



Today

- Terrestrial Planet Geology
- individual cases

Events

- Fall break next Tuesday

Formation of the Moon: Giant Impact Hypothesis



- Moon formed from the debris of the last big planetesimal collision that built the Earth.
- Earth and Theia already differentiated pre-impact
- Mantle material ejected into space, forming a short-lived ring around Earth
- Material in ring coalesced into the moon.

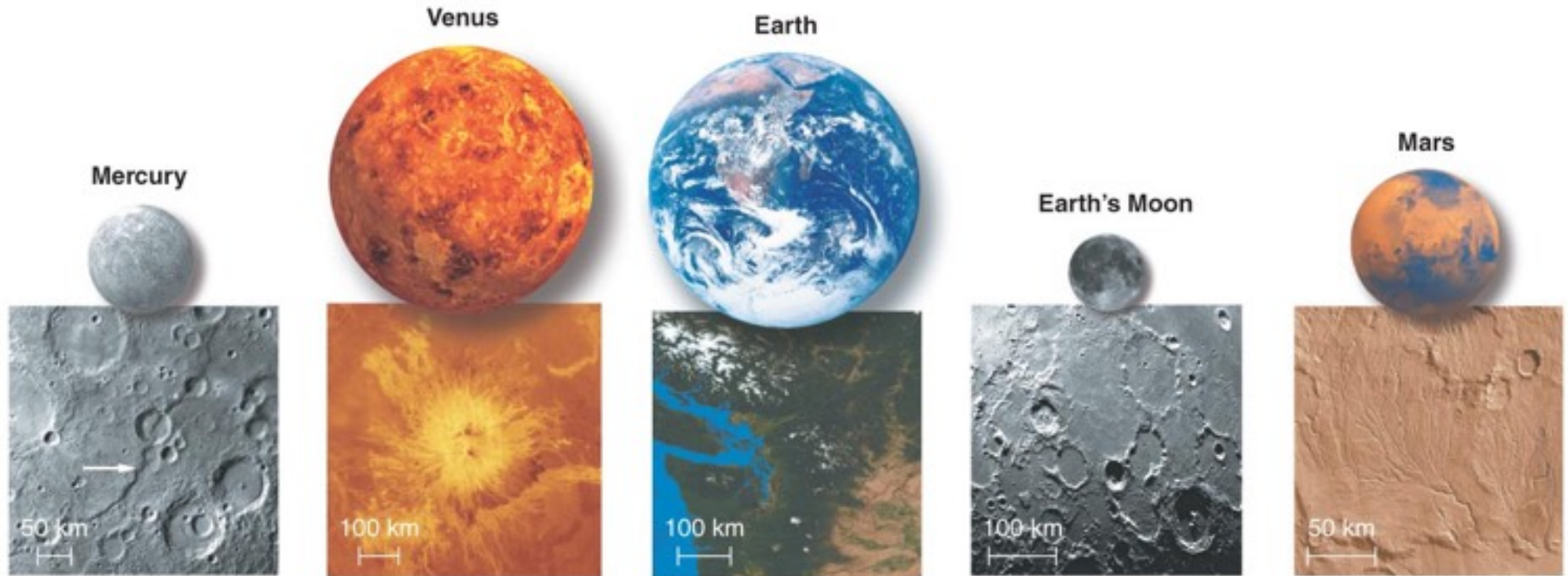
Formation of the Moon: Giant Impact Hypothesis



