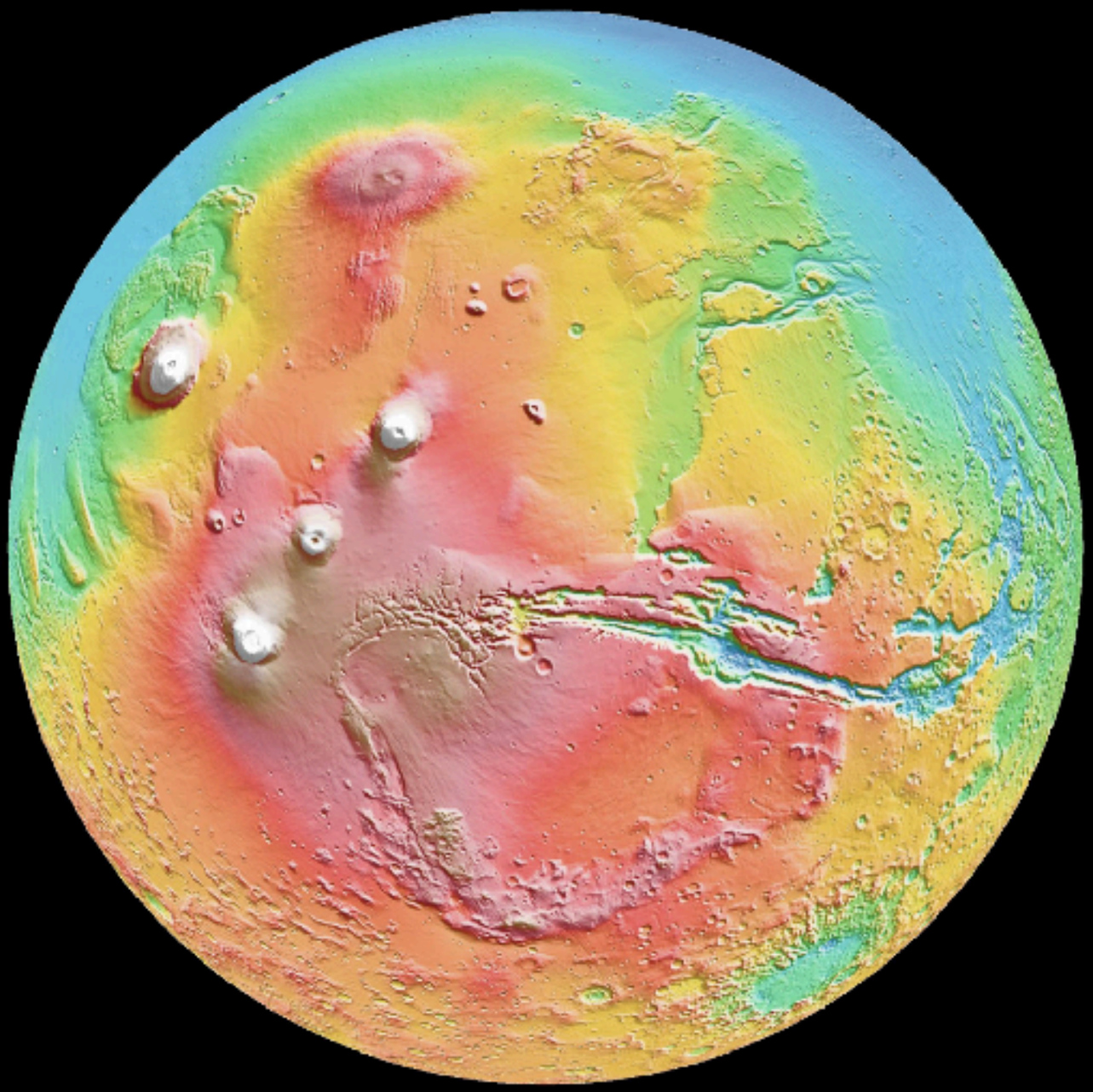
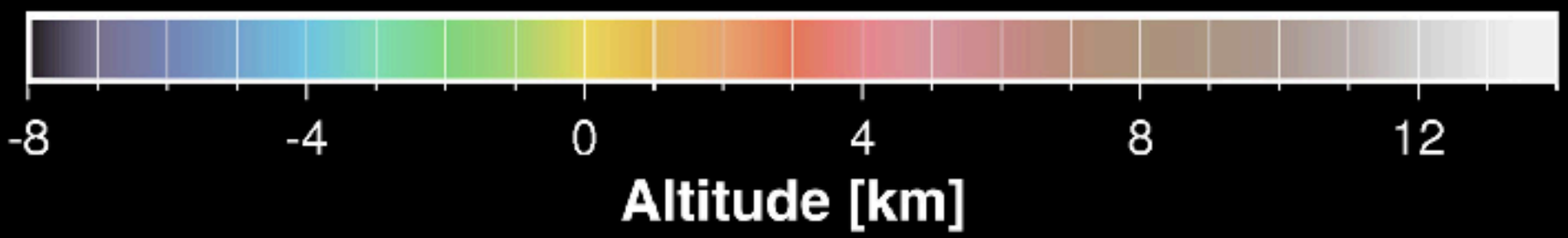


Mars elevation map



Today

- Terrestrial Planet Geology
  - individual cases

Events

- Fall break next Tuesday

Why do the terrestrial planets have different geological histories?

Heavily cratered Mercury has long steep cliffs (arrow).

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

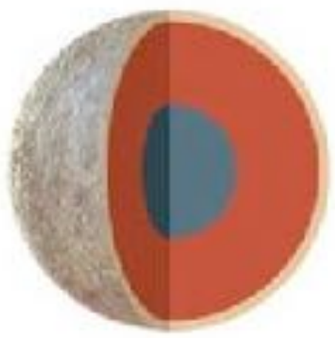
A portion of Earth's surface as it appears without clouds.

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

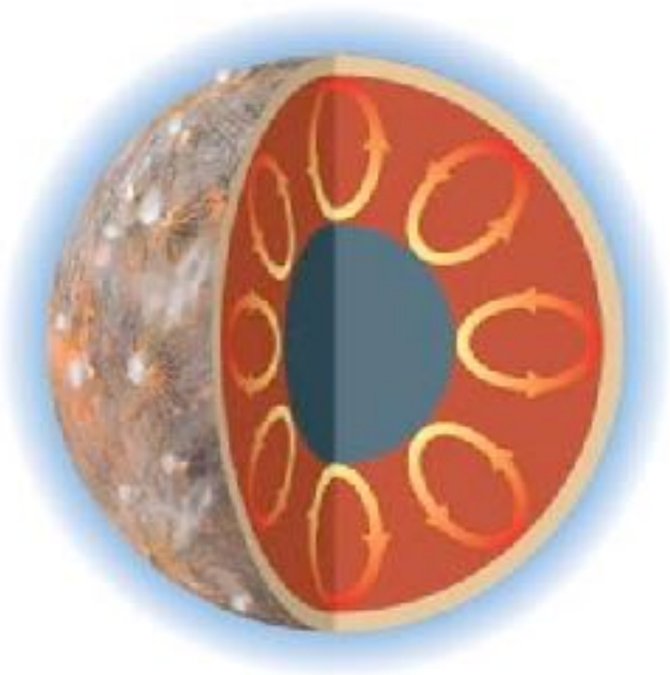
Mars has features that look like dry riverbeds; note the impact craters.

Role of Planetary Size

Small Terrestrial Planets

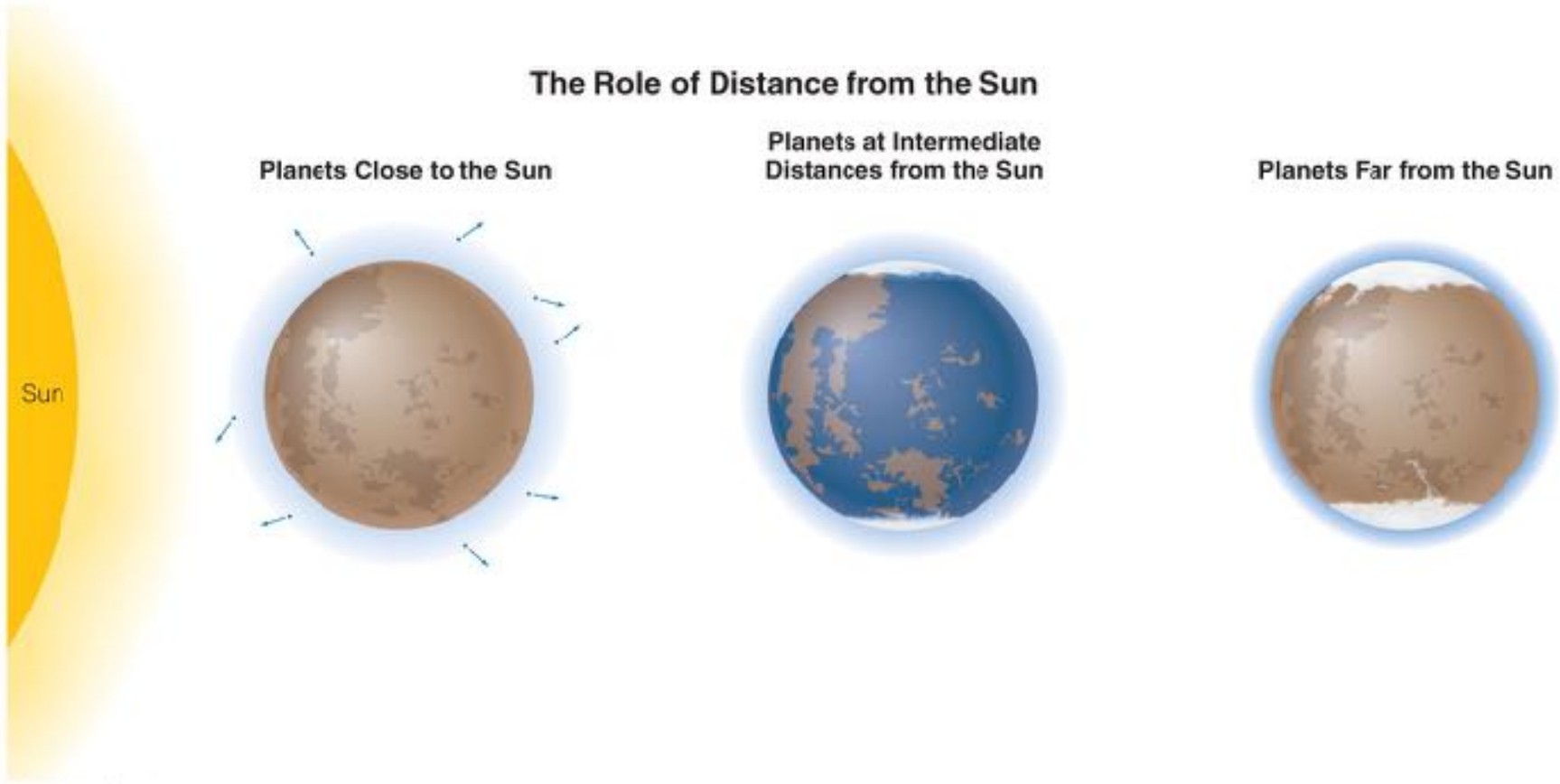


Large Terrestrial Planets



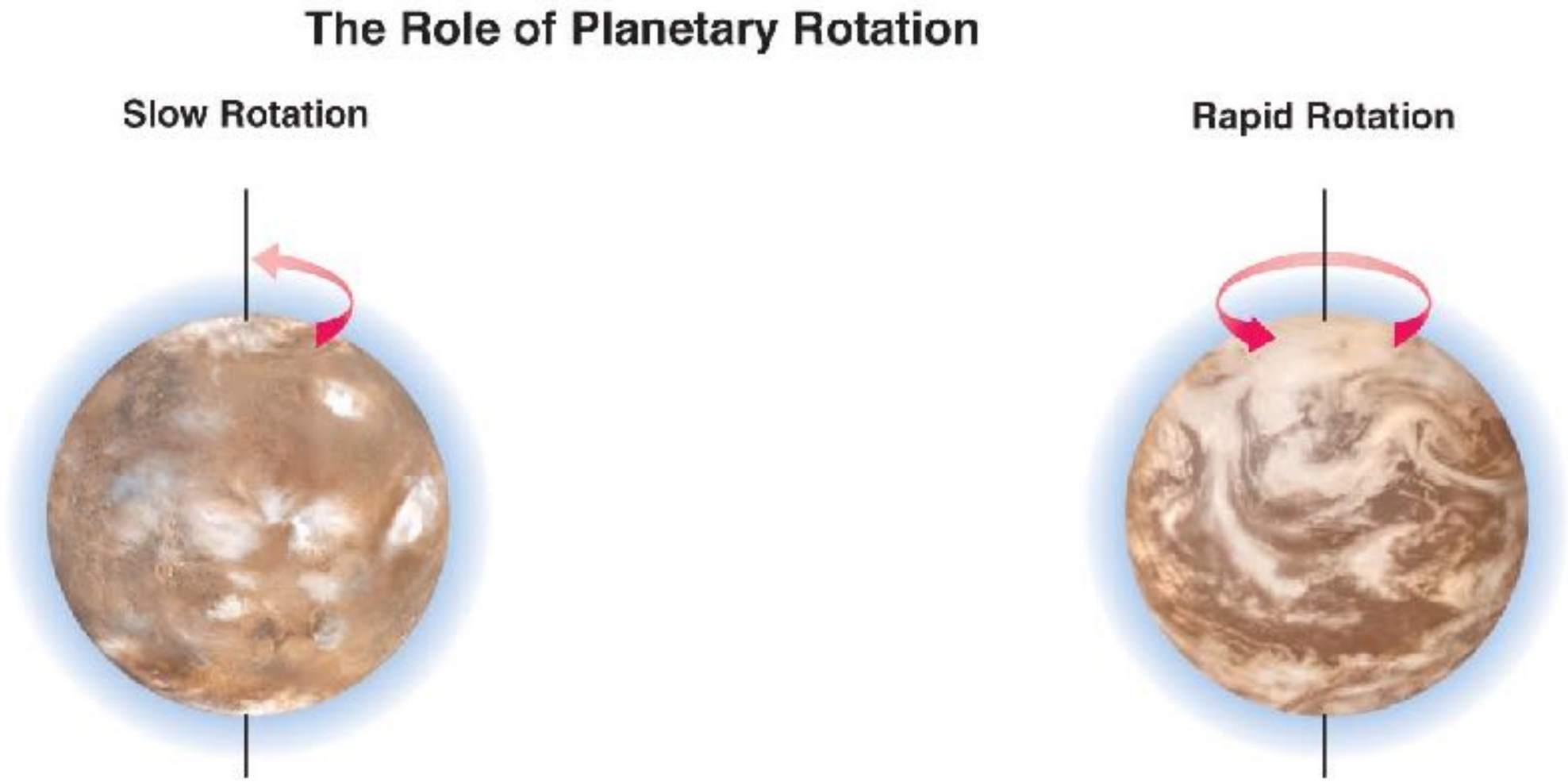
- Smaller worlds cool off faster and harden earlier.
- Larger worlds remain warm inside, promoting volcanism and tectonics.
- Larger worlds also have more erosion because their gravity retains an atmosphere.

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

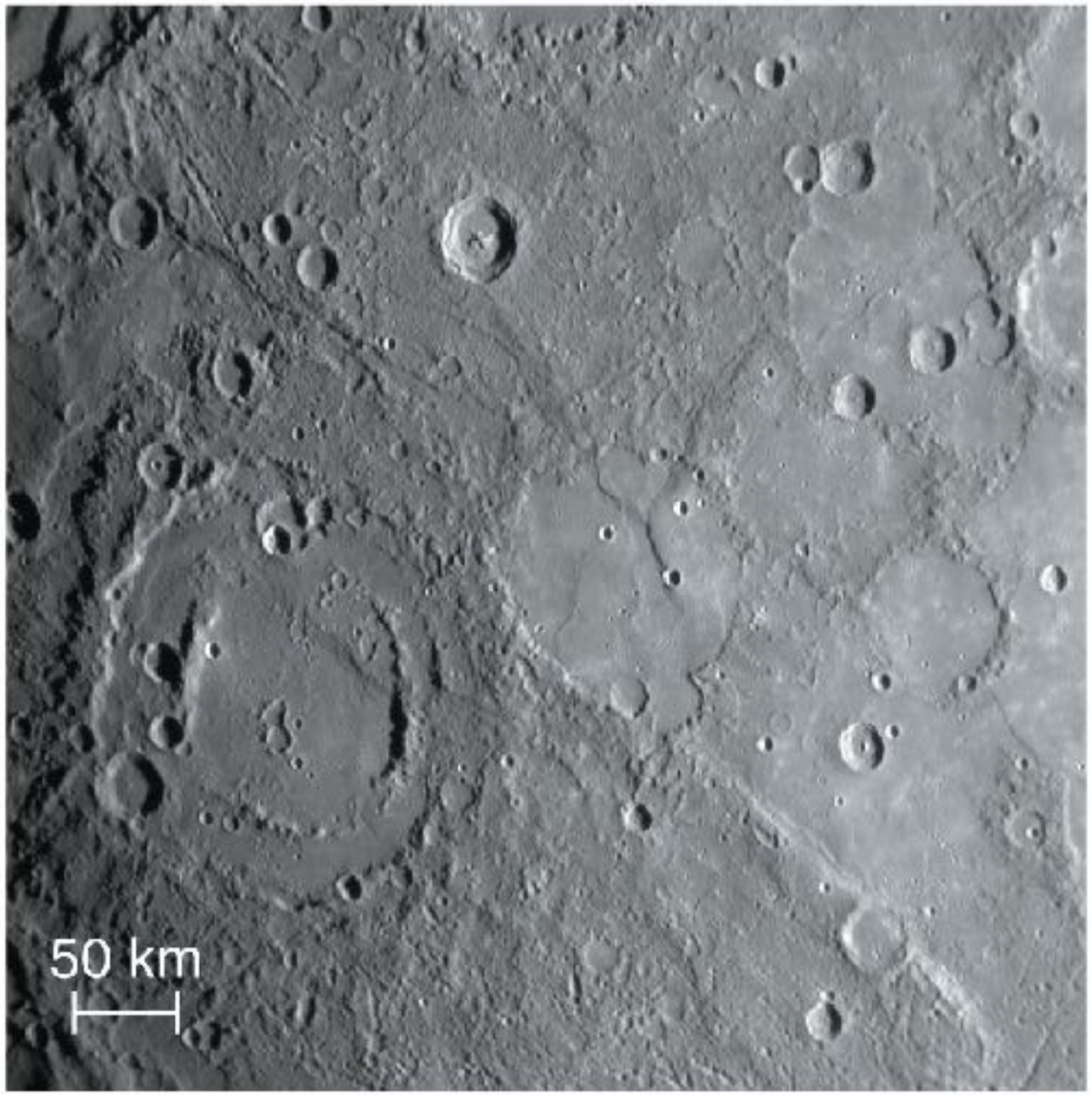


- Planets with slower rotation have less weather, less erosion, and a weak magnetic field.
- Planets with faster rotation have more weather, more erosion, and a stronger magnetic field.

