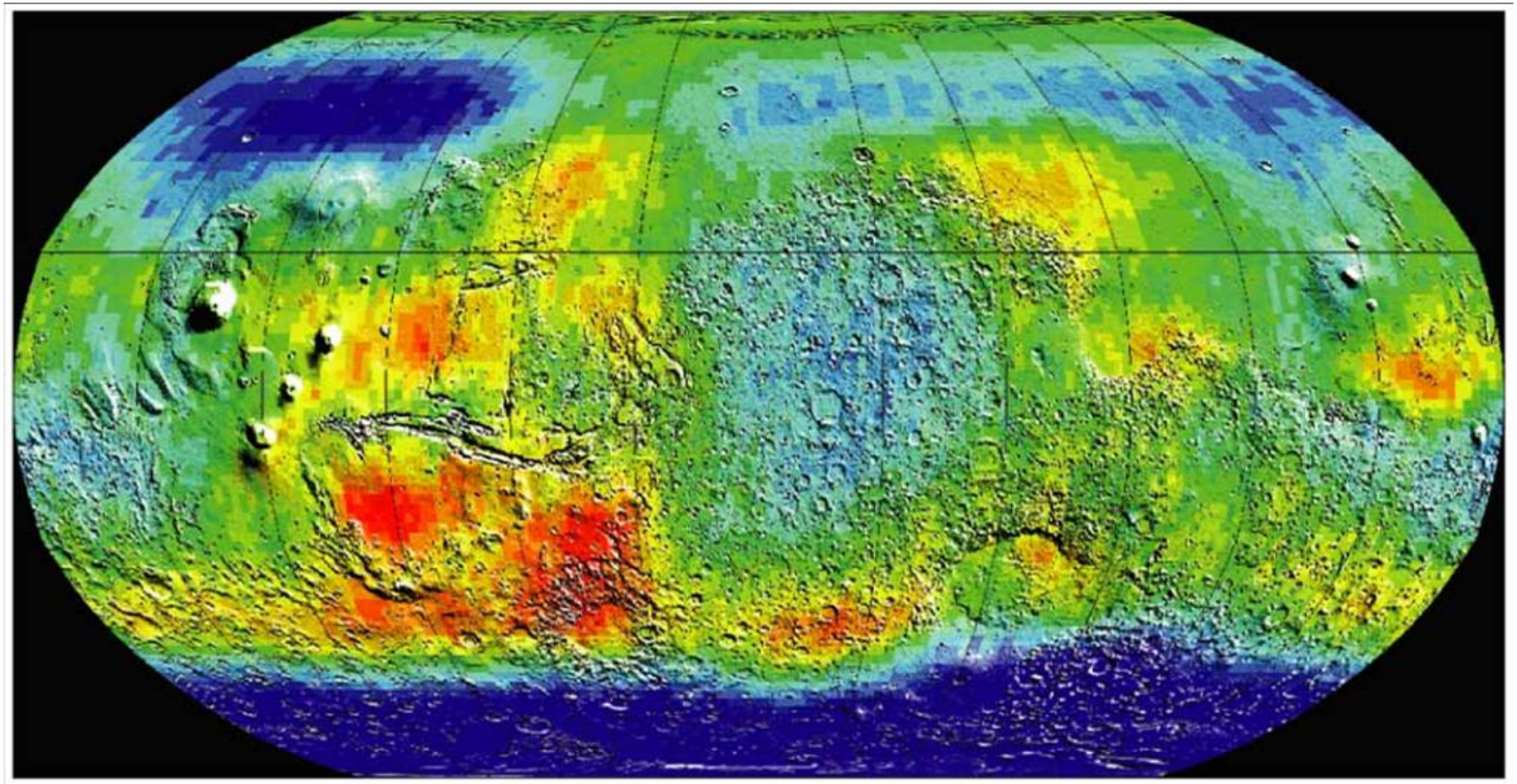
Mars (Endurance Crater)



Earth (Utah)

- Iron-rich hematite and sulfur-rich jarosite found abundantly on Mars, and only form in water on Earth