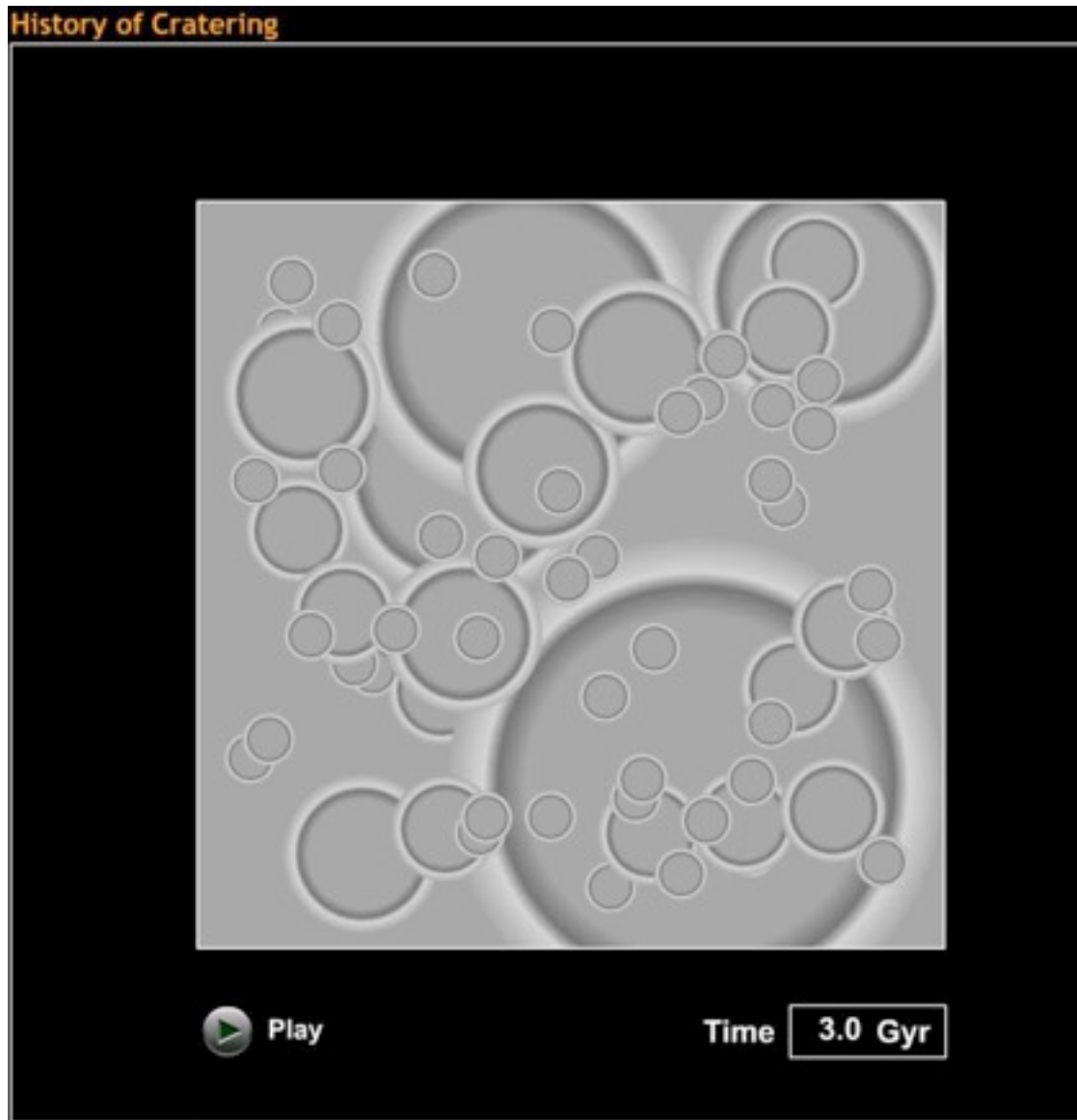
Explains

- Earth's tilt.
- the moon's unusually large size relative to its planet
- the moon's small iron core
 - built of mantle material
- the lack of water and other volatiles on the moon.
- isotope ratios of moon rocks identical to Earth's