Mercury

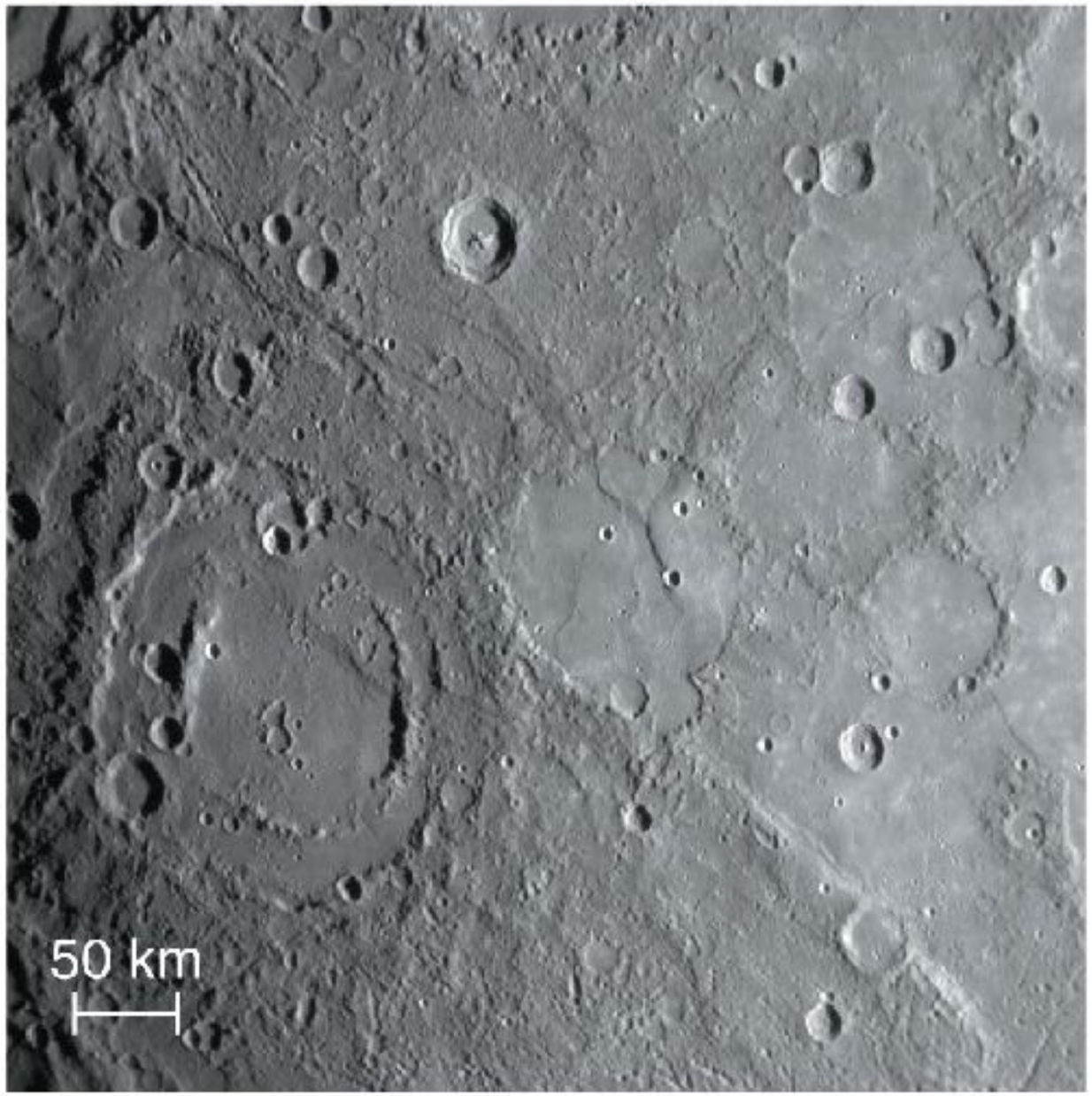
http://www.space.com/19920-mercury-color-video-messenger-spacecraft.html

What geological processes shaped Mercury?



a A close-up view of Mercury's surface, showing impact craters and smooth regions where lava apparently covered up craters.

Cratering of Mercury



- Mercury has a mixture of heavily cratered and smooth regions like the Moon.
- Smooth regions are likely ancient lava flows.

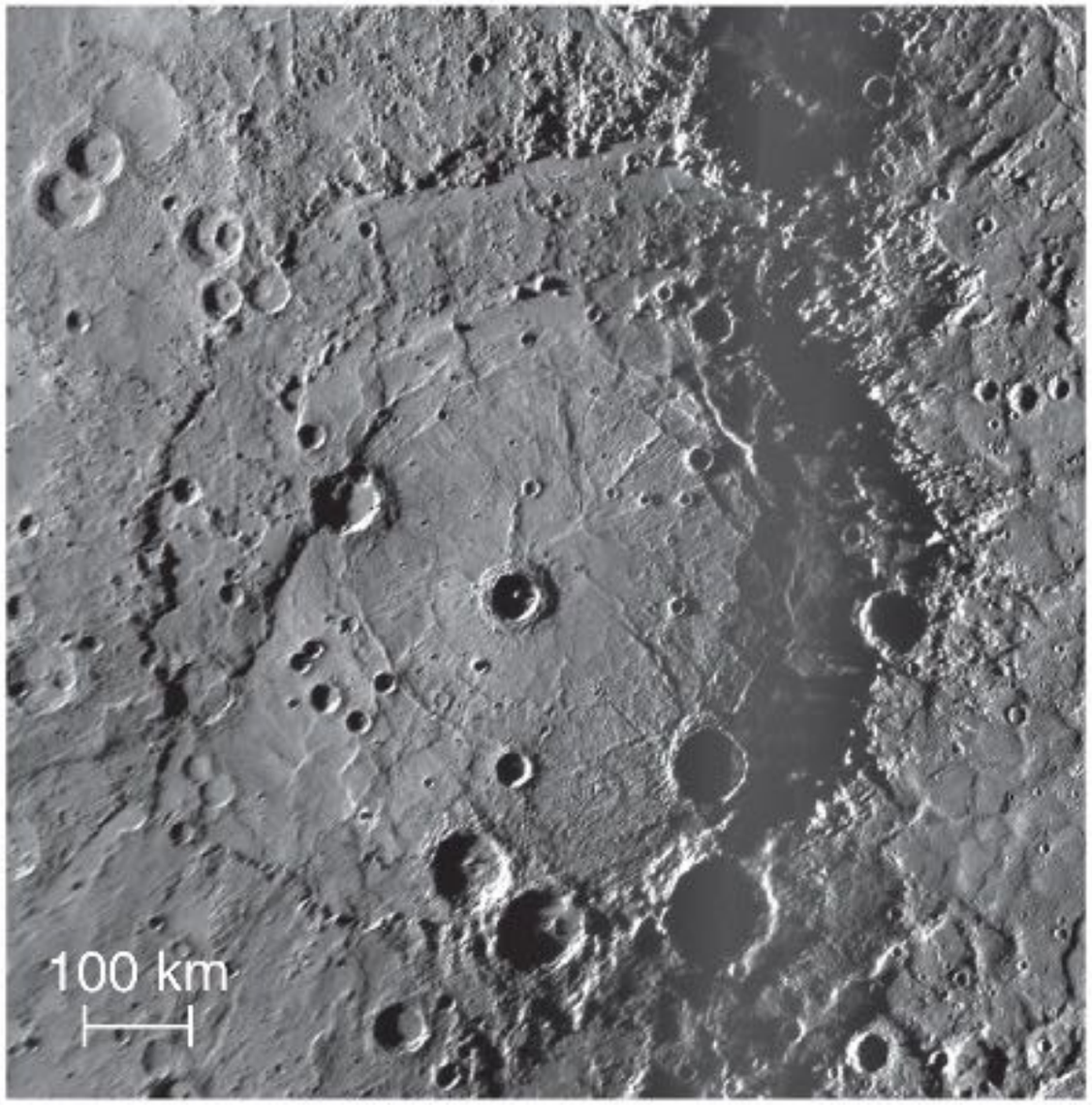
Caloris basin

largest crater in Solar system

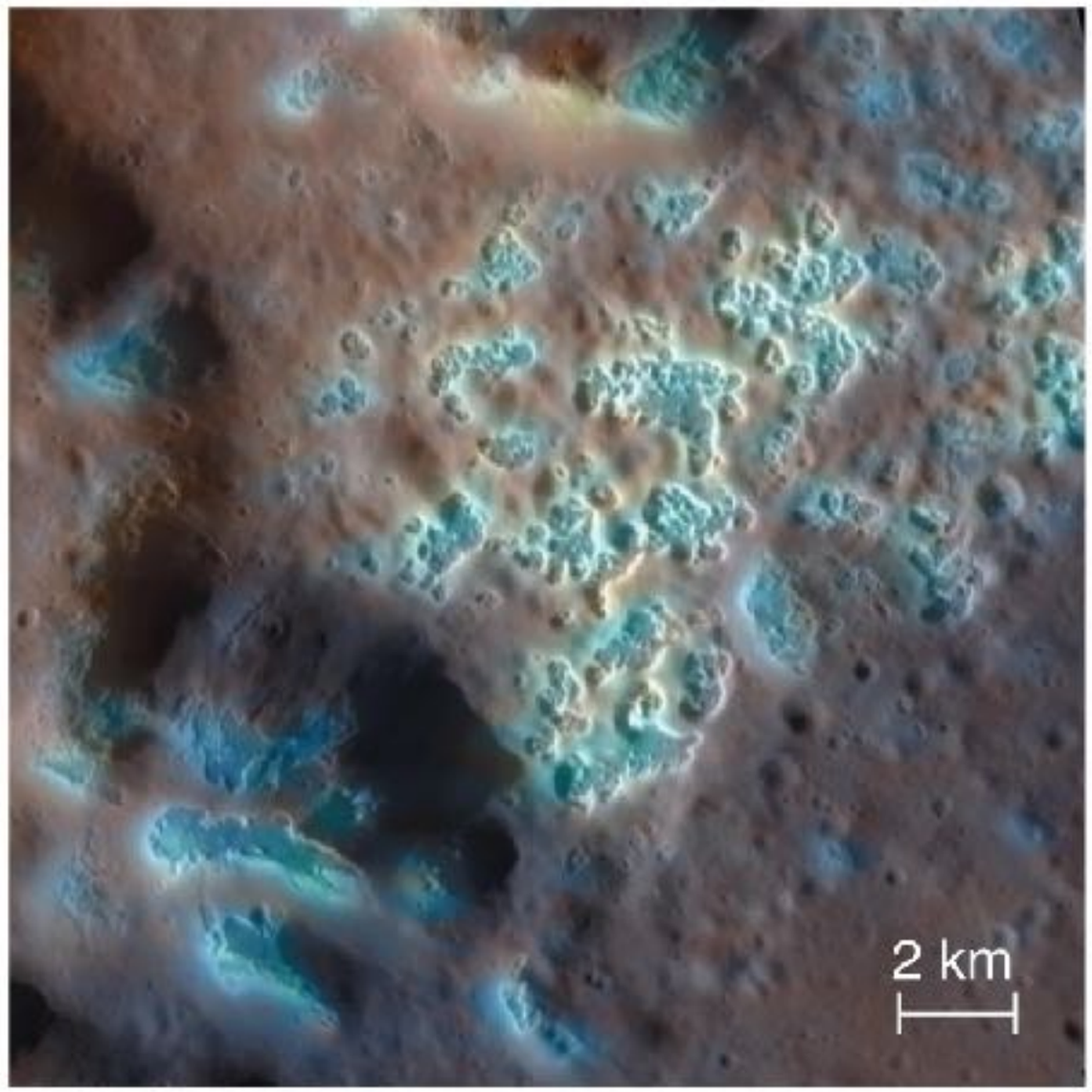
lava (orange)

older material (blue) sometimes excavated by later impact

Cratering of Mercury



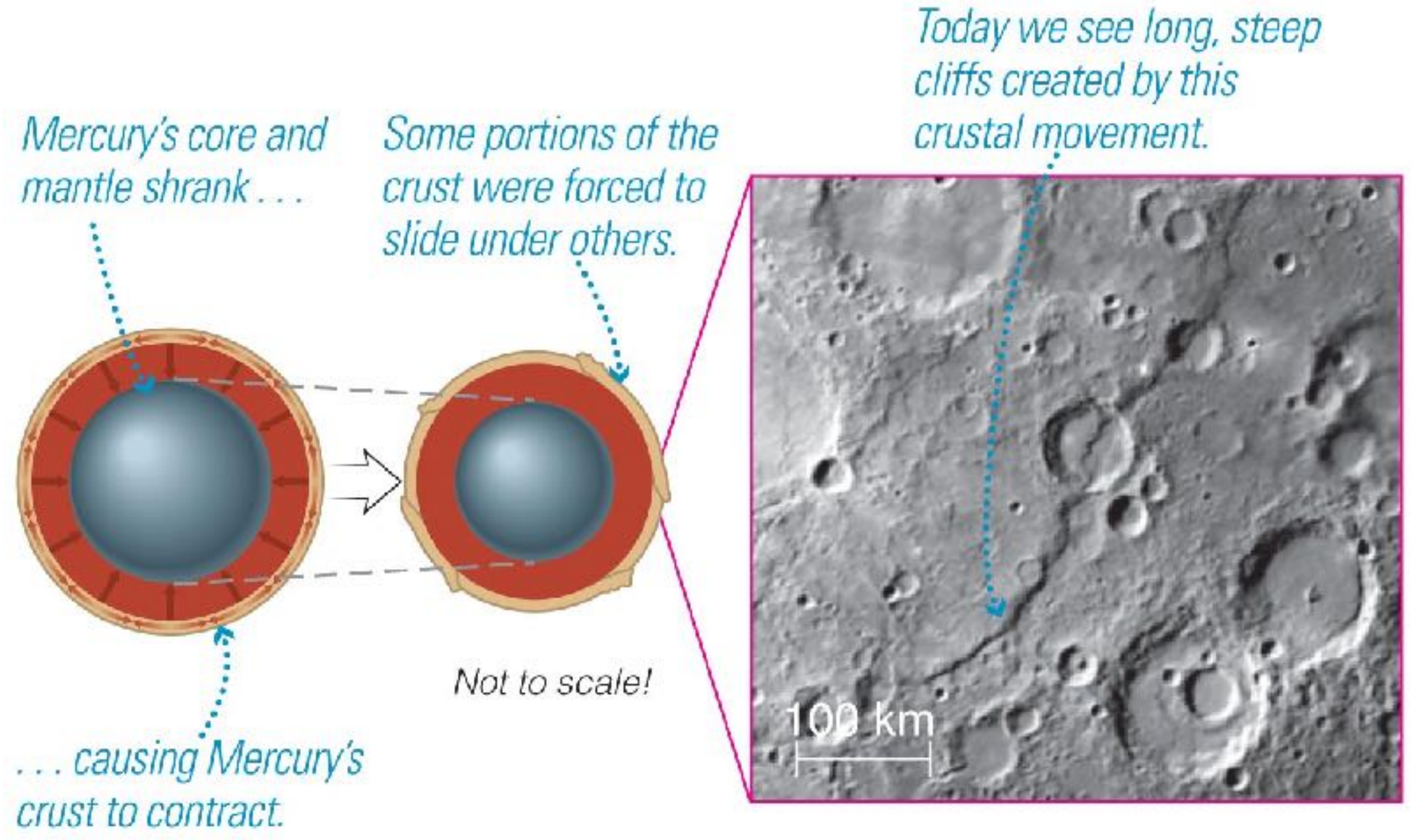
The Rembrandt Basin is a large impact crater on Mercury.



Hollows in a crater floor created by escaping gases.

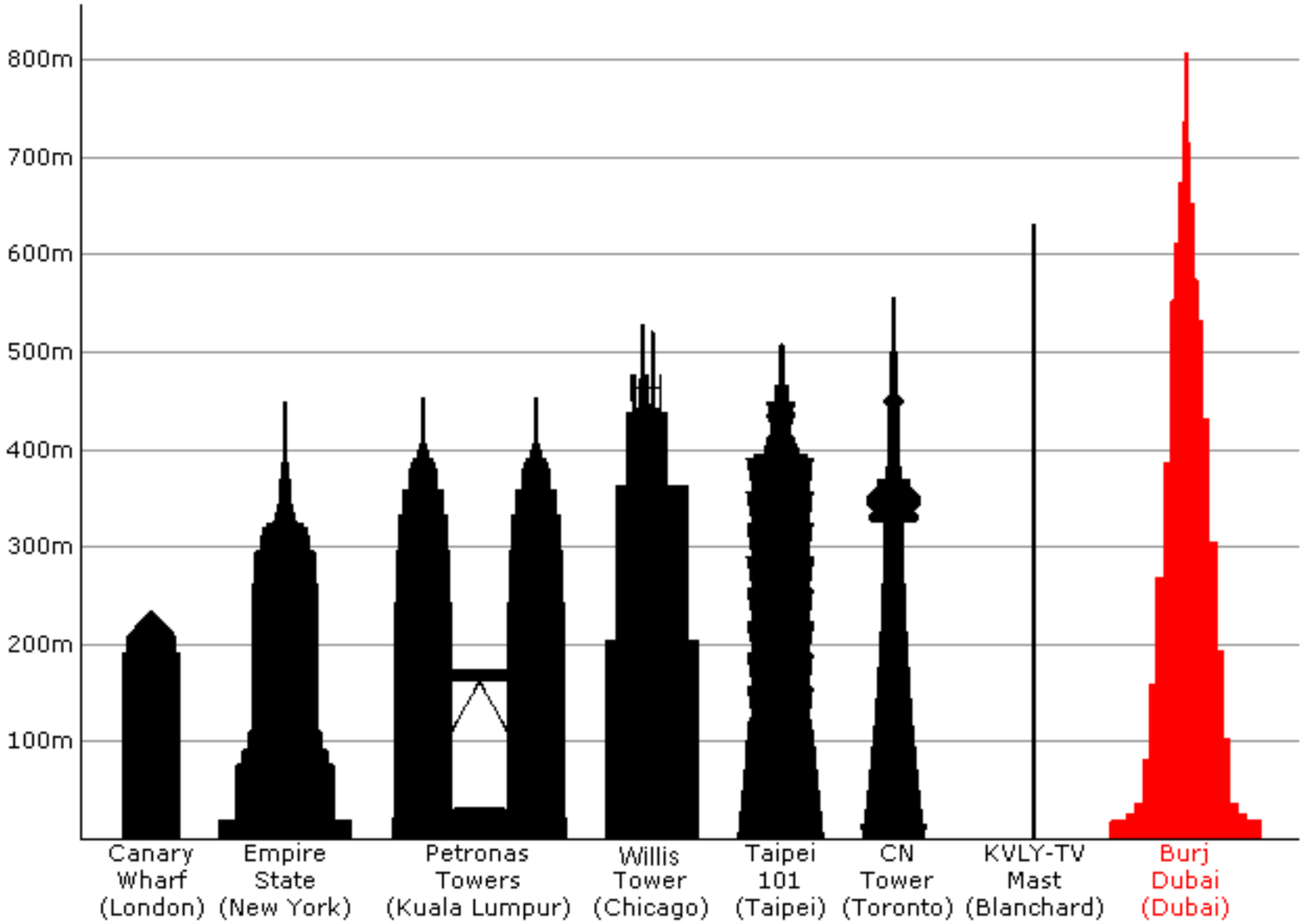
Tectonics on Mercury

Scarps

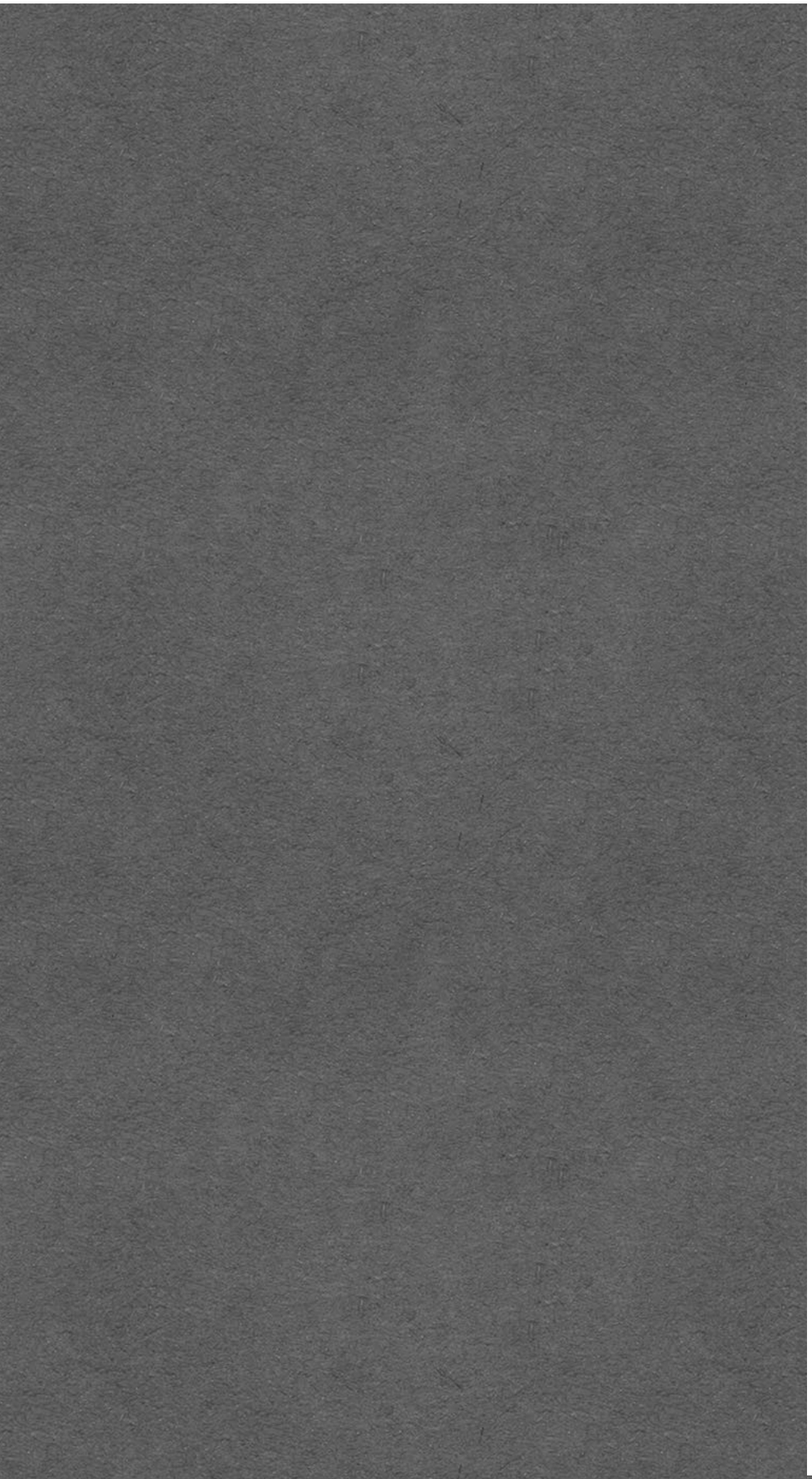


- Long cliffs (scarps) created when Mercury shrank (about 10 km in diameter) as it cooled.