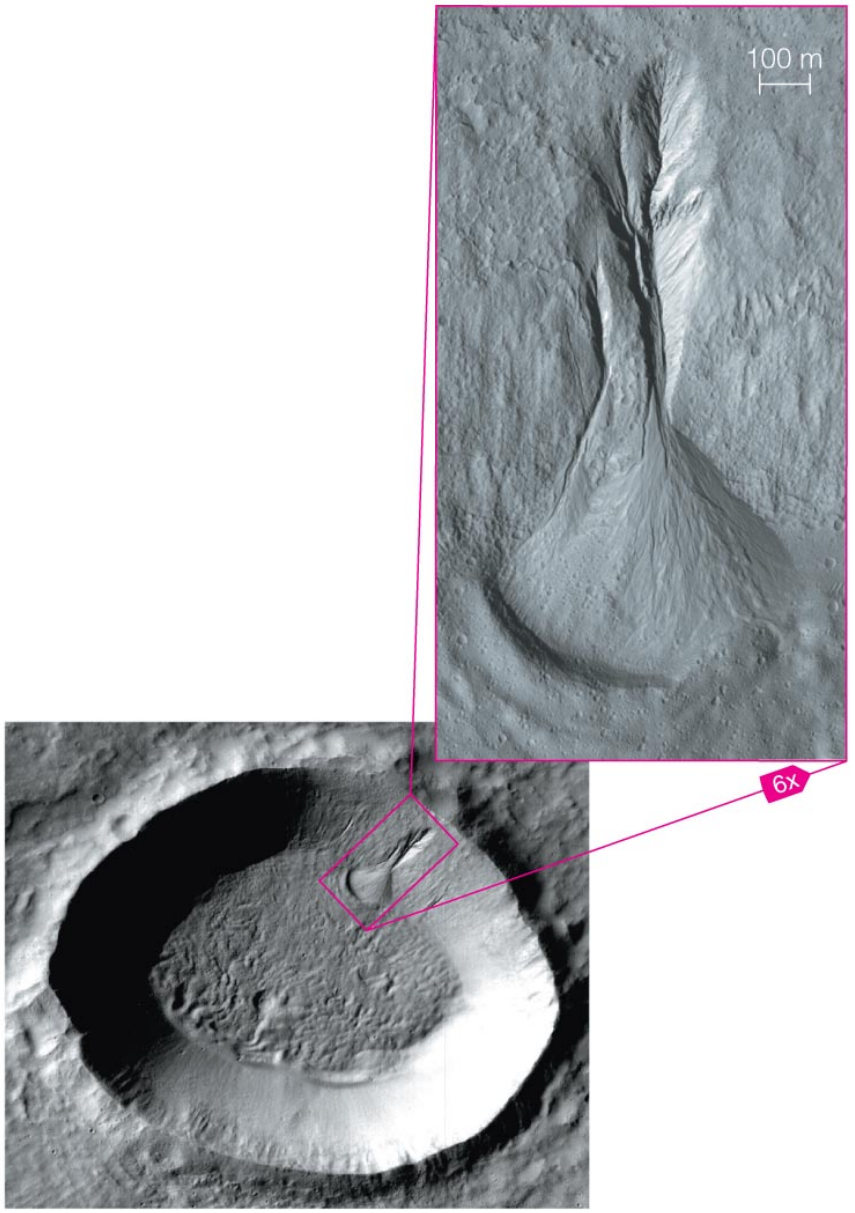
Hydrogen Content



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

Crater Walls

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



What have we learned?

- How did Martians invade popular culture?
  - Surface features of Mars in early telescopic photos were misinterpreted as "canals."
- What are the major geological features of Mars?
  - Differences in cratering across surface
  - Giant shield volcanoes
  - Evidence of tectonic activity
  - Good evidence for widescale flowing water in the distant past

What have we learned?