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



History of Cratering

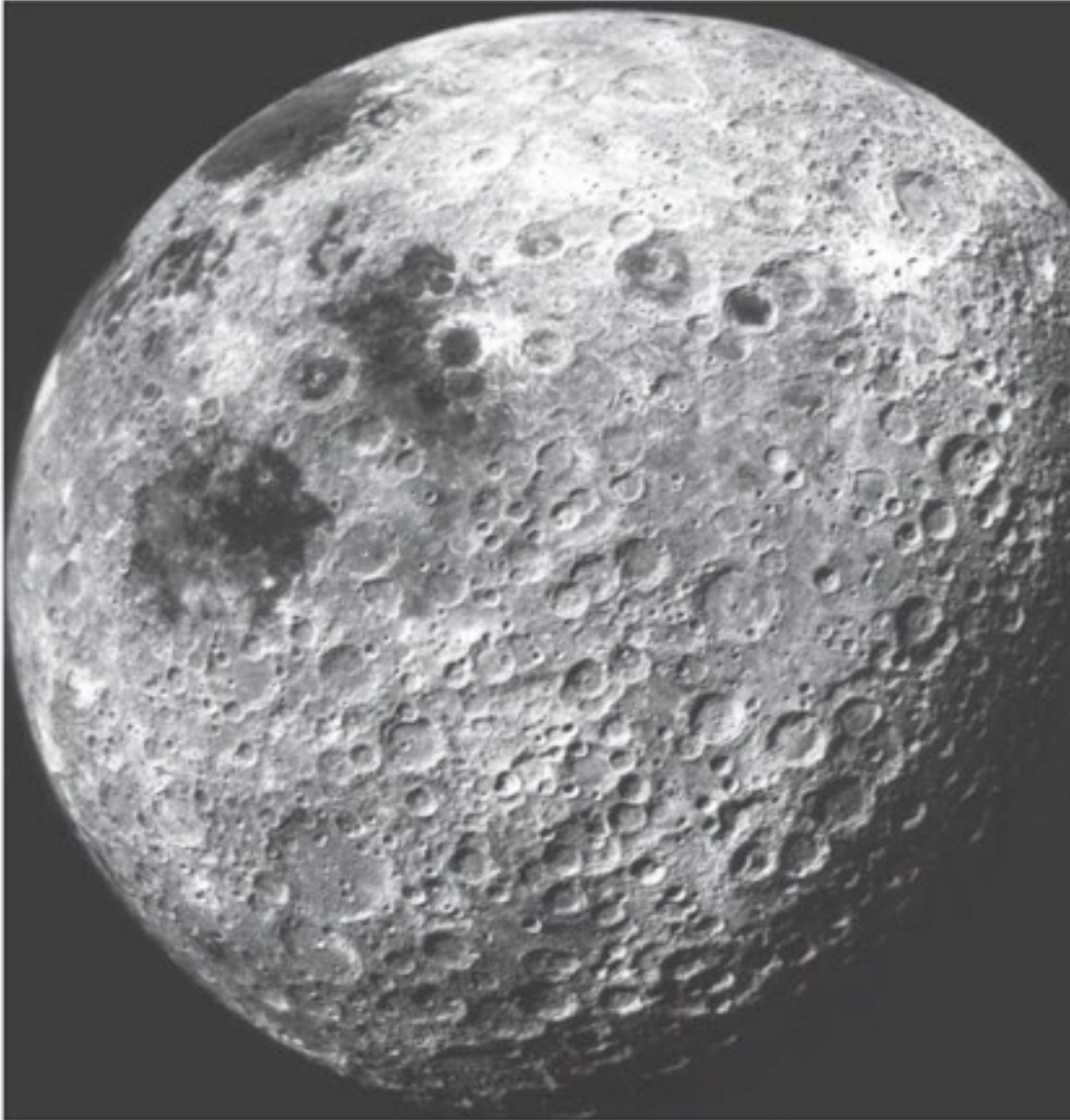


- Most cratering happened in the first billion years.
- A surface with many craters has not changed much in 3 billion years.
 - many craters is a sign of age