Tall buildings on Earth



Scarp on Mercury, to scale



3 km

Surface gravity on Mercury: 3.7 m/s/s

$$d = \frac{1}{2}at^2 \quad \text{so} \quad t = \sqrt{2ad}$$

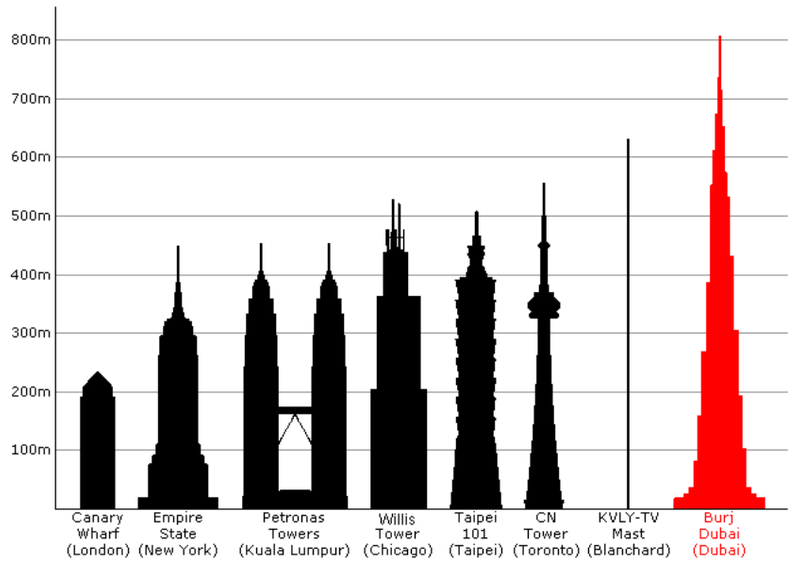
time to fall off scarp
t = 149 s (about 2 and a half minutes)

velocity on impact

$$v = at = (3.7\ \mathrm{m\,s^{-2}})(149\ \mathrm{s})$$

$$v = 551\ \mathrm{m/s}$$

(1,233 mph)



MESSENGER: 10 Years in Space

BY THE NUMBERS*

8 BILLION miles traveled

29 TRIPS around the Sun

255,858 IMAGES returned to Earth

91,730 MPH average speed (relative to the Sun)

60 MILES from the surface at closest approach

6 FLYBYS of the inner planets

35 MILLION SHOTS by the Mercury Laser Altimeter

7 MERCURY SOLAR DAYS and **1,232** EARTH DAYS in orbit

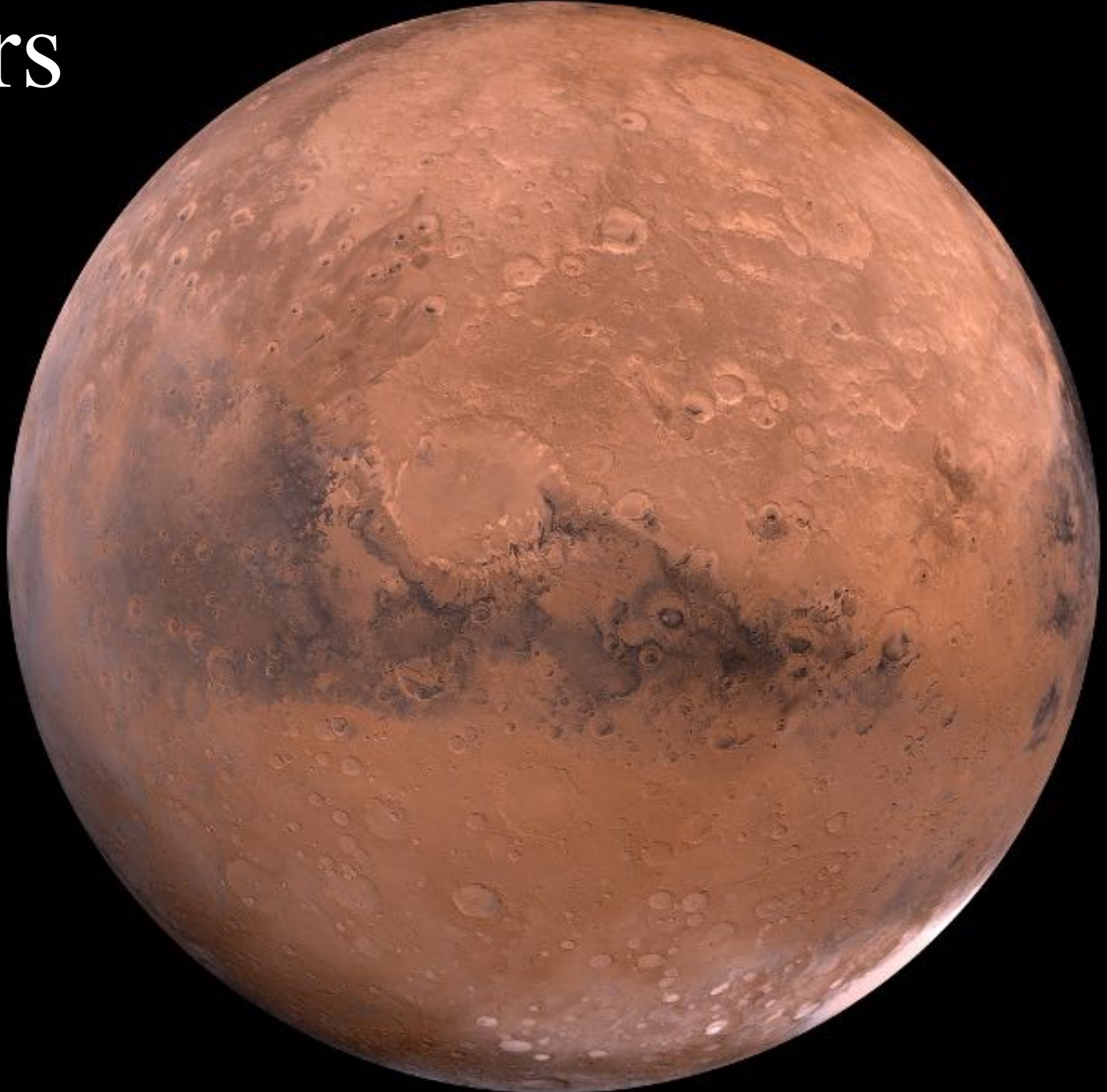
https://www.youtube.com/watch?v=yBF_0wBC_3s

Fly over video

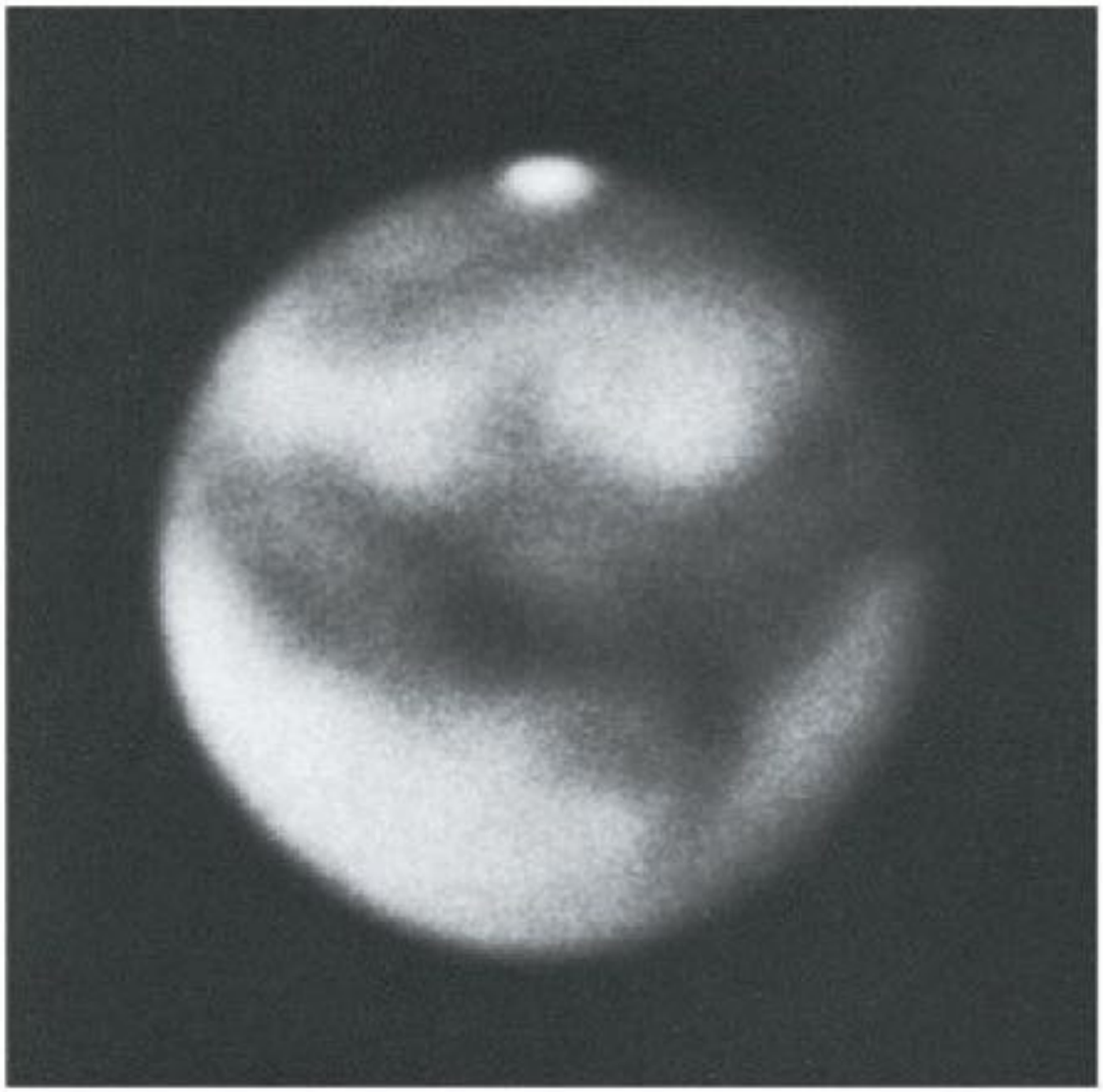
3,308 ORBITS

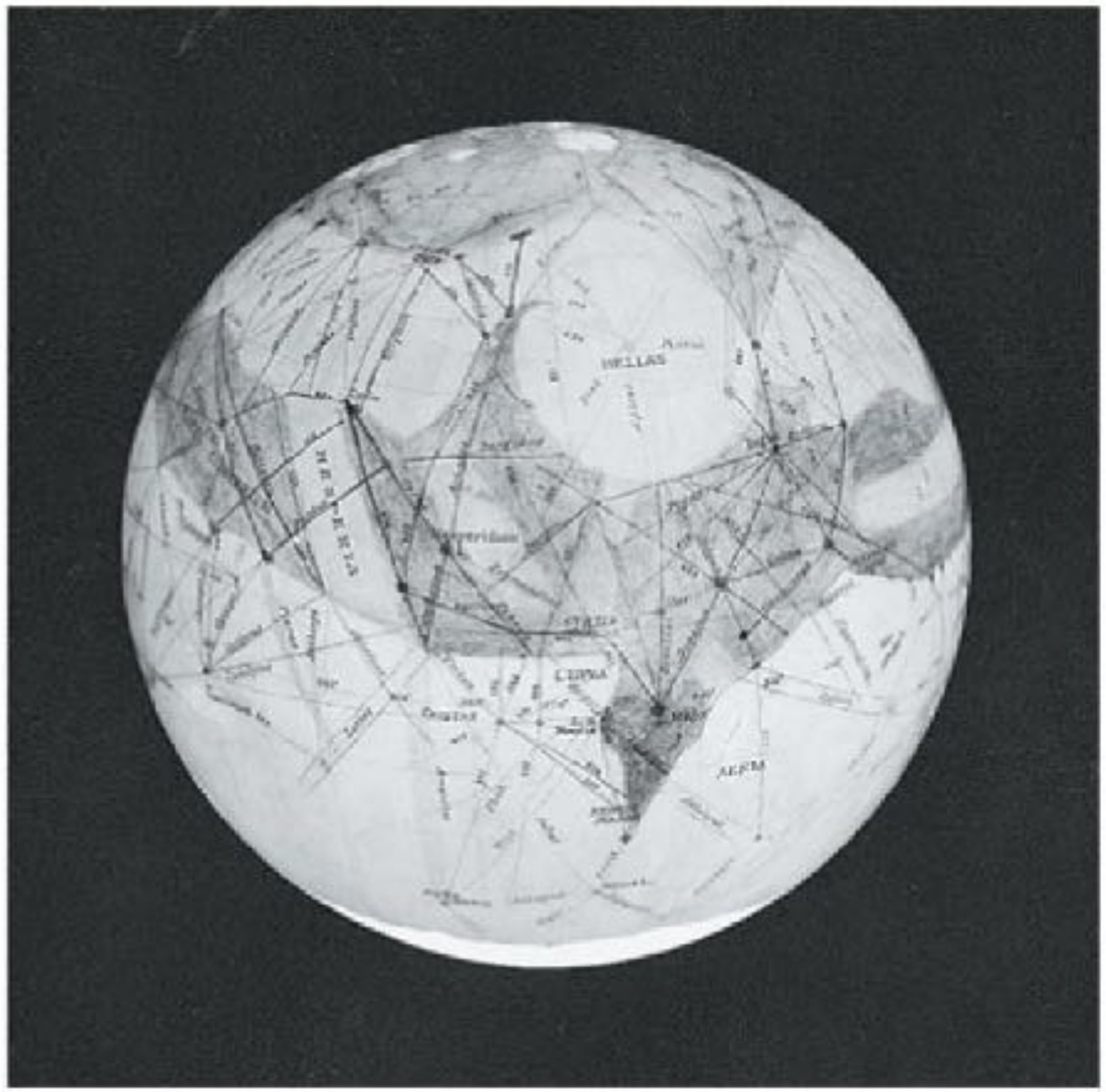
CRASHED 4/30/15

Mars



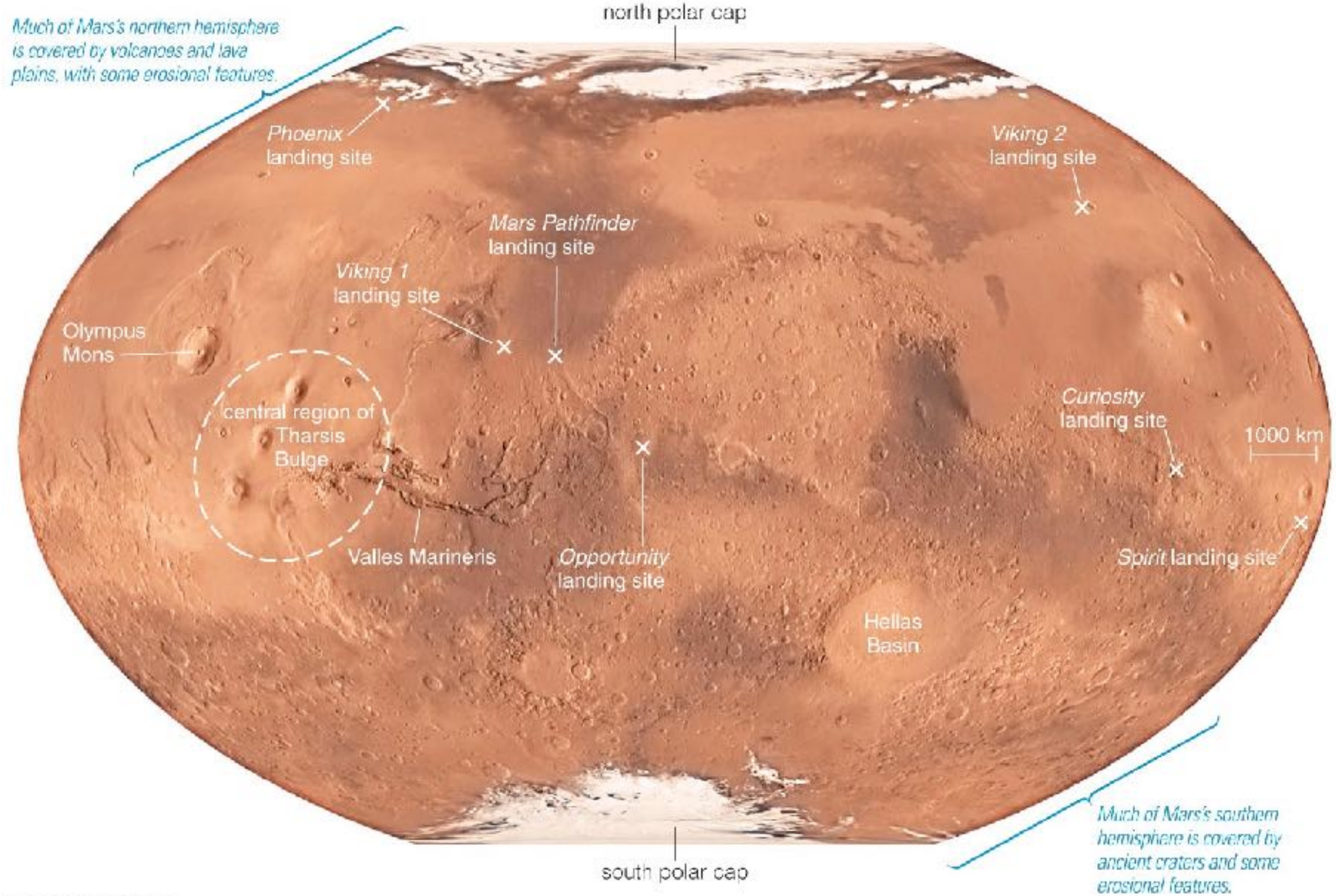
"Canals" on Mars



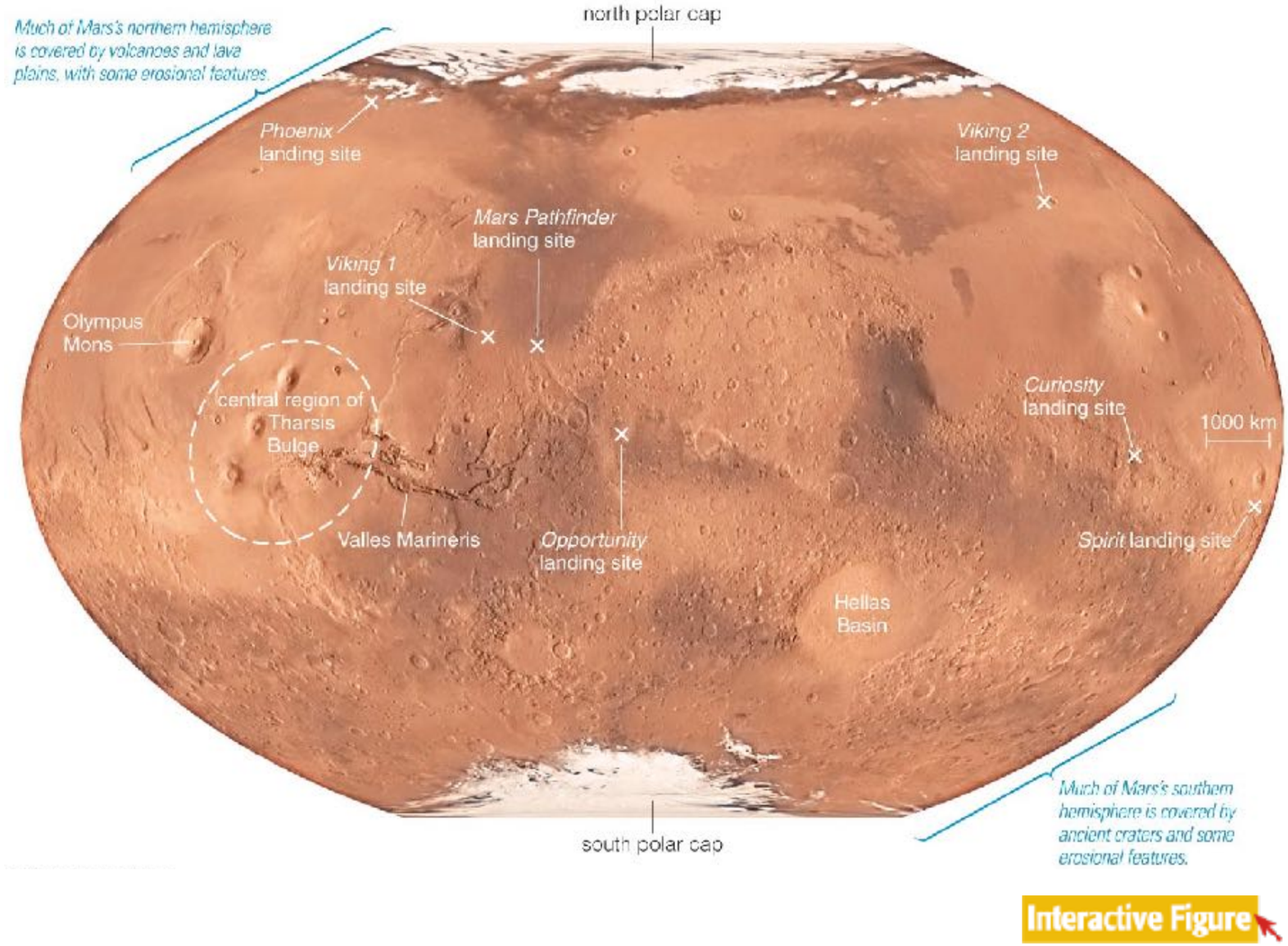


- Percival Lowell misinterpreted surface features seen in telescopic images of Mars.