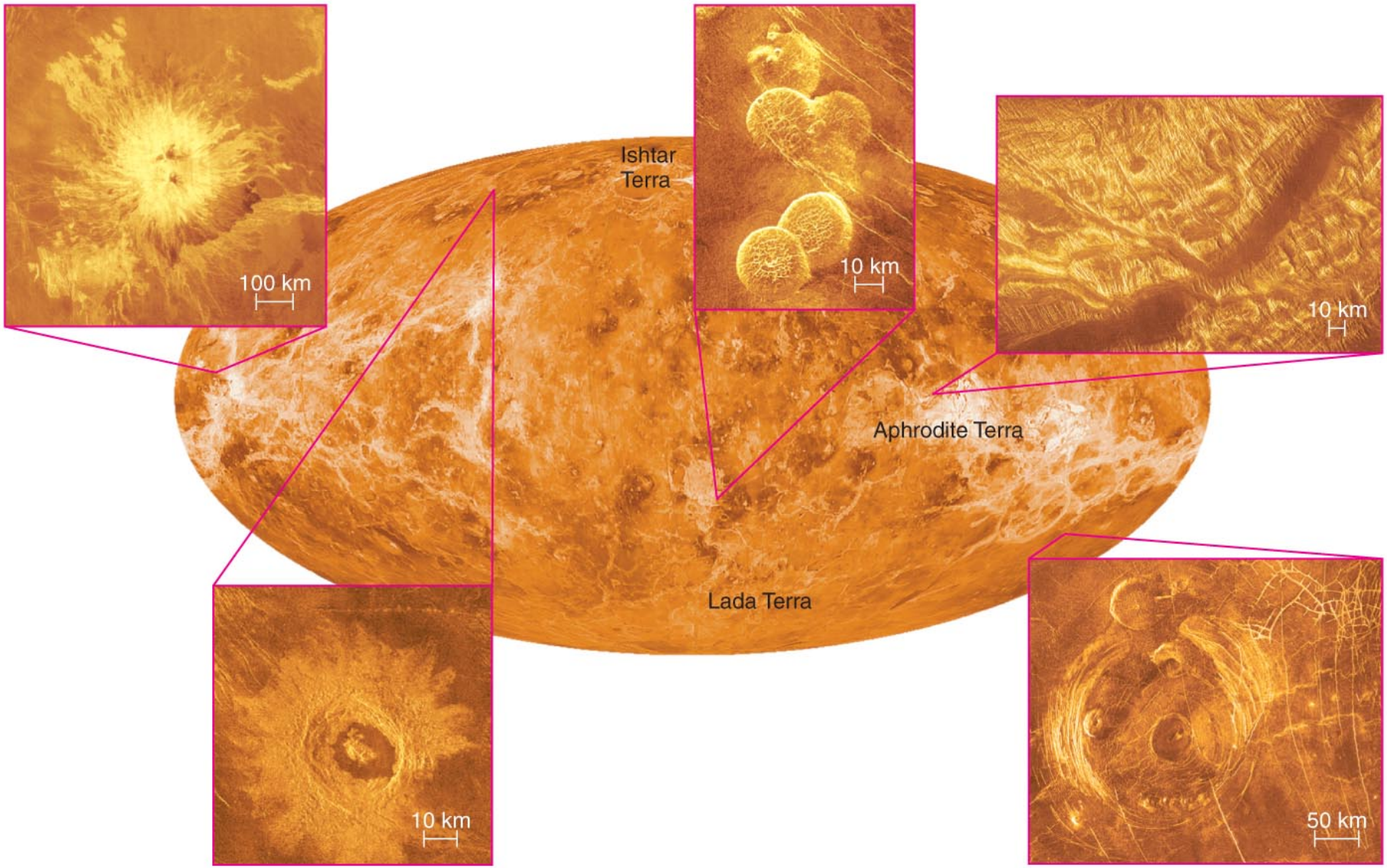
- What geological evidence tells us that water once flowed on Mars?
  - Some surface features look like dry riverbeds.
  - Some craters appear to be eroded.
  - Rovers have found rocks that appear to have formed in water.
  - Gullies in crater walls may indicate recent water flows.

9.5 Geology of Venus

Our goals for learning:

- What are the major geological features of Venus?
- Does Venus have plate tectonics?