09_HistoryOfCratering.swf

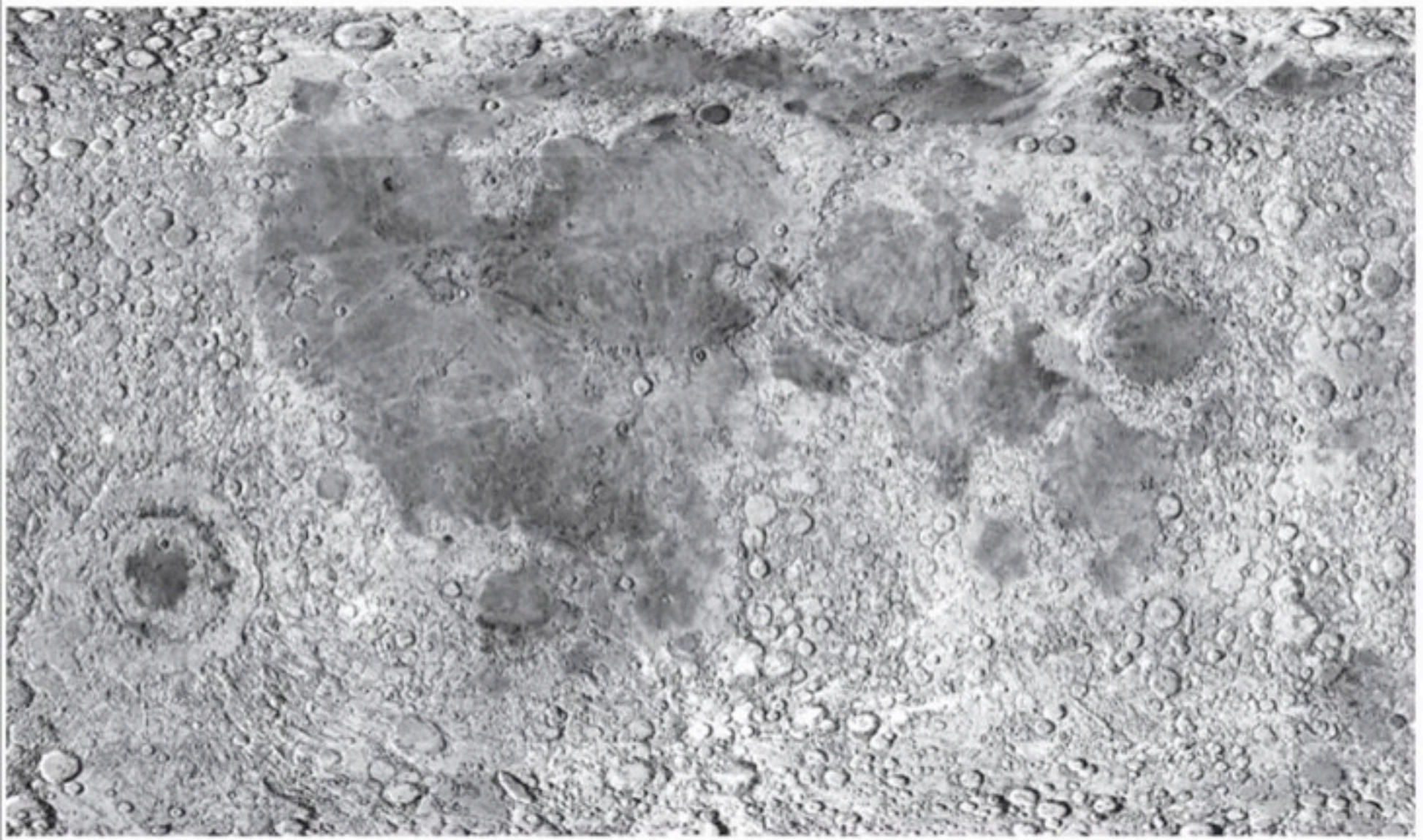
Interactive Figure 

Cratering of Moon

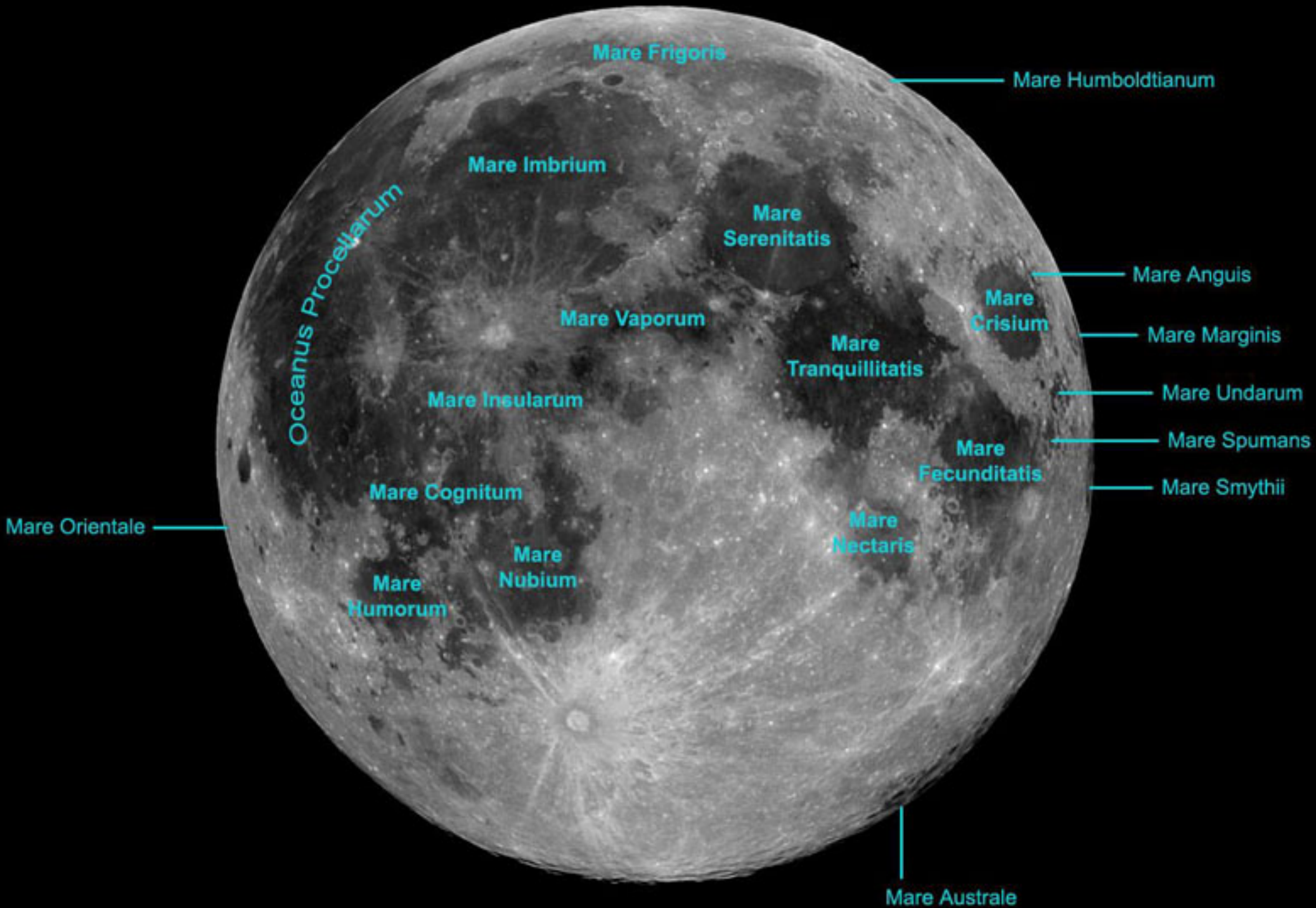


- Some areas of Moon are more heavily cratered than others.
- Younger regions were flooded by lava after most cratering.
 - mare