What geological processes have shaped Mars?



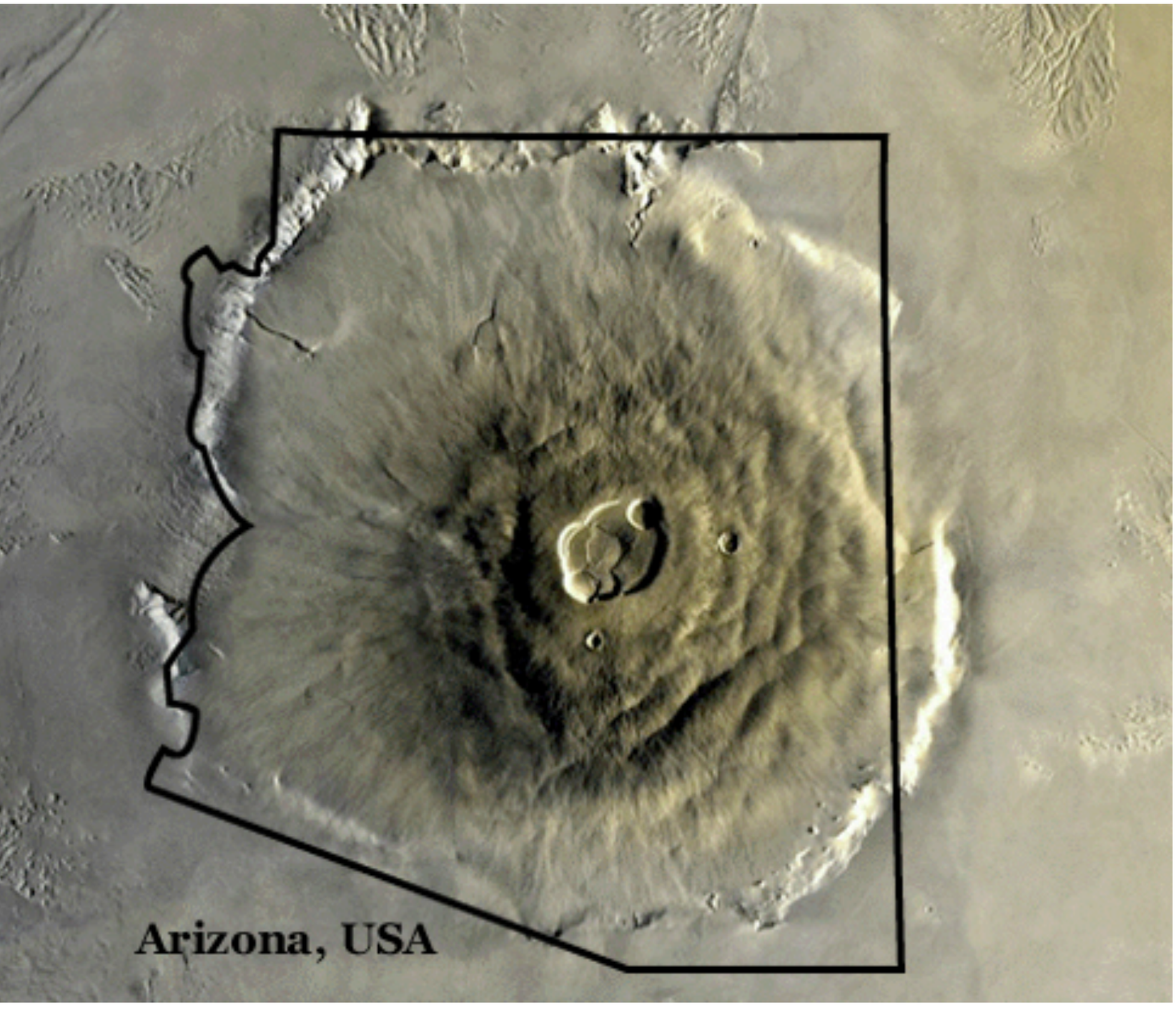
Cratering on Mars



- The amount of cratering differs greatly across Mars's surface.
- Many early craters have been erased.

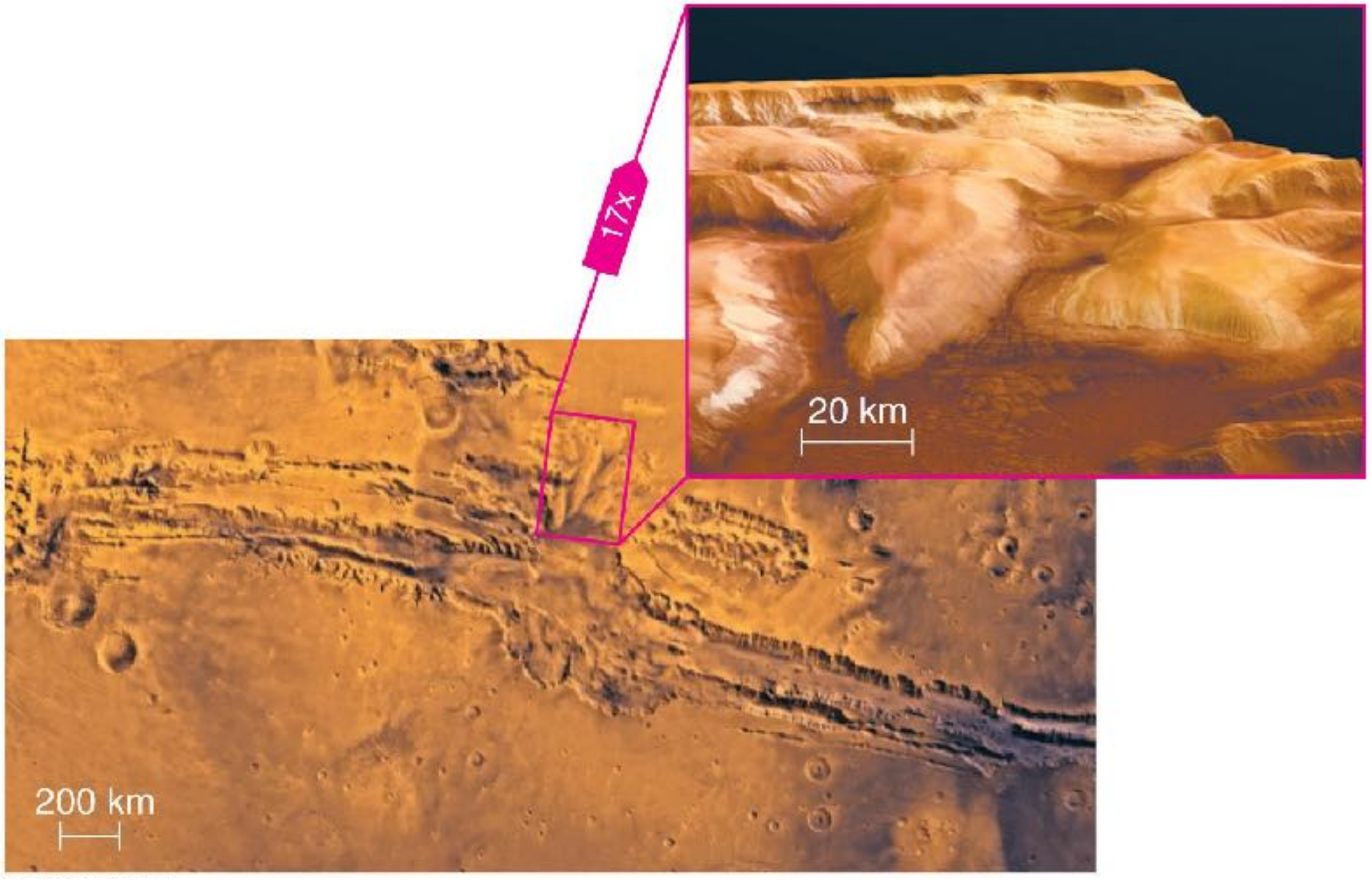
IF_09_25_MarsFeatures

Volcanism on Mars



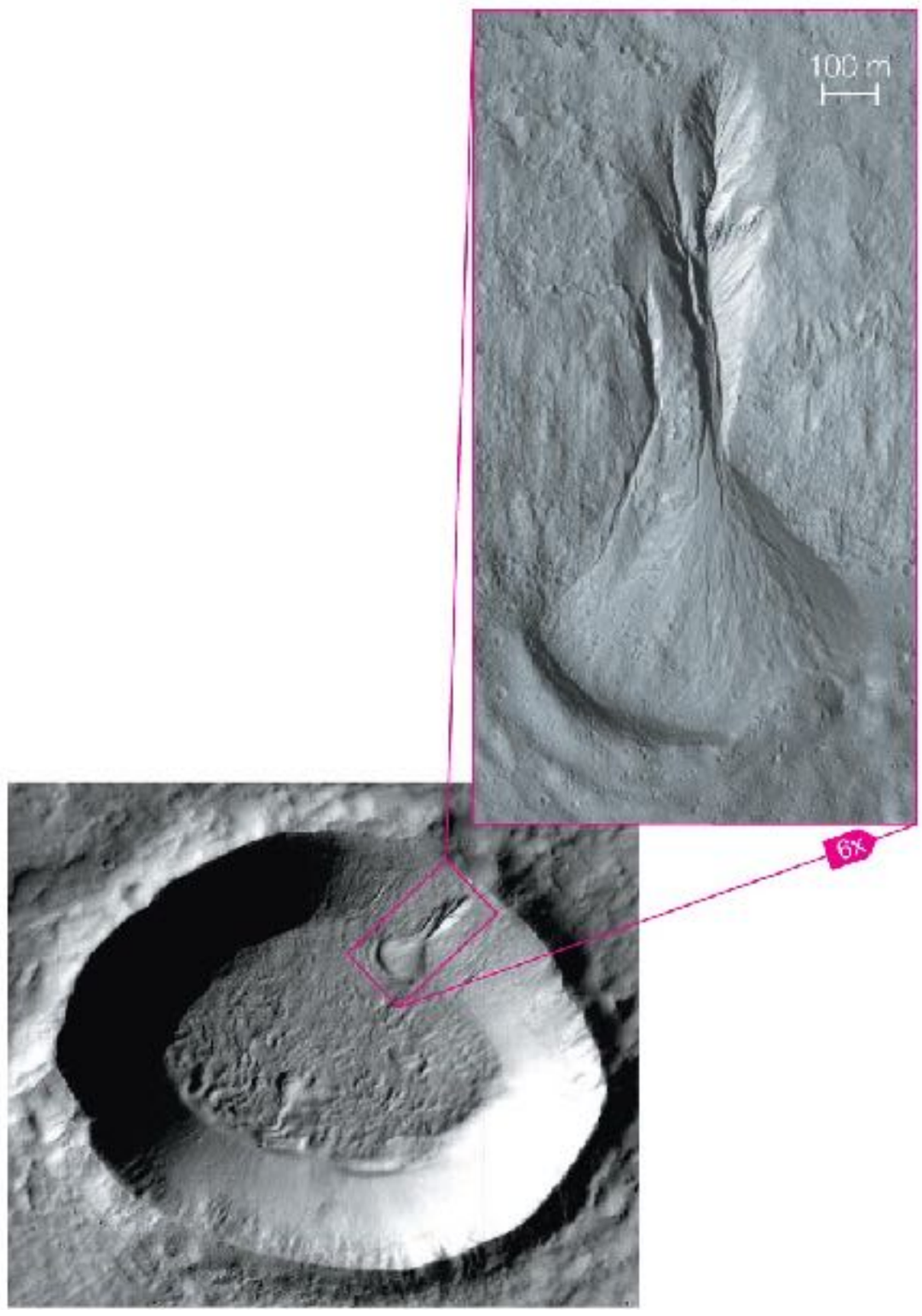
- Mars has many large shield volcanoes.
- Olympus Mons is largest volcano in solar system.

Tectonics on Mars



- The system of valleys known as Valles Marineris is thought to originate from tectonics.

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

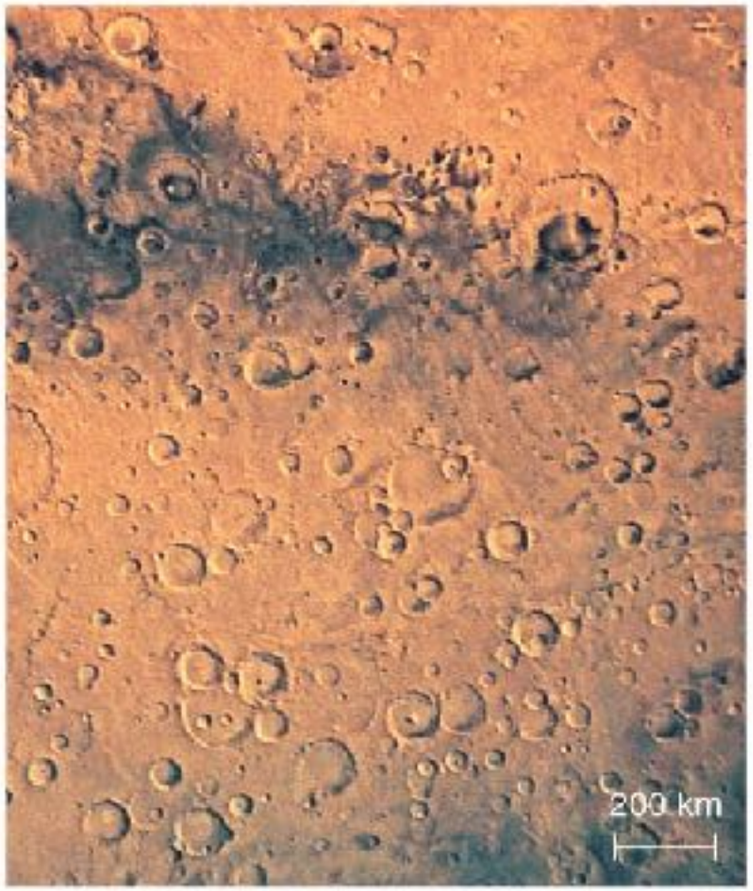


Dry Riverbeds?

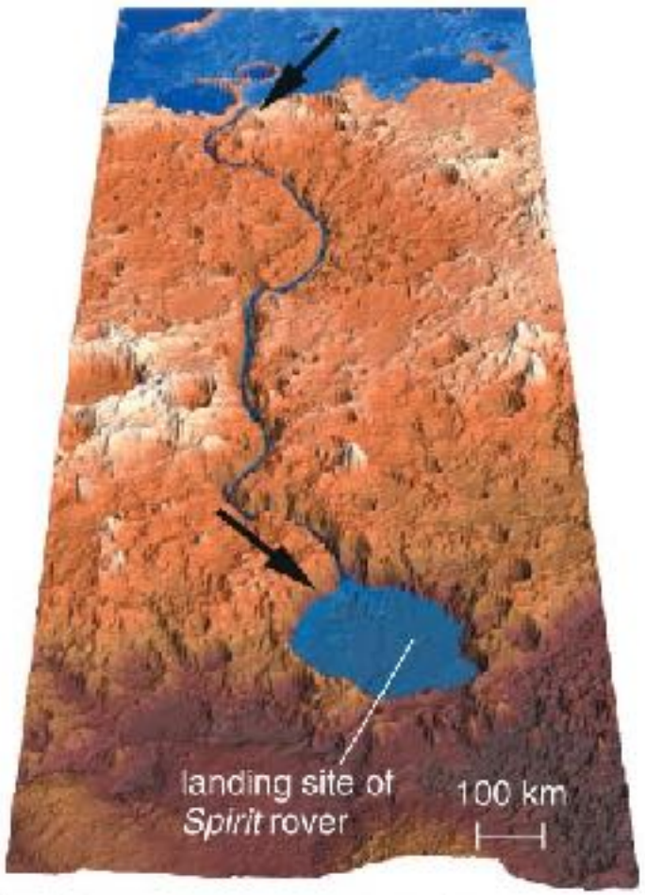
- Close-up photos of Mars show what appear to be dried-up riverbeds.

Erosion of Craters

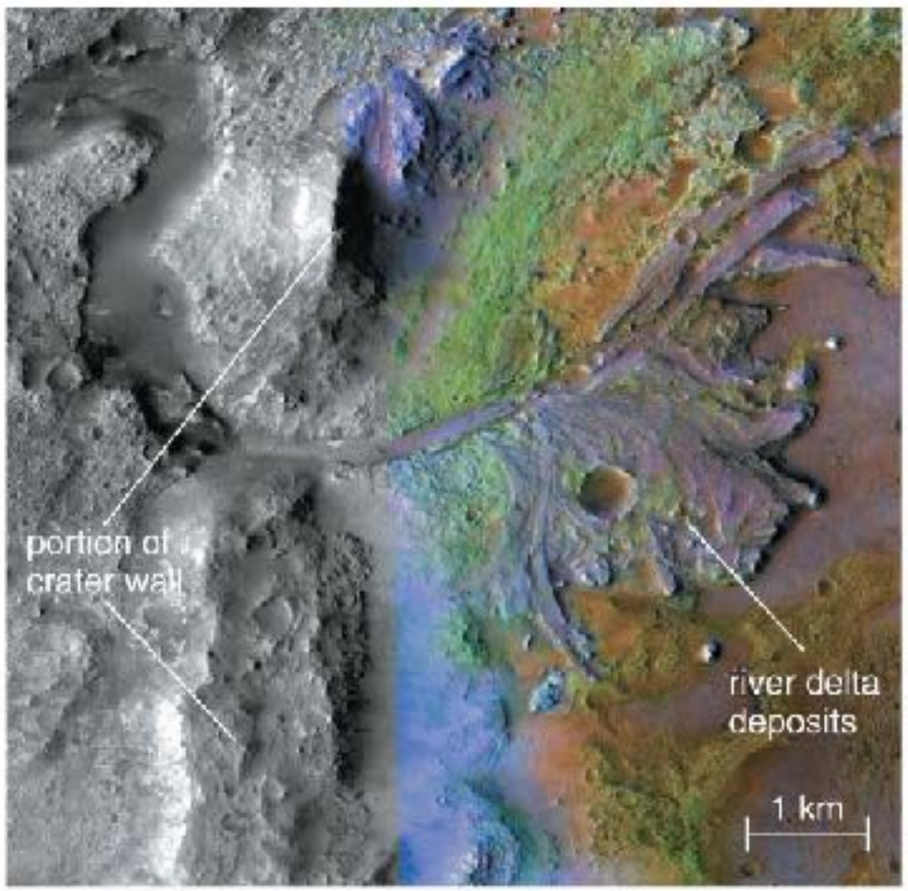
- Details of some craters suggest they were once filled with water.



a This photo shows a broad region of the southern highlands on Mars. The eroded rims of large craters and the relative lack of small craters suggest erosion by rainfall.



b This computer-generated perspective view shows how a Martian valley forms a natural passage between two possible ancient lakes (shaded blue). Vertical relief is exaggerated 14 times to reveal the topography.



c Combined visible/infrared image of an ancient river delta that formed where water flowing down a valley emptied into a lake filling a large crater (portions of the crater wall are identified). Clay minerals are identified in green.