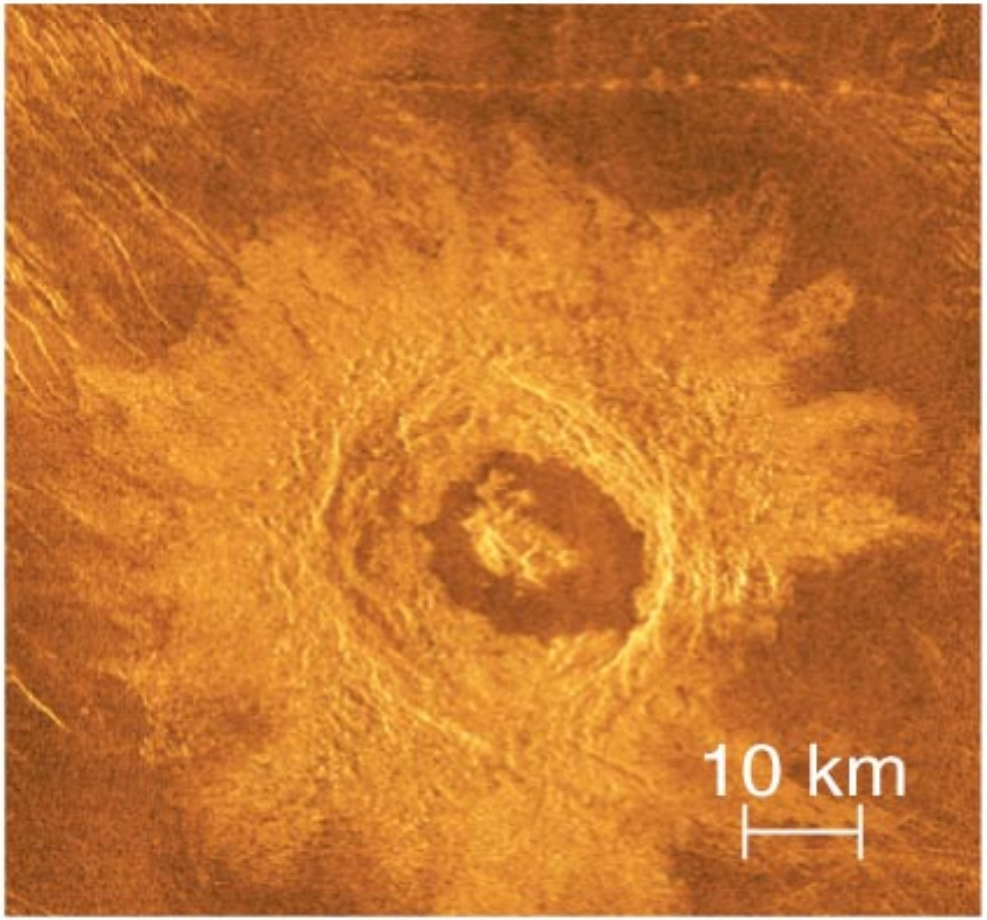
What are the major geological features of Venus?