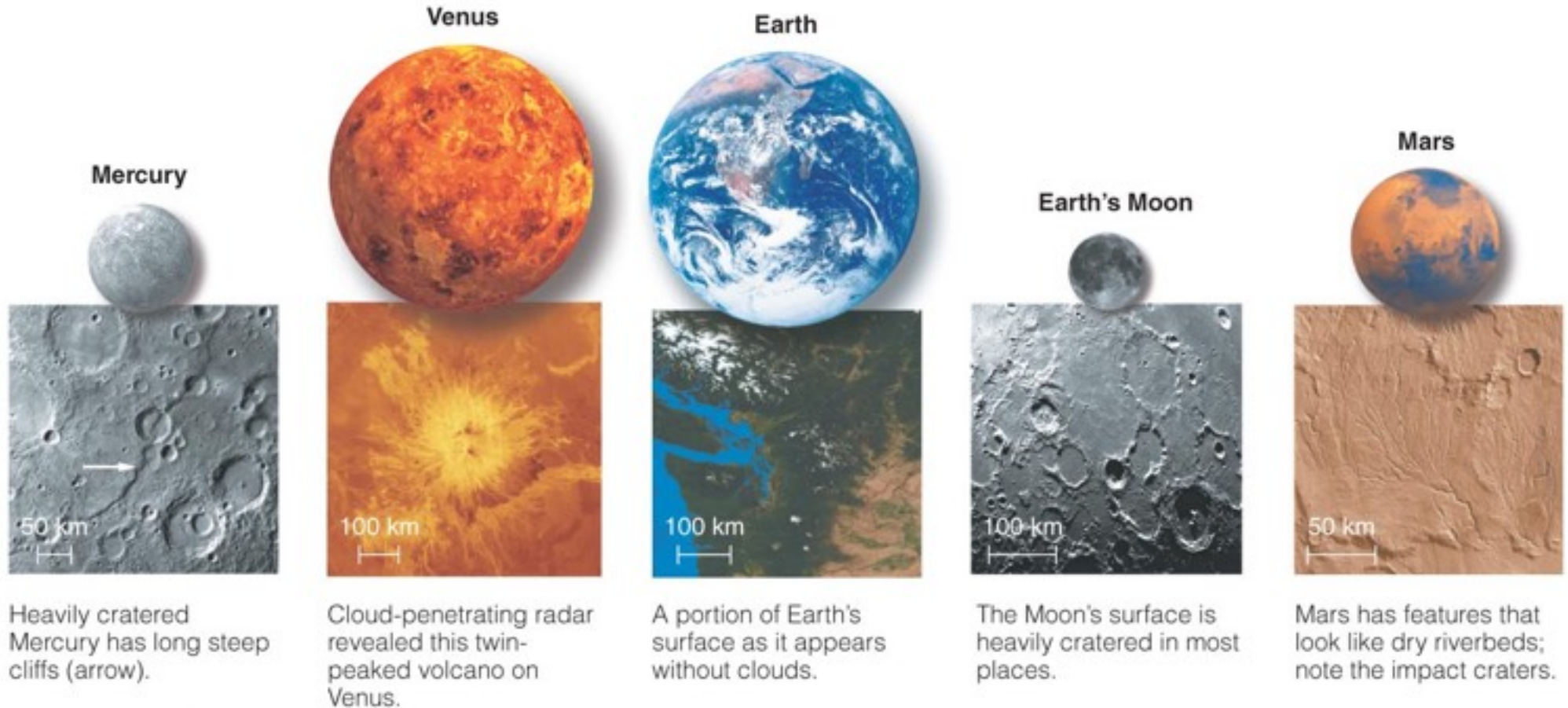
Cratering of Moon



Cratering map of the Moon's entire surface

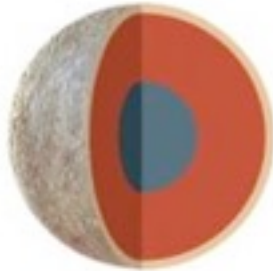


Why do the terrestrial planets have different geological histories?