Rovers photoshopped together for scale

Spirit & Opportunity (2004)

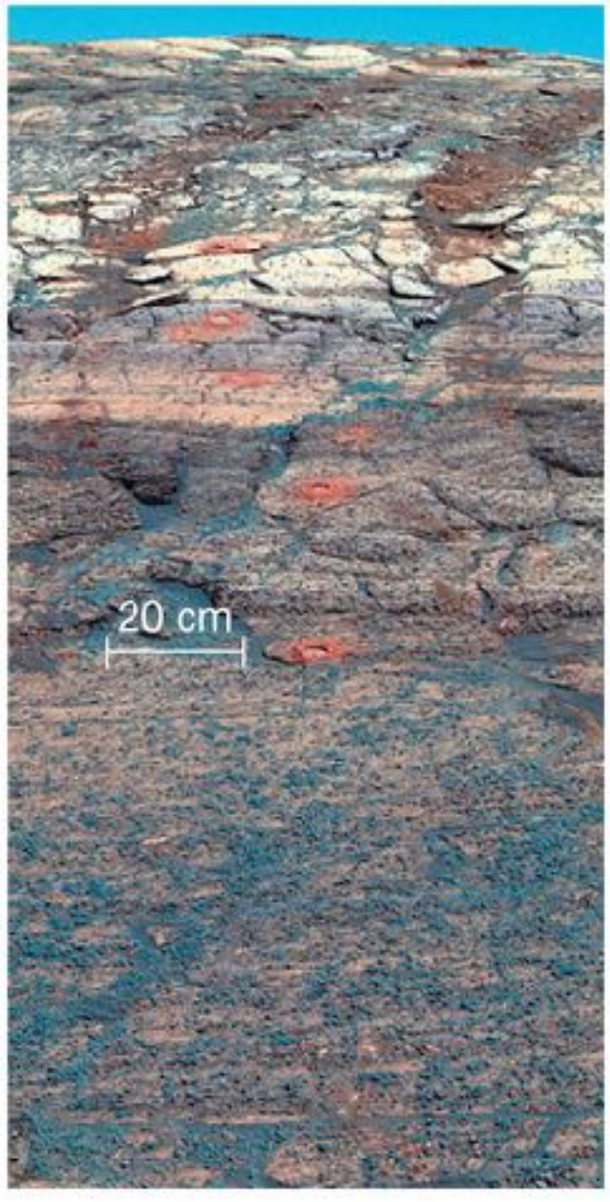
Curiosity (2012)

Pathfinder (1997)

https://www.youtube.com/watch?v=5-cBjI2zgB0

Pathfinder landing video

Martian Rocks



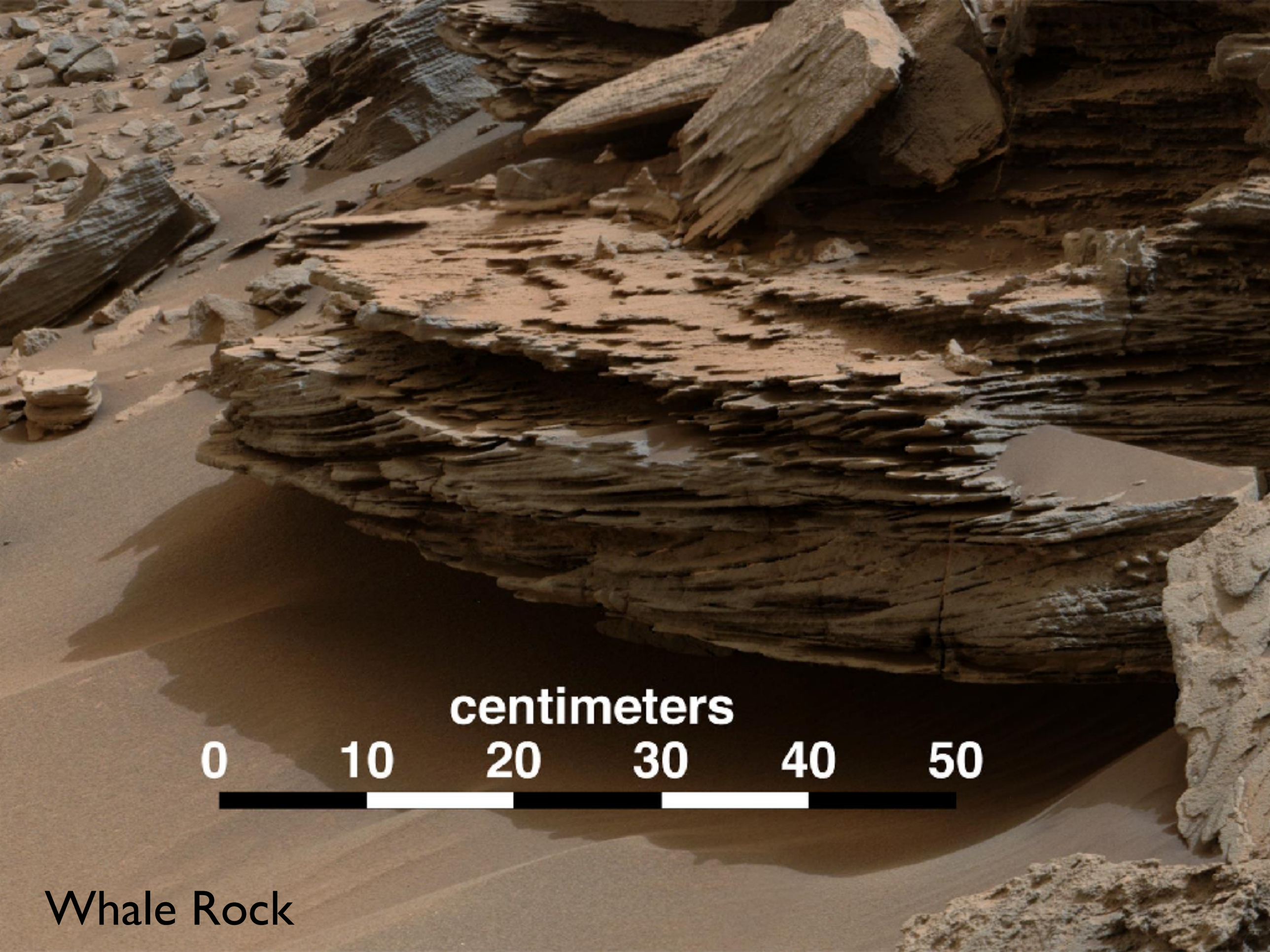
Mars (Endurance Crater)

Earth (Utah)

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

Martian Rocks

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



Whale Rock

Hydrogen Content

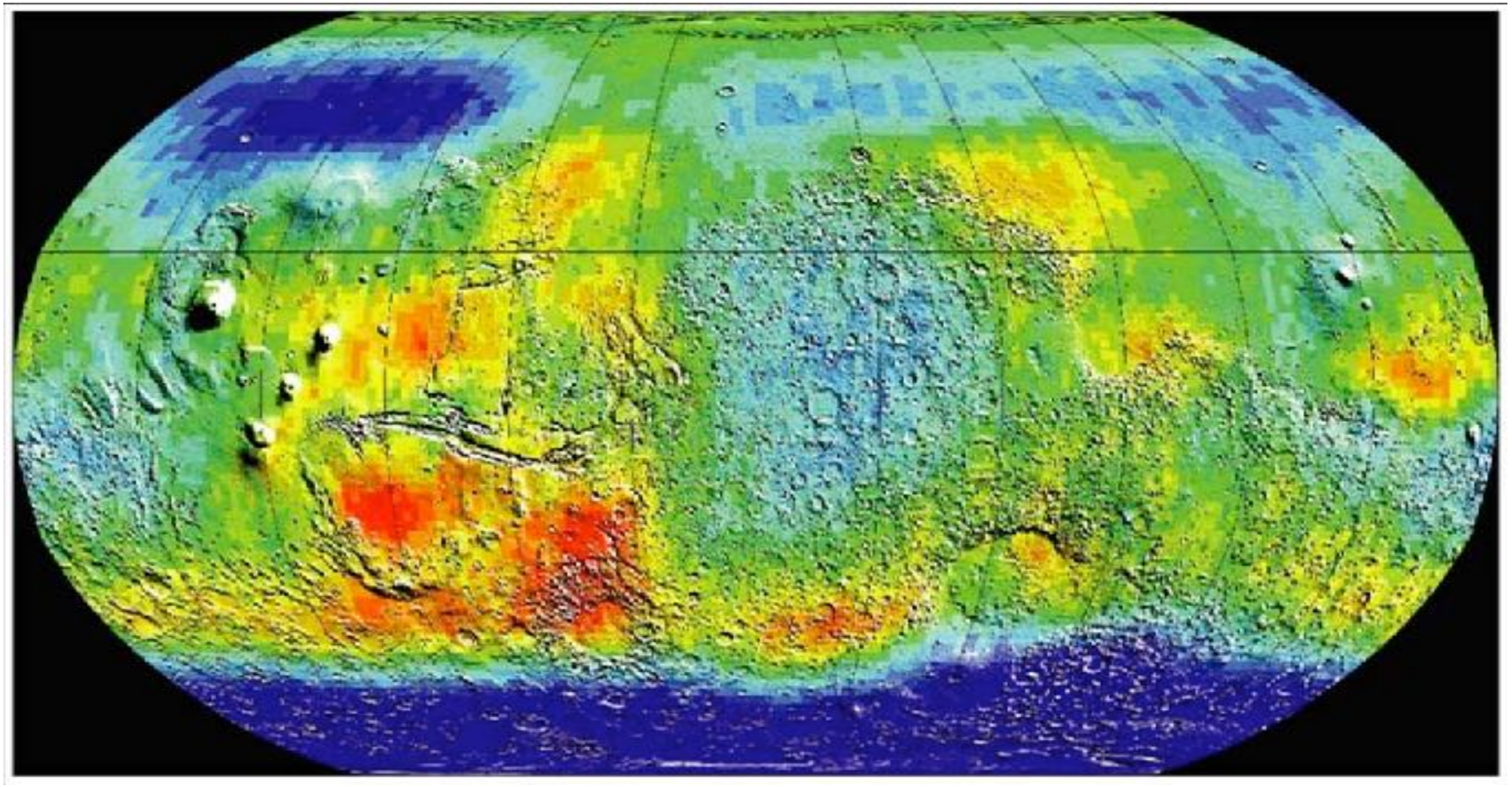


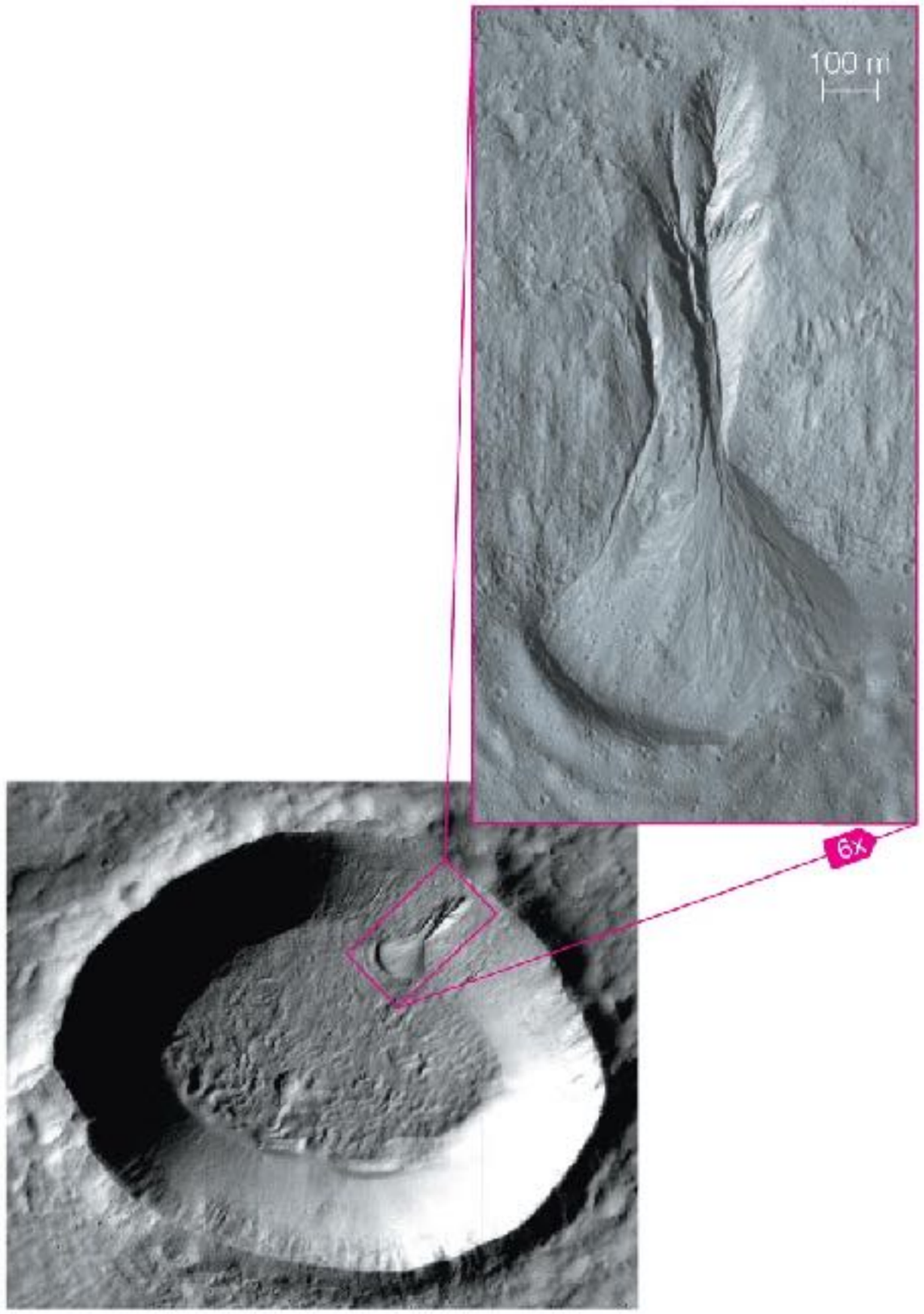
Image Credit: NASA/JPL

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

Crater Walls

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

- or, like, now

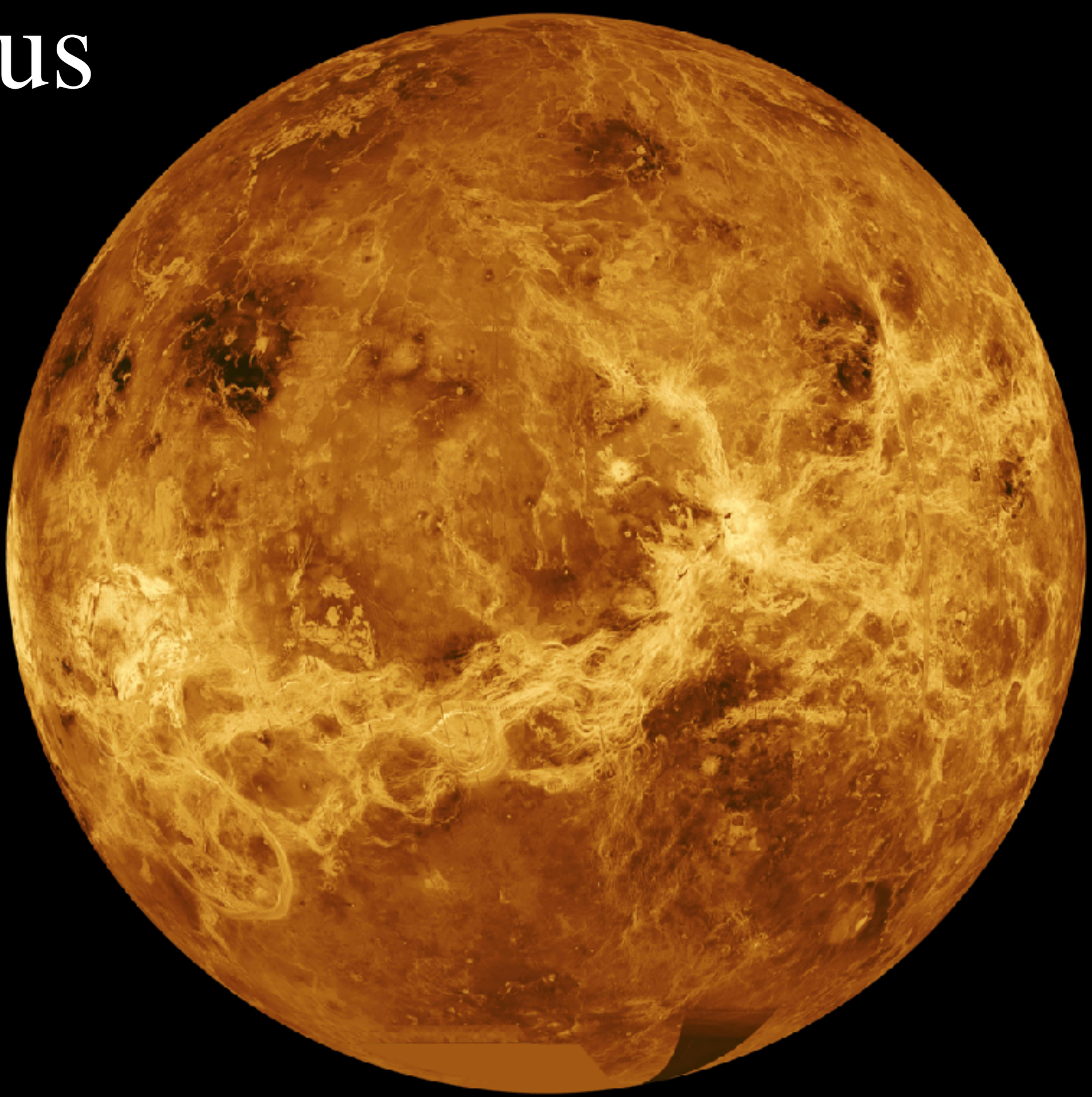


https://static01.nyt.com/newsgraphics/2015/09/28/mars-water/d910b431eb0ab62d9a5542dd1c10f5373df35383/images/flows.gif