Mapping Venus with Radar

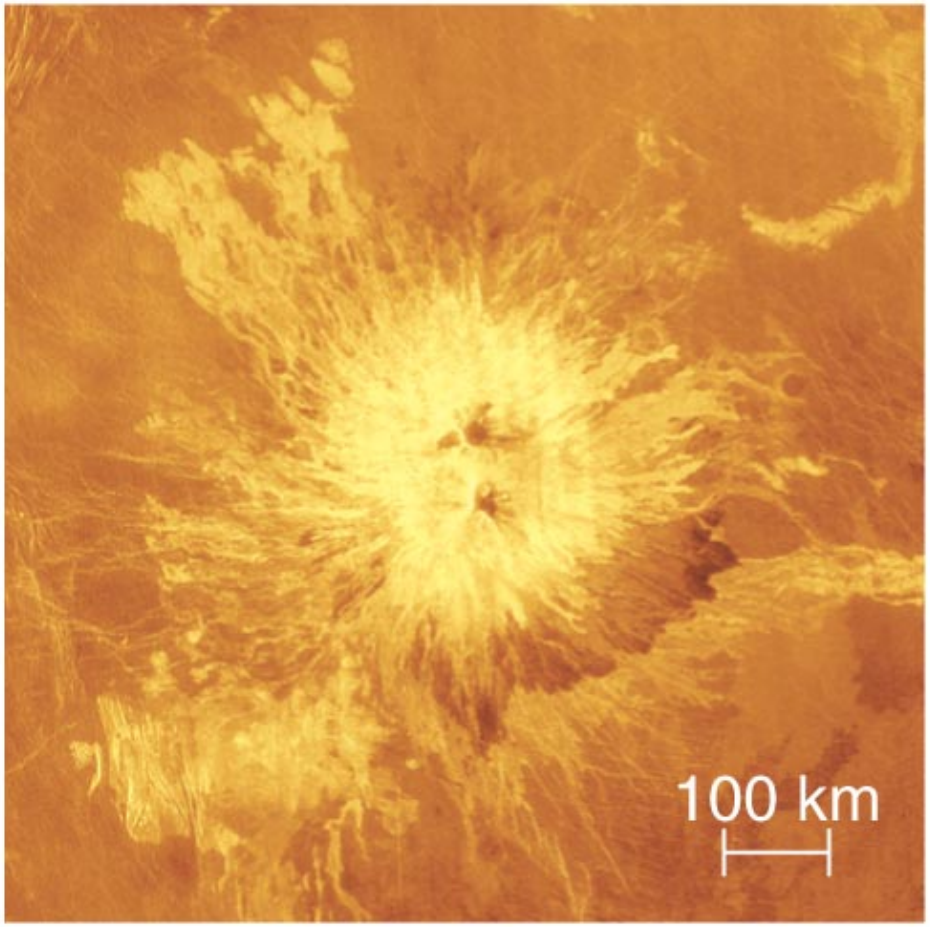
Atmosphere is transparent to radio waves---we just send them out and they bounce back

Cratering on Venus



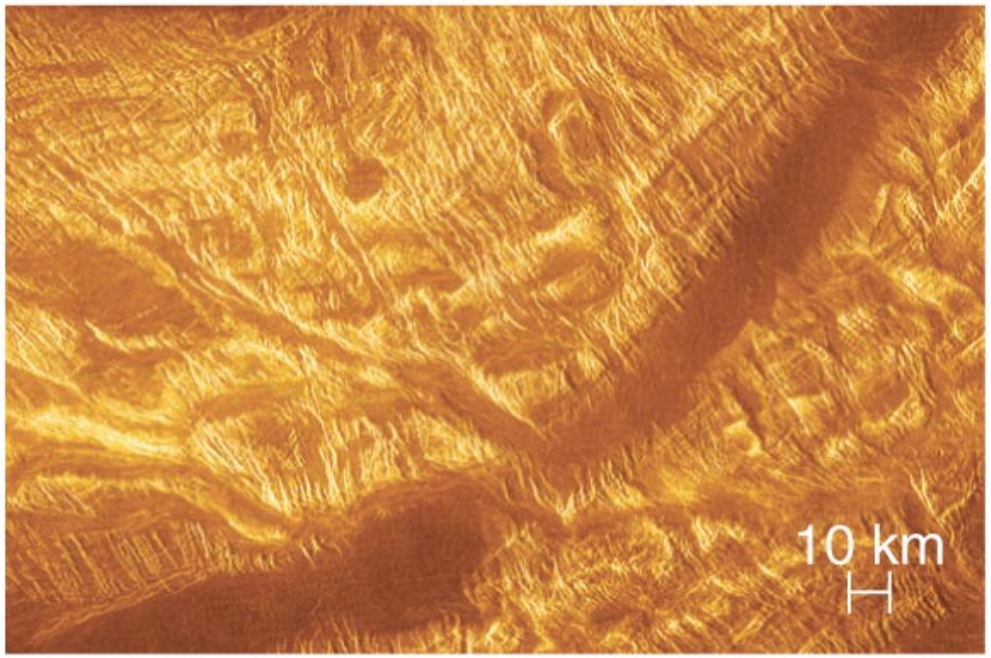
- Venus has impact craters, but fewer than the Moon, Mercury, or Mars.
- All craters are large —there are no small craters