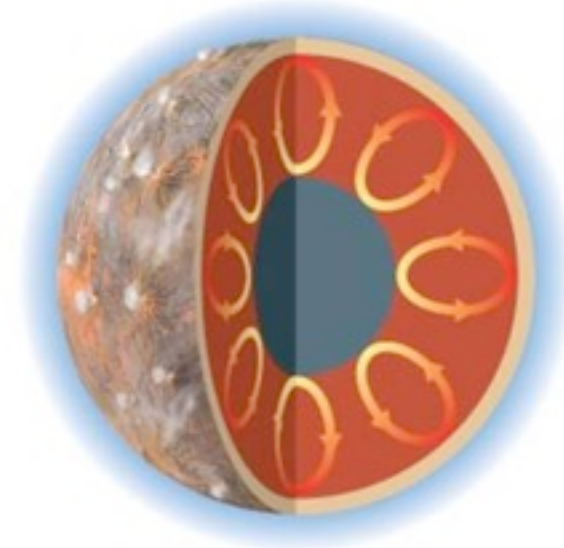


Role of Planetary Size

Small Terrestrial Planets

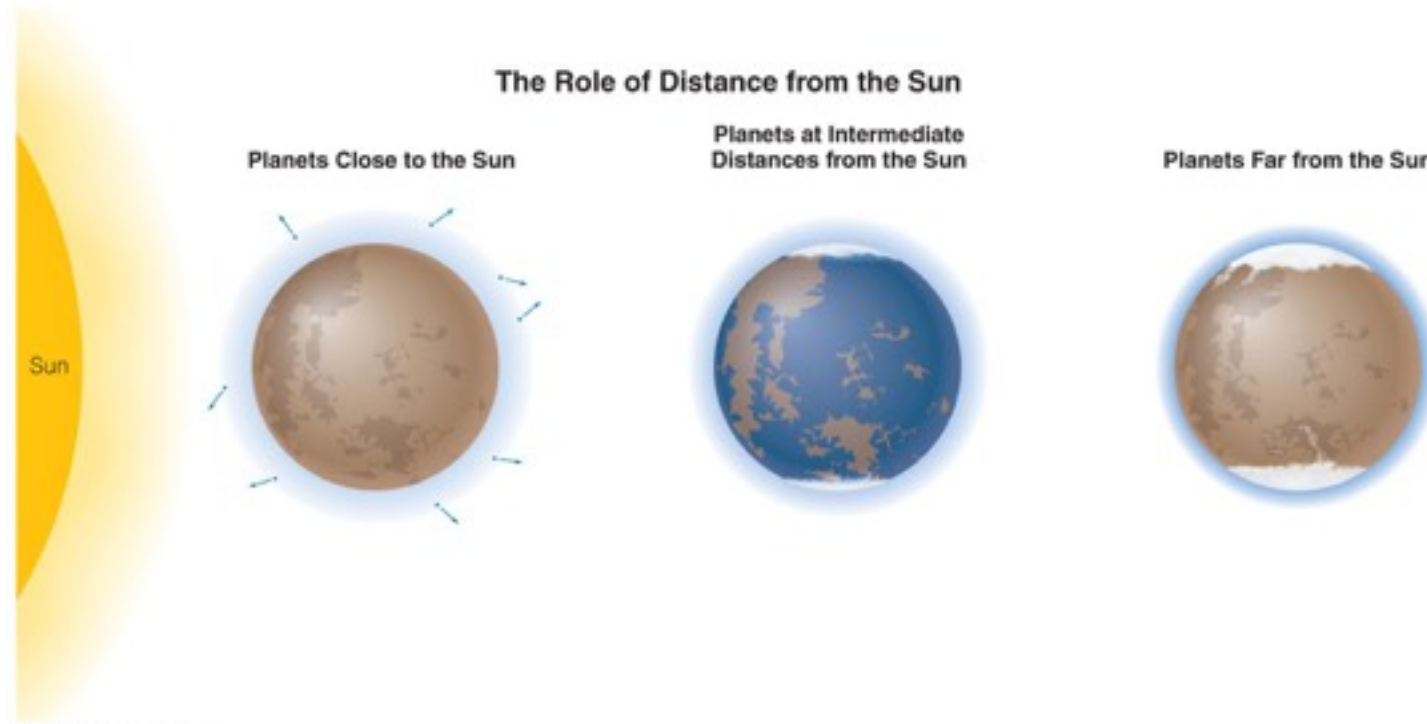


Large Terrestrial Planets



- 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

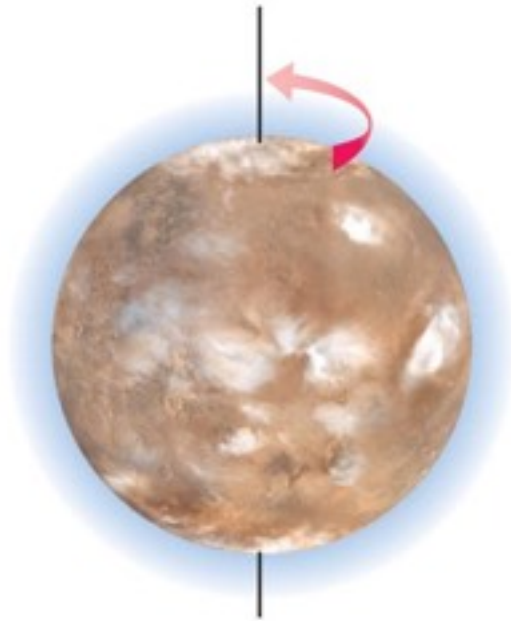


- Planets close to the Sun are too hot for rain, snow, ice and so have less erosion.
- Hot planets have more difficulty retaining an atmosphere.
- Planets far from the Sun are too cold for rain, limiting erosion.
- Planets with liquid water have the most erosion.