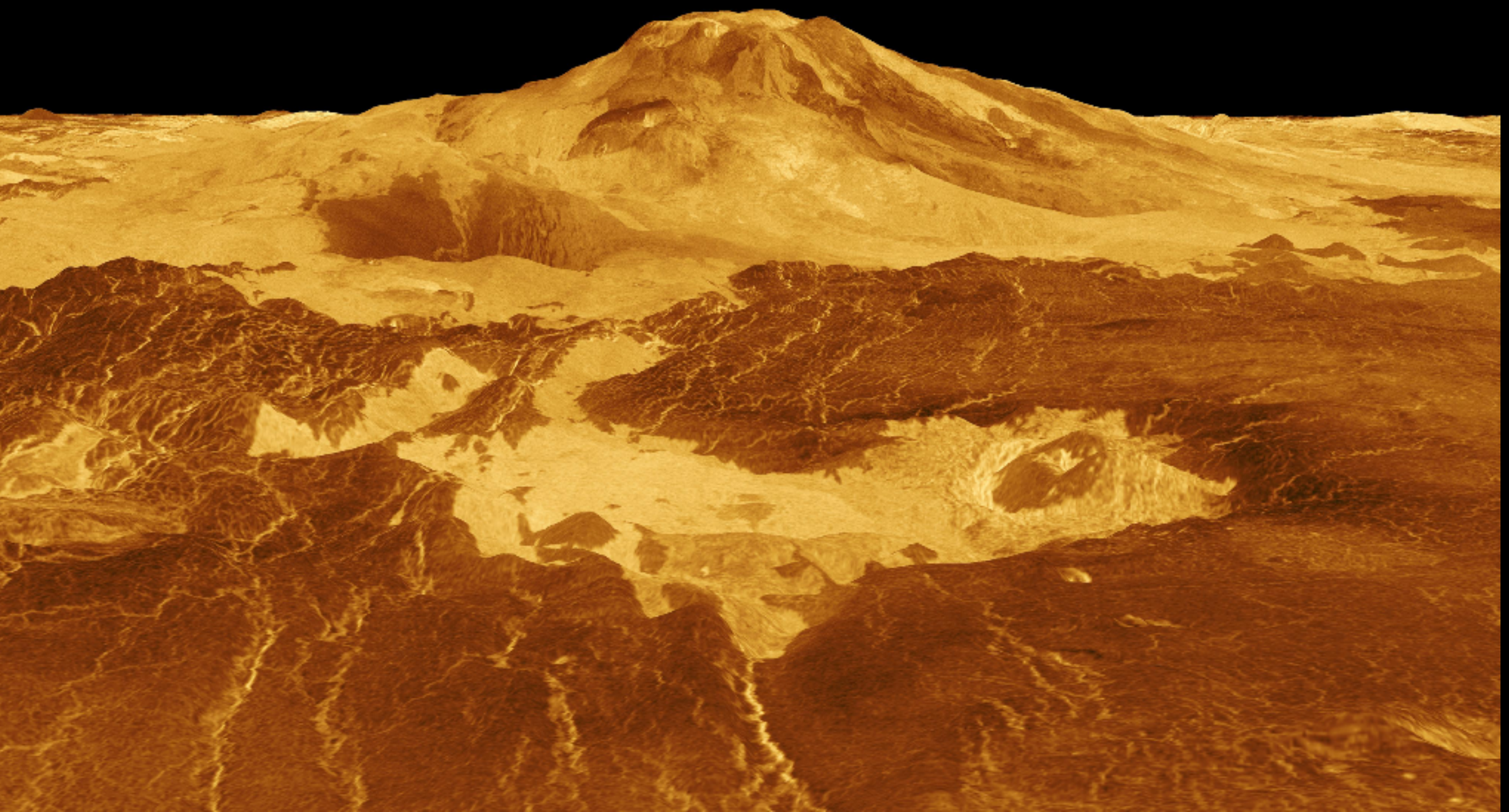
- Major geological features of Mars
  - Differences in cratering across surface
  - Giant shield volcanoes
  - Evidence of tectonic activity
- Evidence that water once flowed on Mars
  - Some surface features look like dry riverbeds.
  - Some craters appear to be eroded.
  - Rovers have found rocks composed of minerals that form in water.
  - Gullies in crater walls may indicate recent water flows.

https://www.nasa.gov/mission_pages/msl/images/index.html

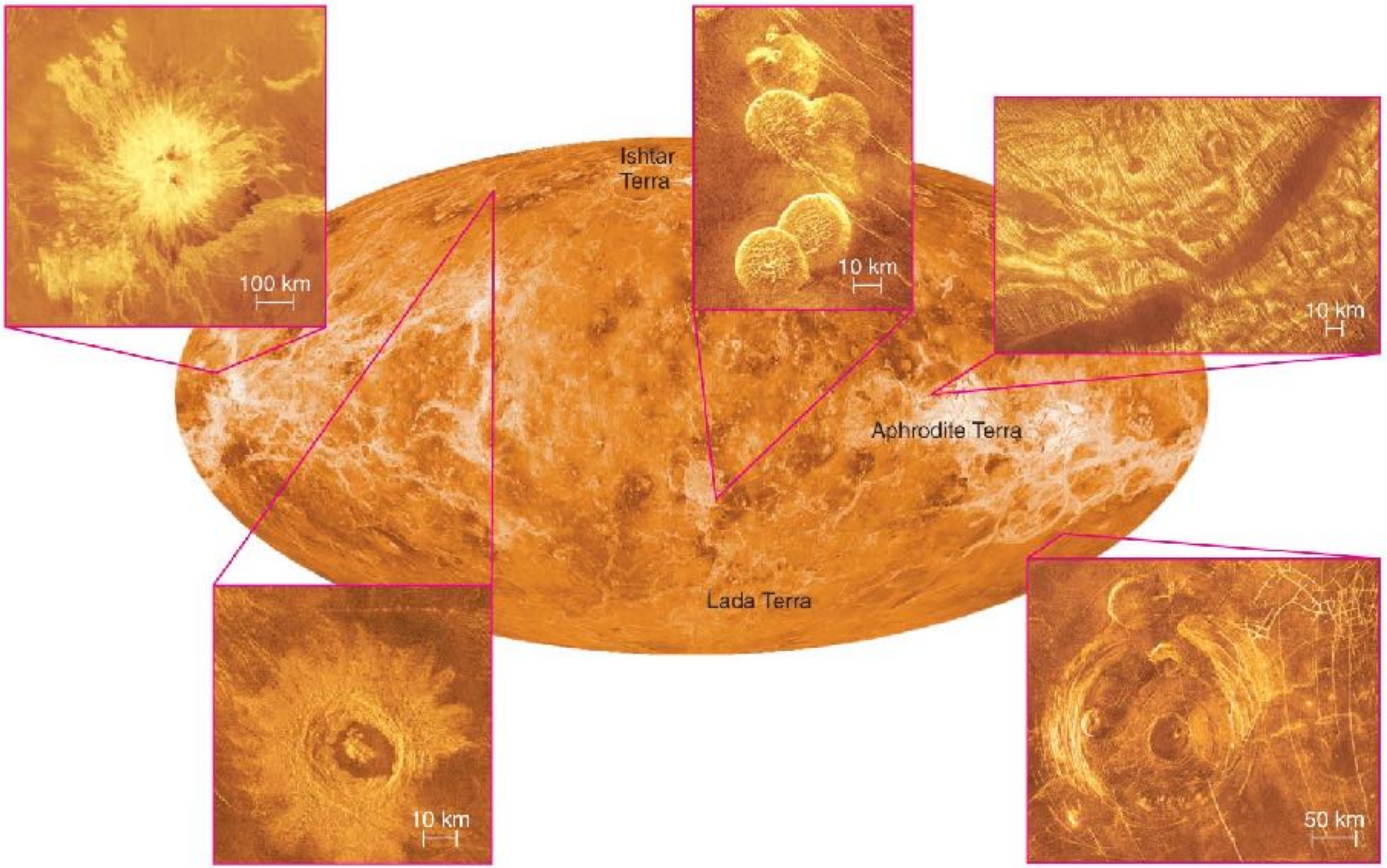
Venus



- Surface mapped by radar to penetrate thick clouds
- Magellan orbiter (1990 - 1994)
  - burned up in atmosphere

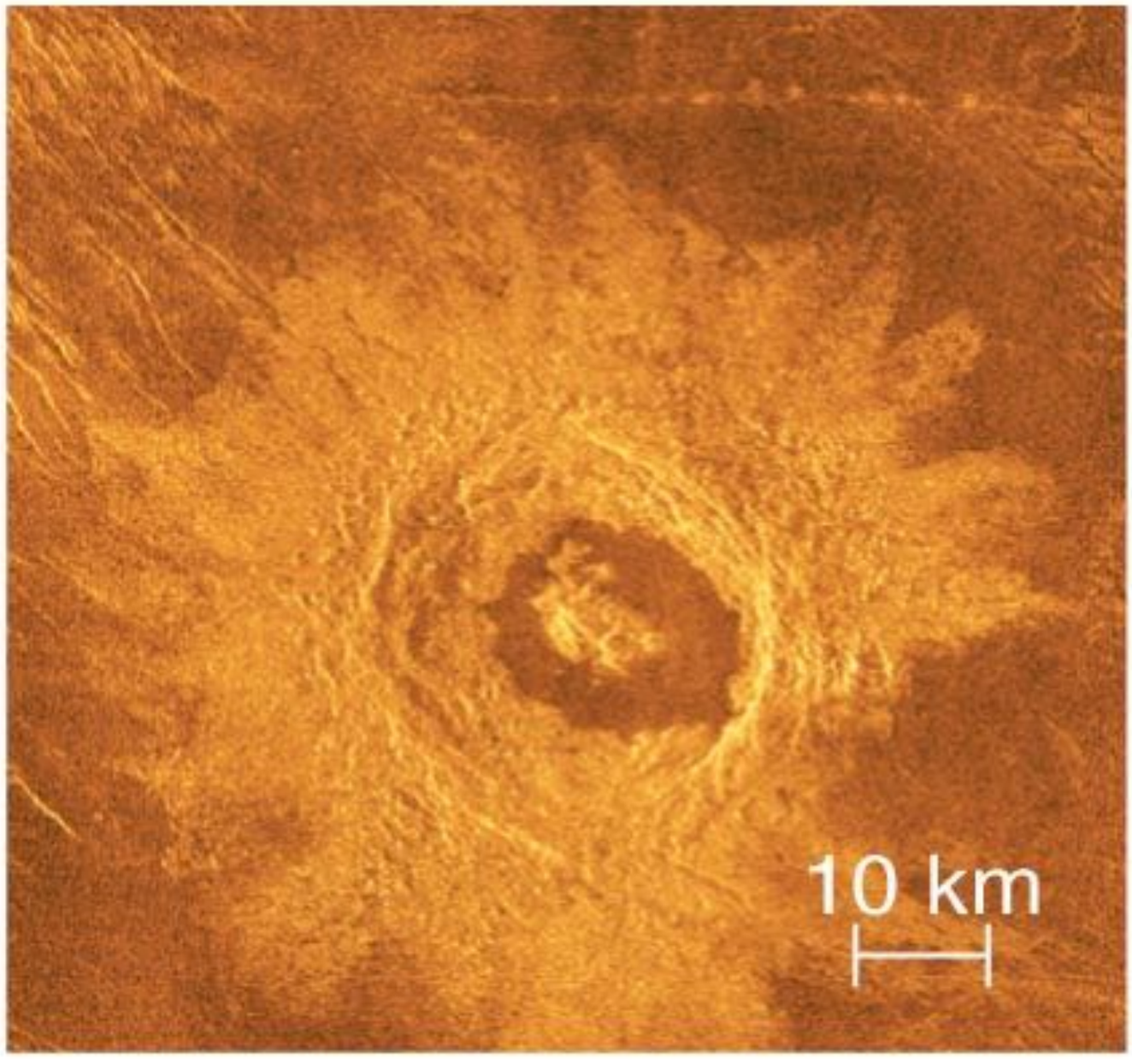


What geological processes have shaped Venus?



https://www.youtube.com/watch?v=Ub_bBs_oh_c

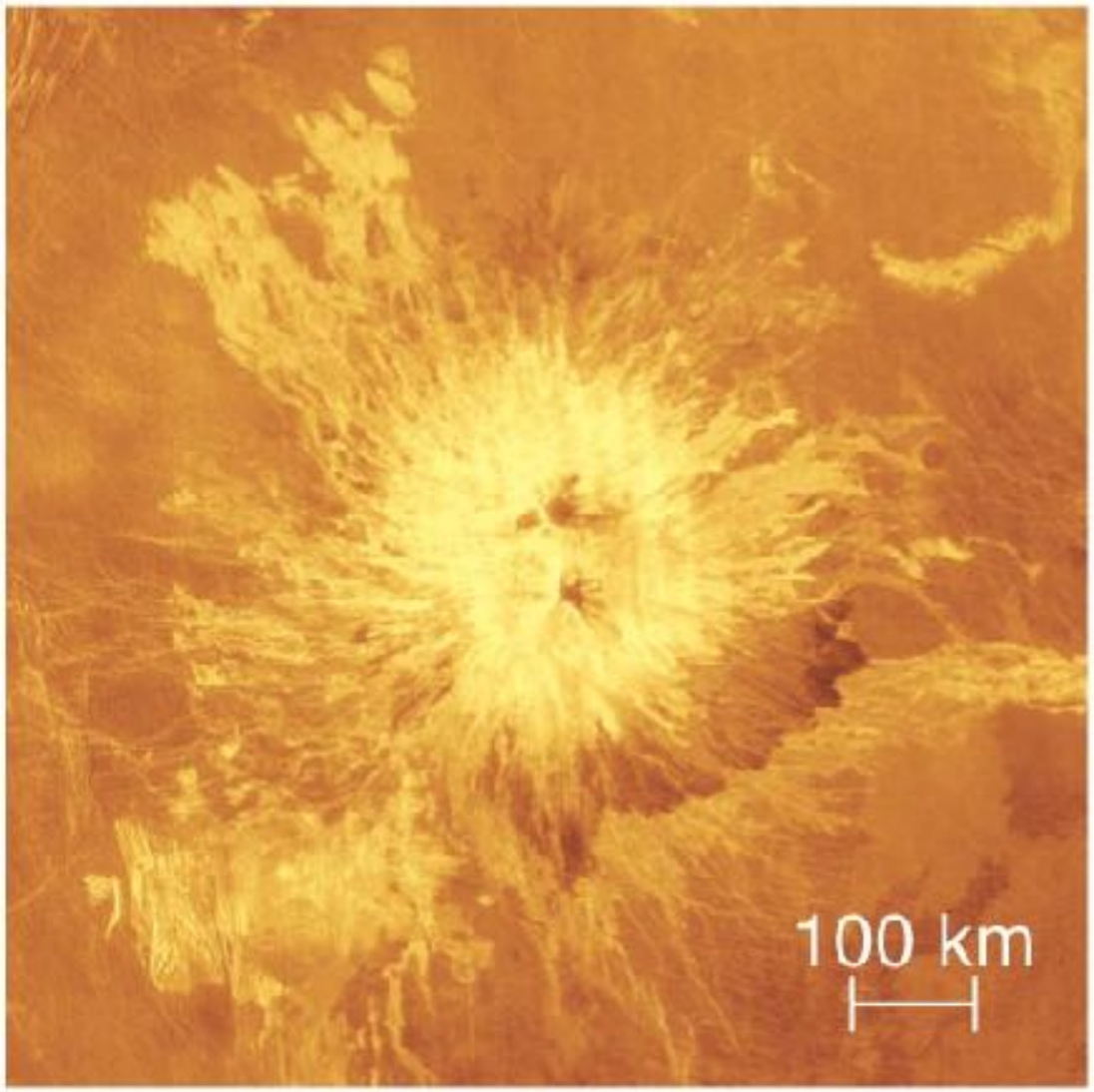
Cratering on Venus



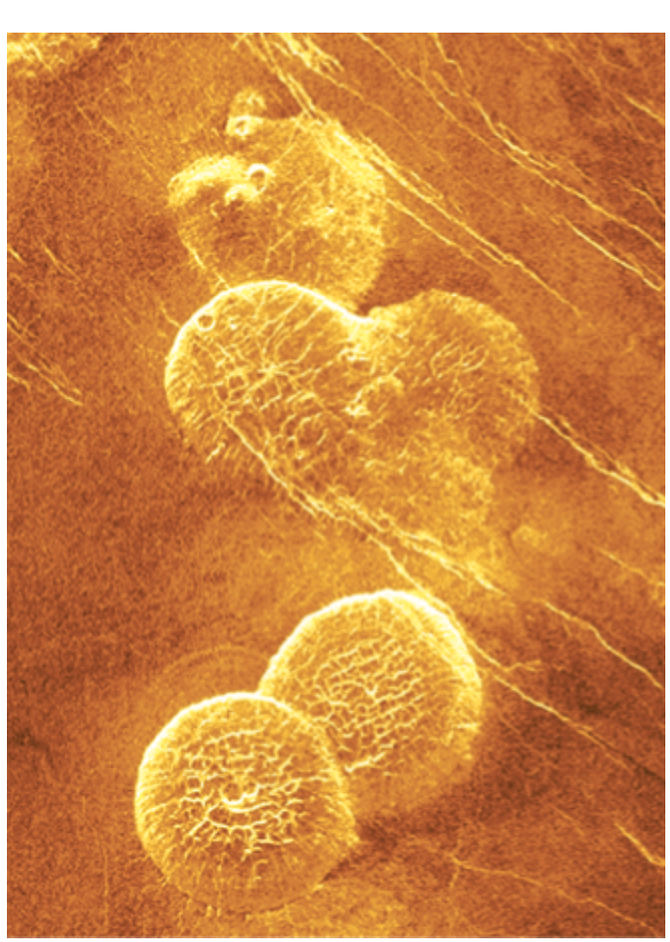
- Venus has impact craters, but fewer than the Moon, Mercury, or Mars.