Volcanoes on Venus



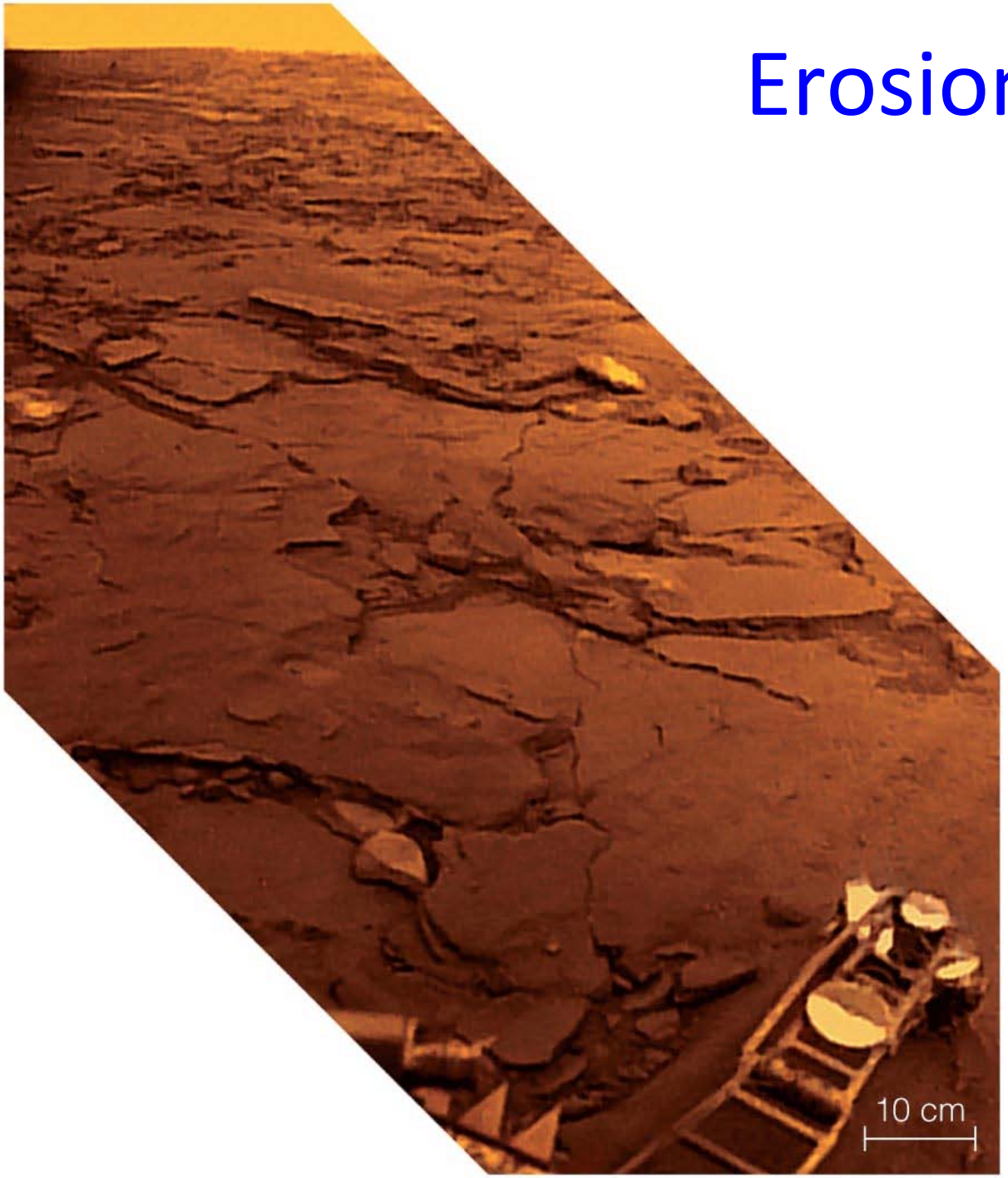
- It has many volcanoes, including both shield volcanoes and stratovolcanoes.
- Outgassing MUST provide the supply of SO_2 for the sulfuric acid clouds
- Earth-size planet should have Earth-like amounts of volcanism