- Mostly large craters
  - shielded from small impactors by thick atmosphere

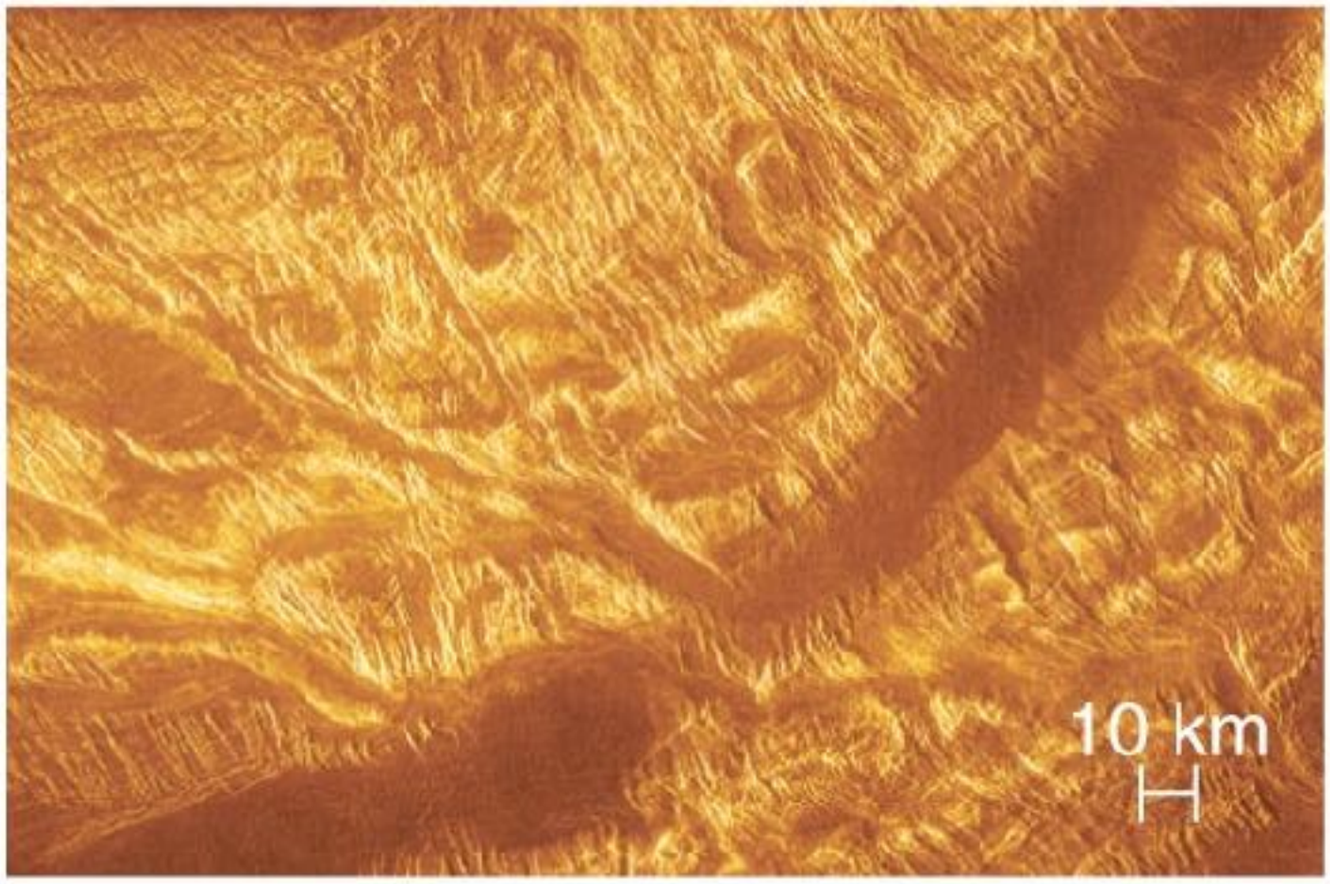
Volcanoes on Venus



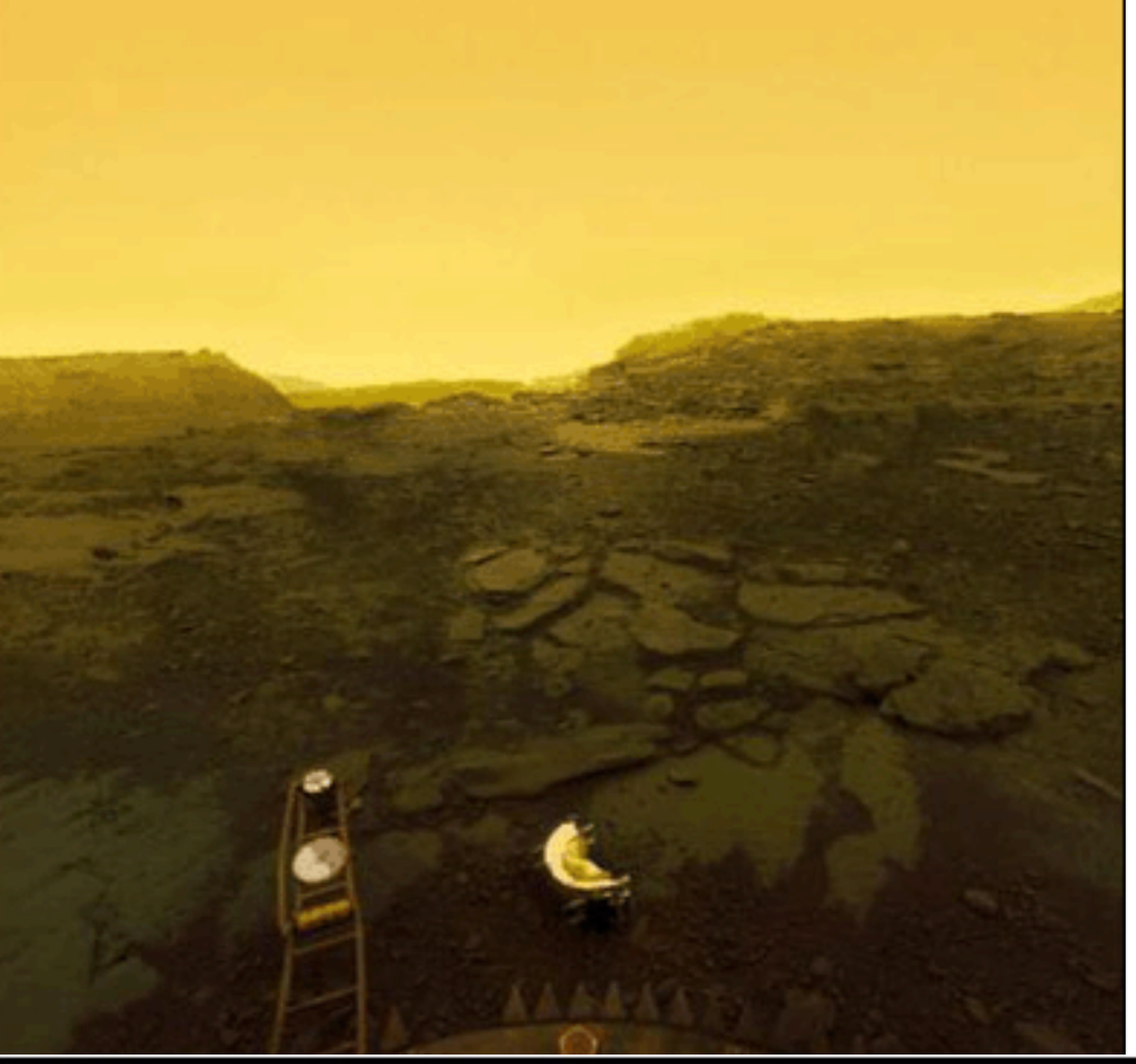
- It has many volcanoes, including both shield volcanoes and stratovolcanoes.

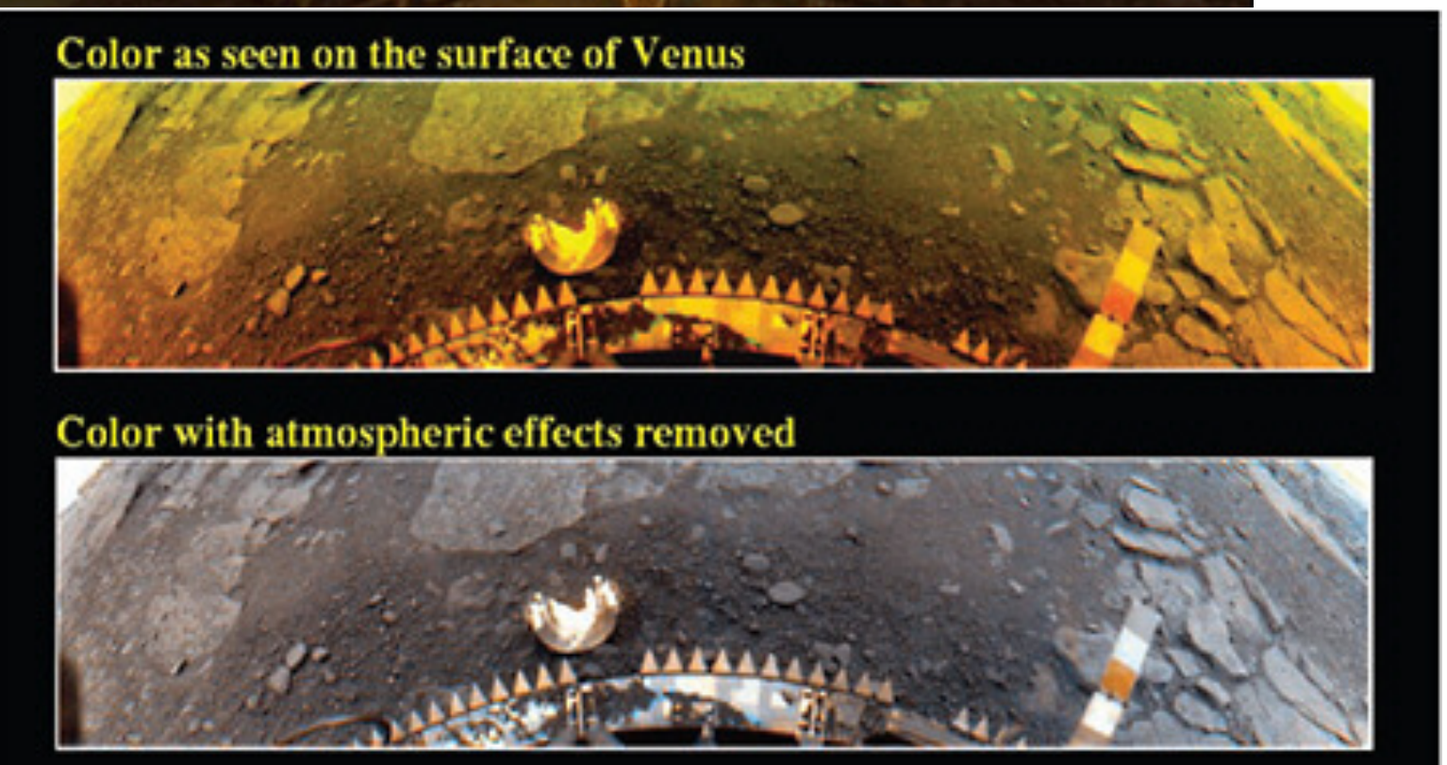


Tectonics on Venus



- The planet's fractured and contorted surface indicates tectonic stresses.





- Photos of rocks taken by landers show little erosion.

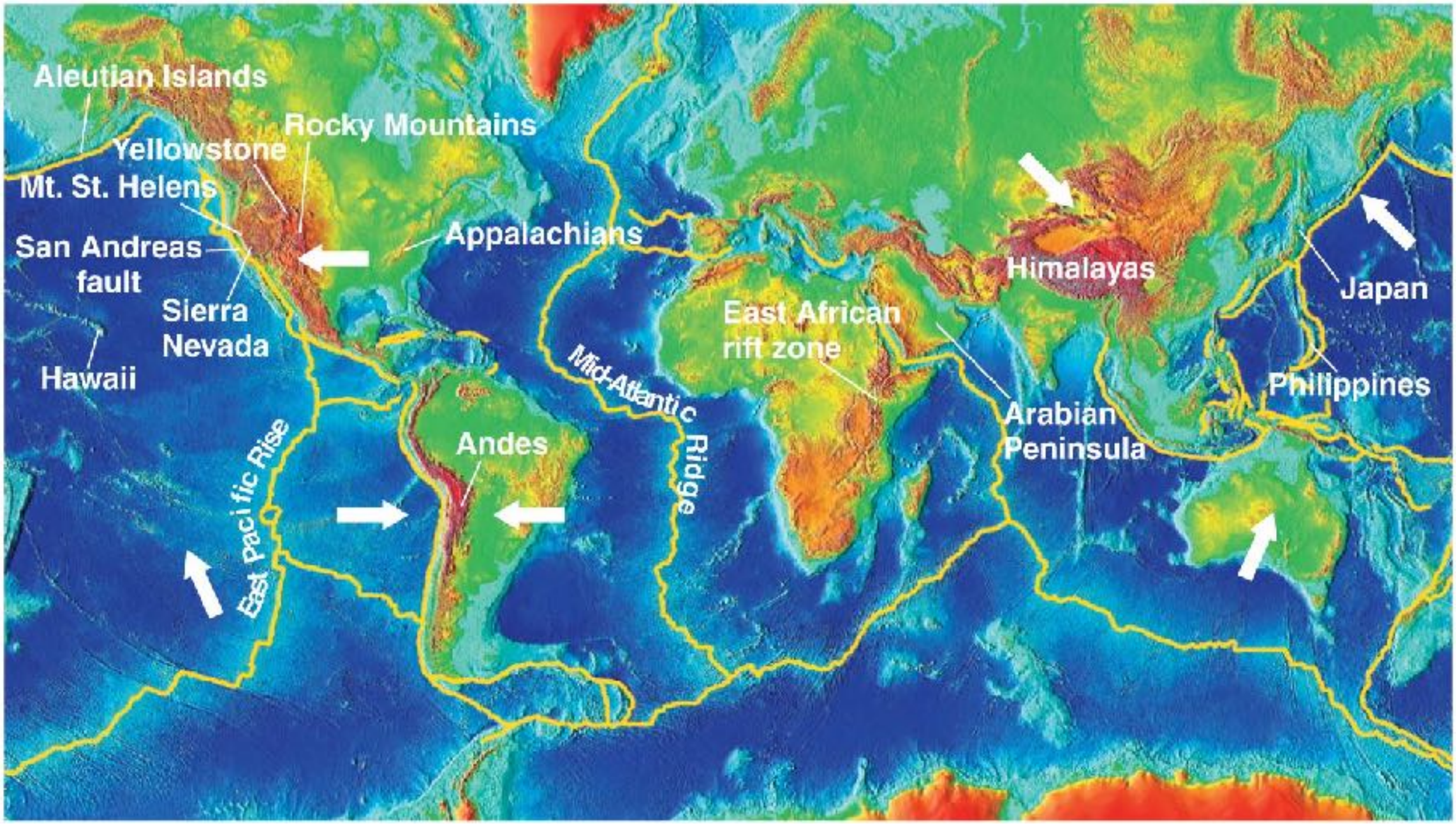
- No flowing water

- Series of Russian landers; lasted from 23 minutes to a couple of hours

Does Venus have plate tectonics?

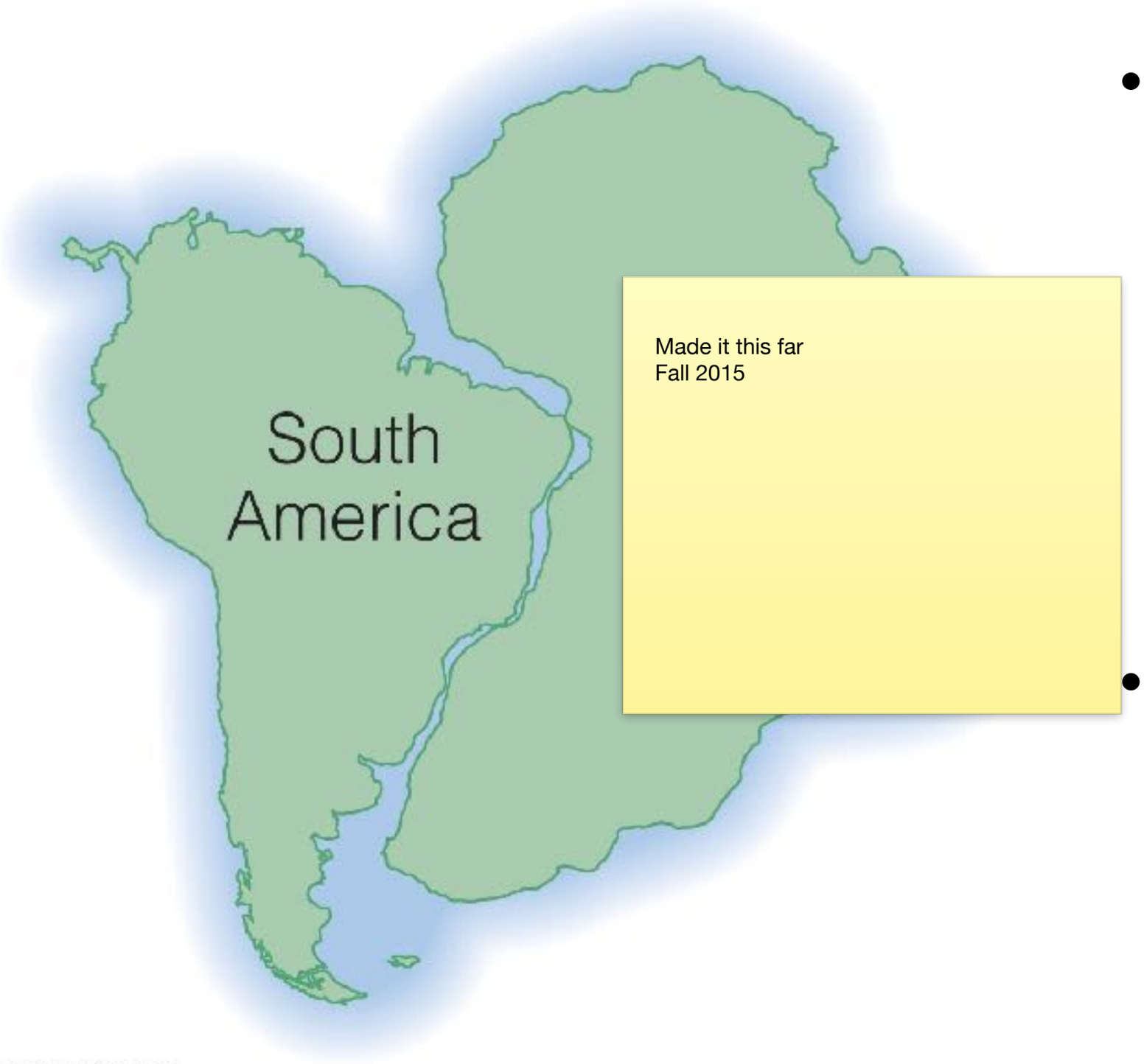
- Venus does not appear to have plate tectonics, but entire surface seems to have been "repaved" 750 million years ago.
  - Weaker convection?
  - Thicker or more rigid lithosphere?
    - Some role for water in greasing plate tectonics on Earth?

Continental Motion

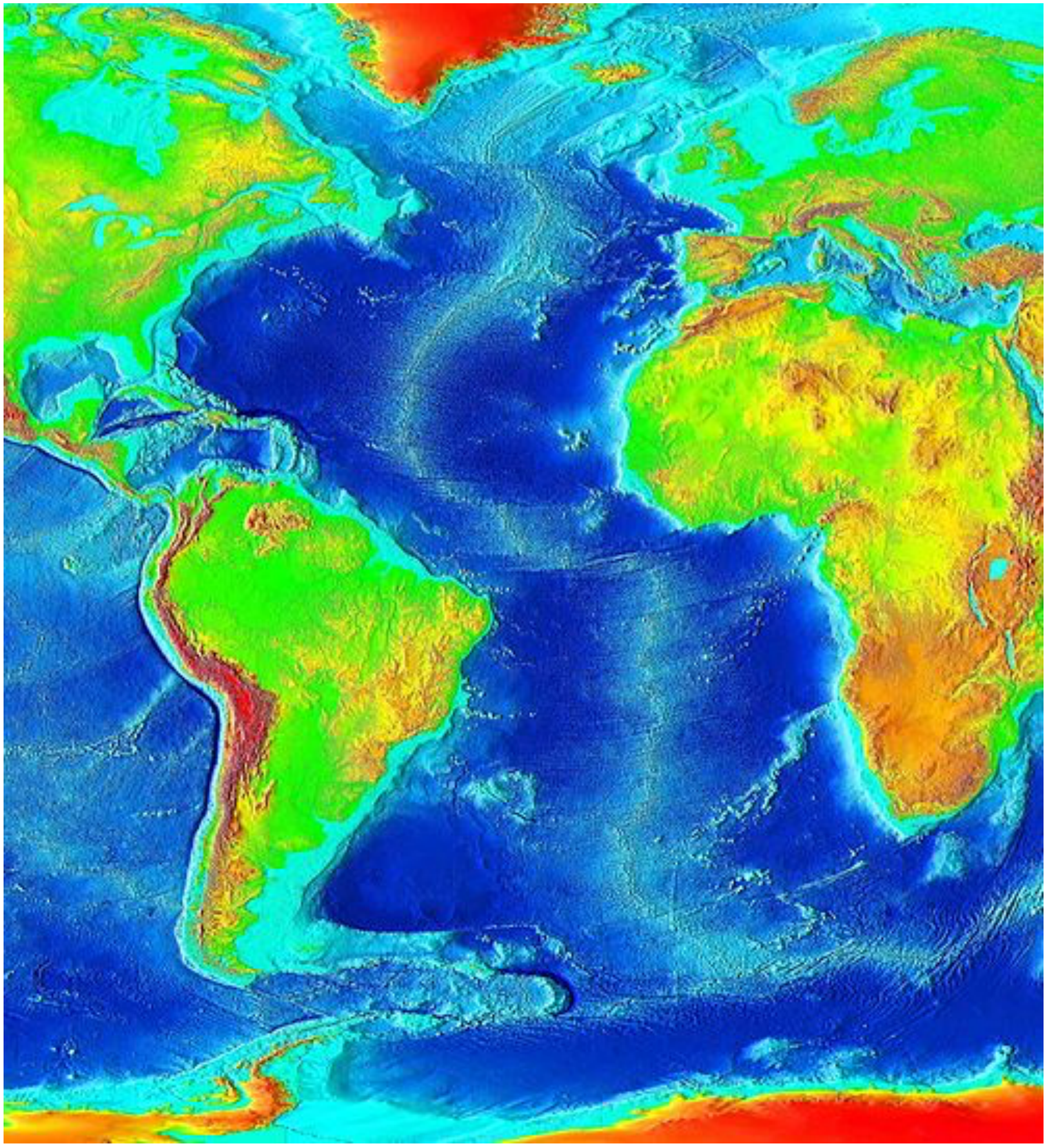


- Motion of the continents can be measured with GPS.