Tectonics on Venus



- The planet's fractured and contorted surface indicates tectonic stresses.
- Fractures are often near volcanoes

Erosion on Venus



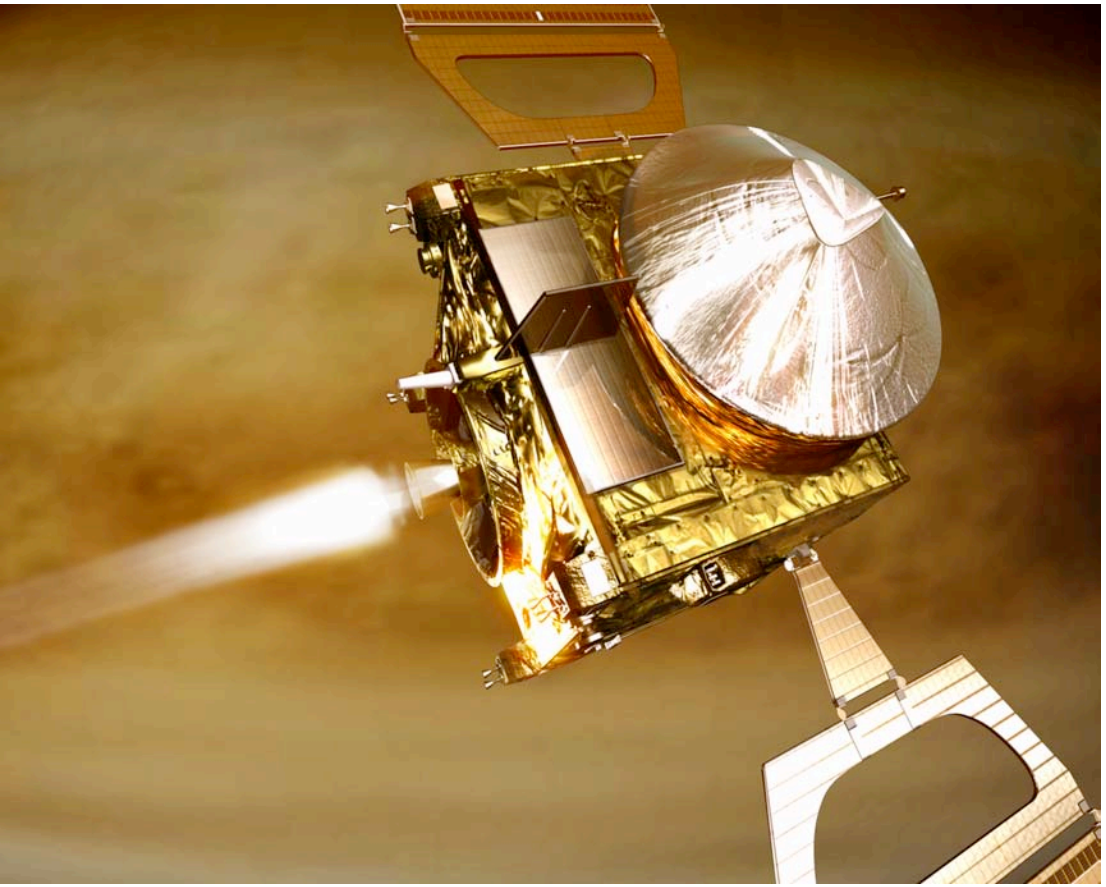
- Photos of rocks taken by landers show little erosion.
- Very slow planet rotation yield slow winds
- No rain

Does Venus have plate tectonics?

- Venus does not appear to have plate tectonics, but entire surface seems to have been "repaved" 750 million years ago.
  - Distribution of larger craters is basically uniform around the entire surface

- Very hot temperatures → less water in the rock → less malleable rock → rigid planet-wide crust?

Current Missions to Venus



Venus Express
European—in orbit now

Venus Climate Orbiter
Japanese—will launch later this year

(NASA Magellan visited in early 90s)

What have we learned?

- What are the major geological features of Venus?
  - Venus has cratering, volcanism, and tectonics but not much erosion.
- Does Venus have plate tectonics?
  - The lack of plate tectonics on Venus is a mystery, but probably is related to its dryness