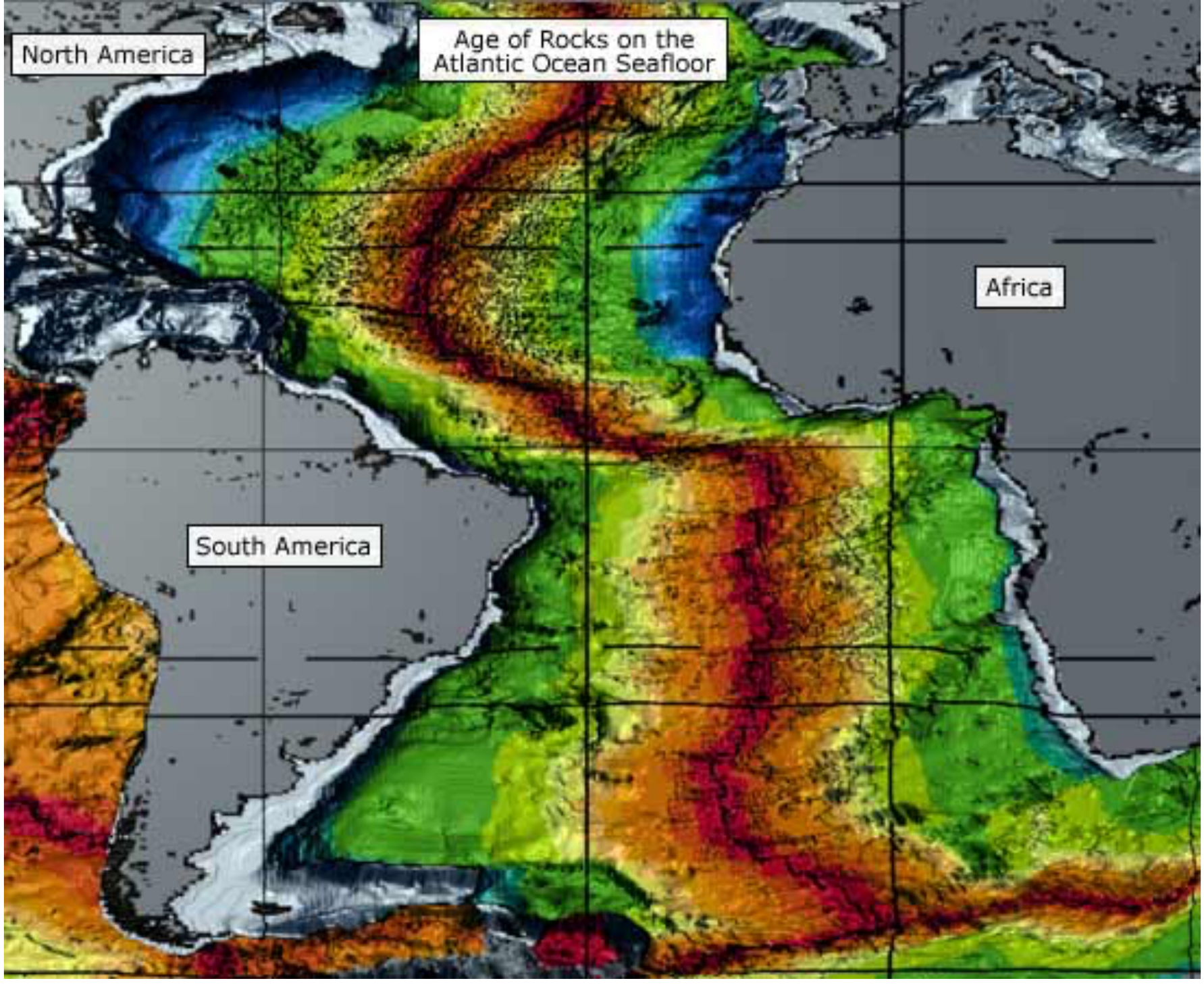
Continental Motion



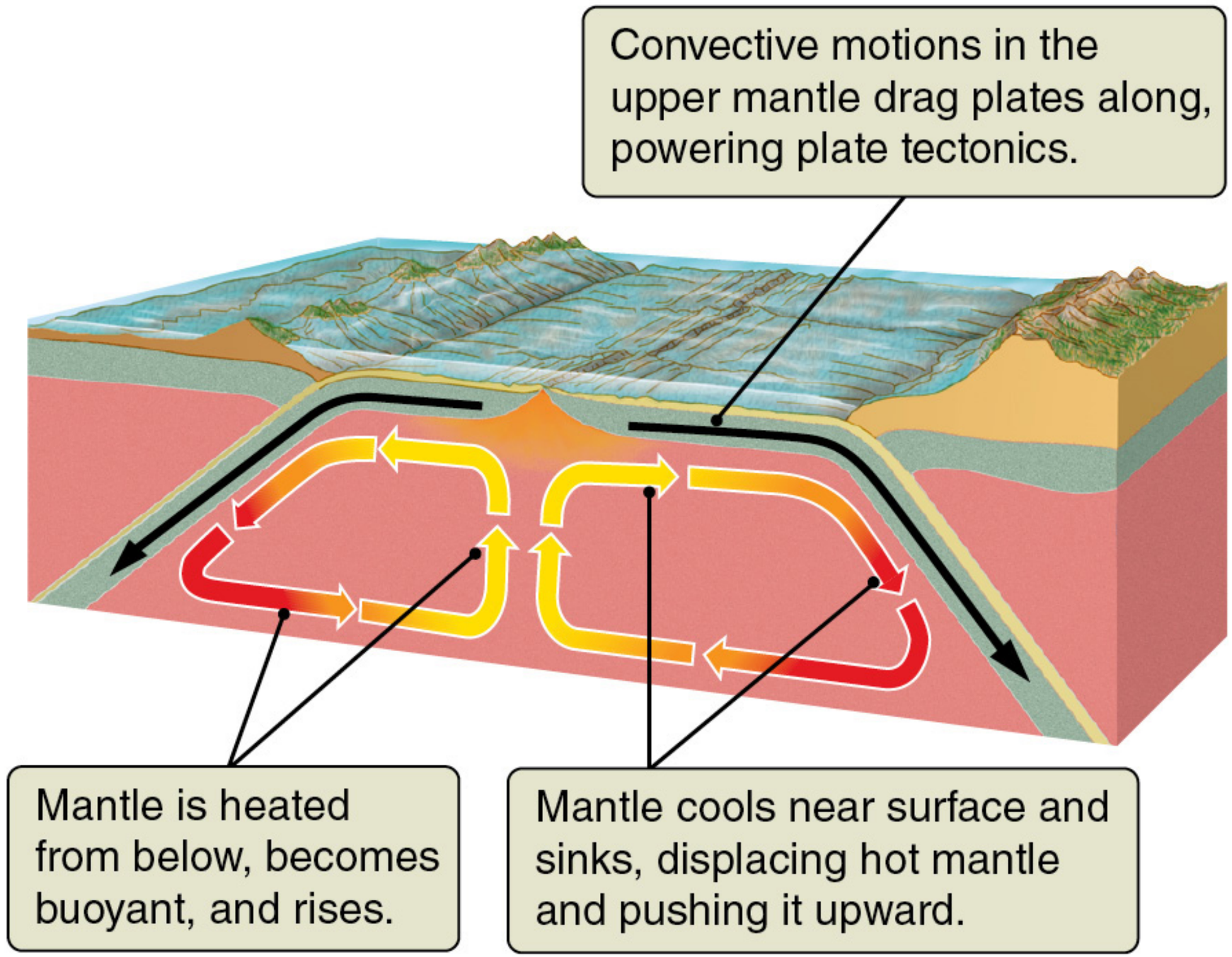
- The idea of continental drift was inspired by the puzzle-like fit of the continents.
- Mantle material erupts where the seafloor spreads.

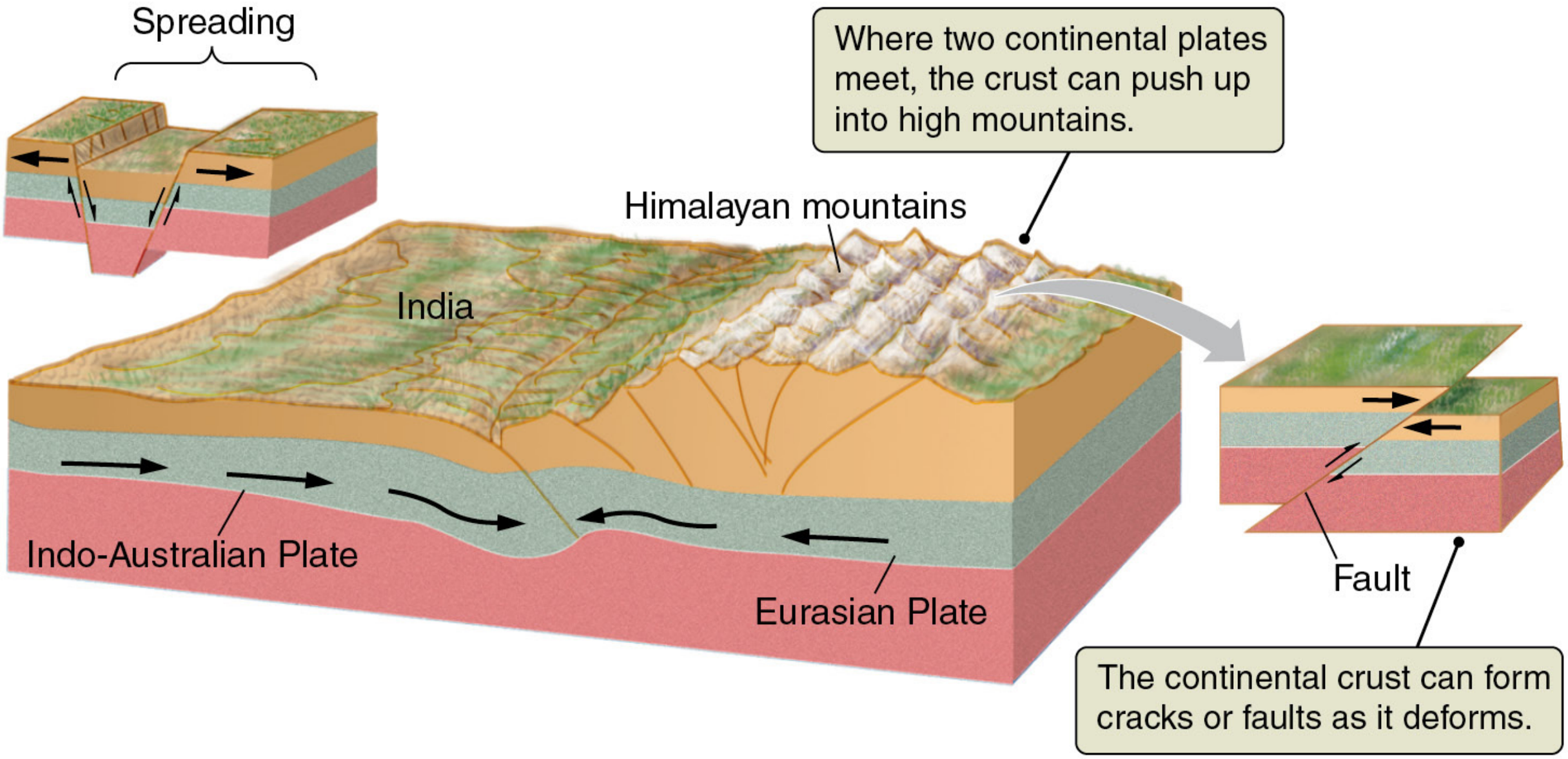


- Mid-Atlantic ridge
- Chain of mountains from whence seafloor spreads
- Age gradient in rocks with youngest at the center of spreading



Younger rocks colored red

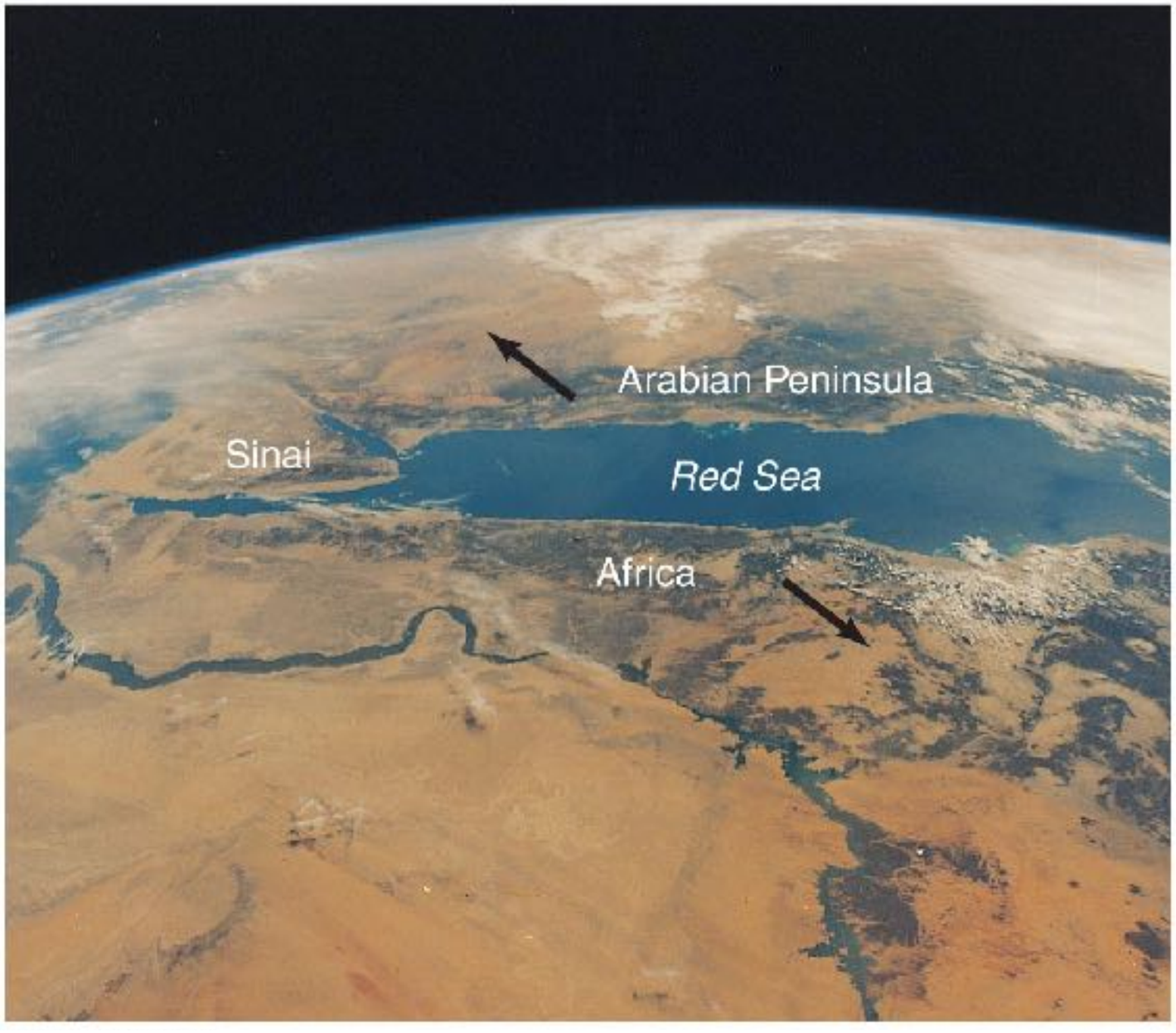

Convective motions in the upper mantle drag plates along, powering plate tectonics.
Mantle is heated from below, becomes buoyant, and rises.
Mantle cools near surface and sinks, displacing hot mantle and pushing it upward.


Spreading
Where two continental plates meet, the crust can push up into high mountains.
Himalayan mountains
India
Indo-Australian Plate
Eurasian Plate
Fault
The continental crust can form cracks or faults as it deforms.

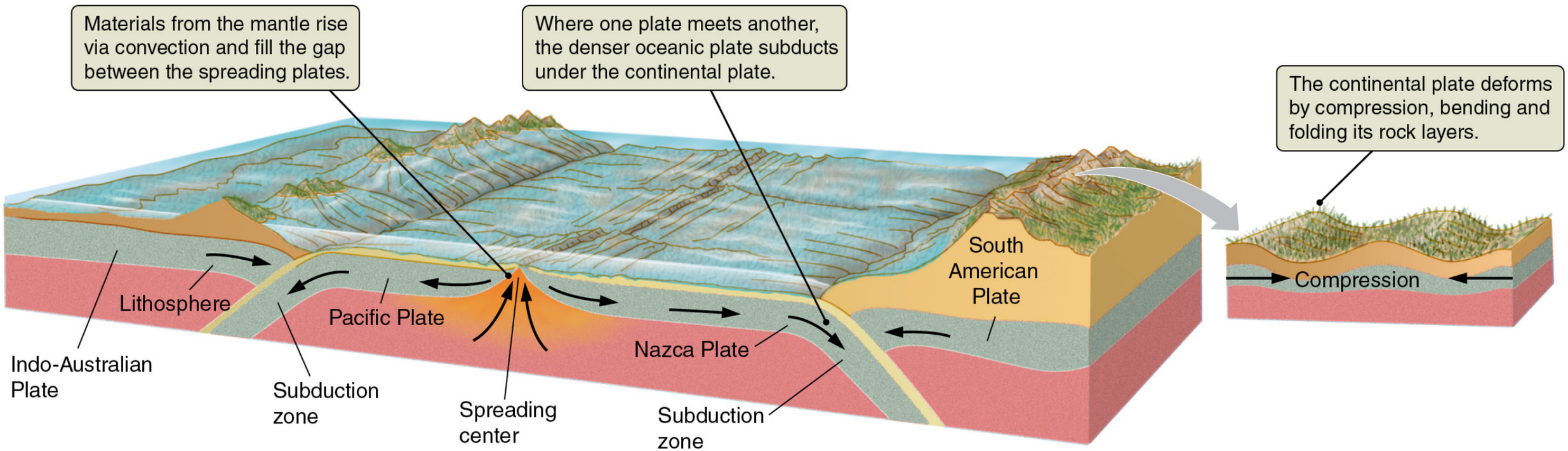
Surface Features

- The Himalayas formed from a collision between plates.

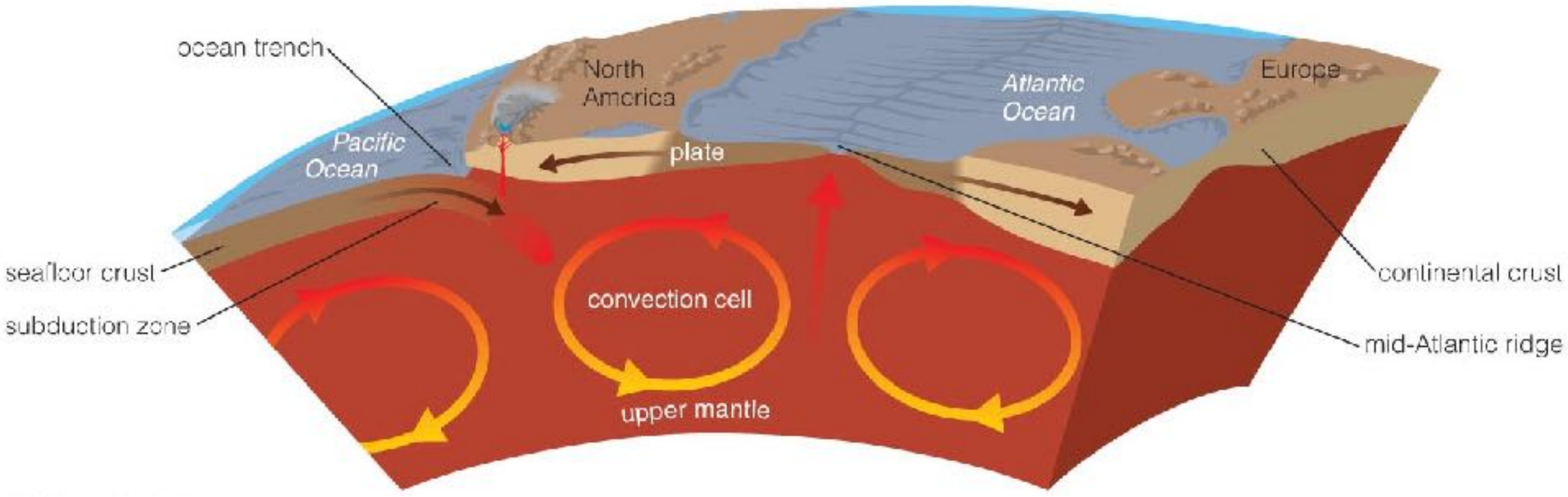
Surface Features



- The Red Sea is formed where plates are pulling apart.


Materials from the mantle rise via convection and fill the gap between the spreading plates.
Where one plate meets another, the denser oceanic plate subducts under the continental plate.
The continental plate deforms by compression, bending and folding its rock layers.
Lithosphere
Pacific Plate
South American Plate
Indo-Australian Plate
Subduction zone
Spreading center
Nazca Plate
Subduction zone
Compression

Seafloor Recycling



- Seafloor is recycled through a process known as subduction.