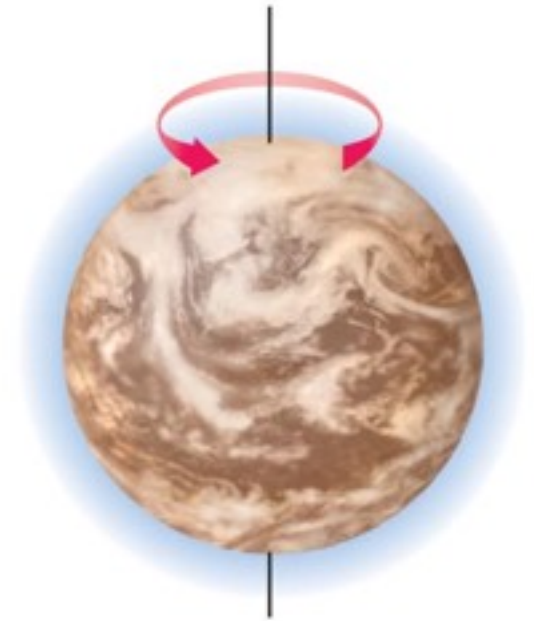
Role of Rotation

The Role of Planetary Rotation

Slow Rotation

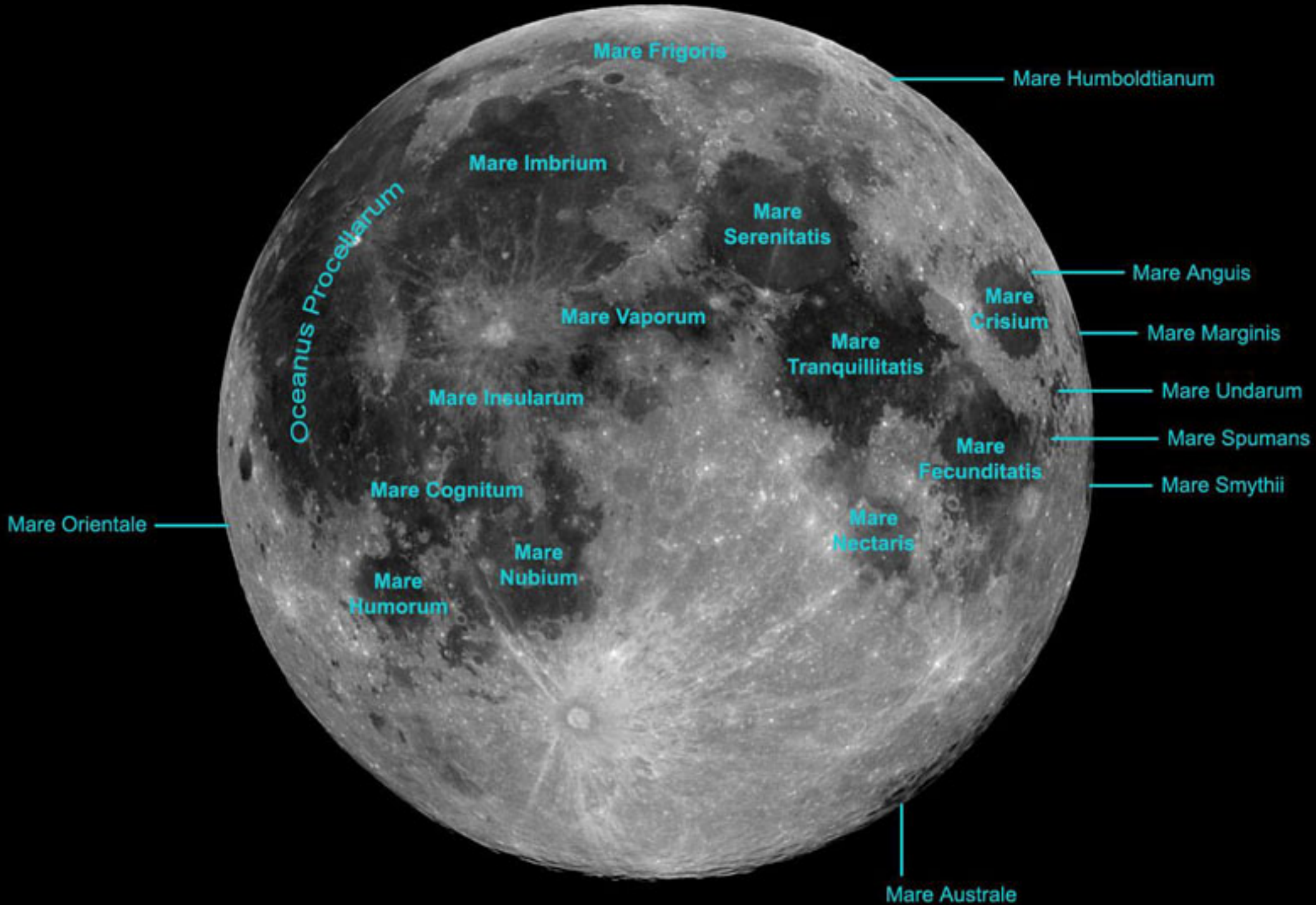


Rapid Rotation

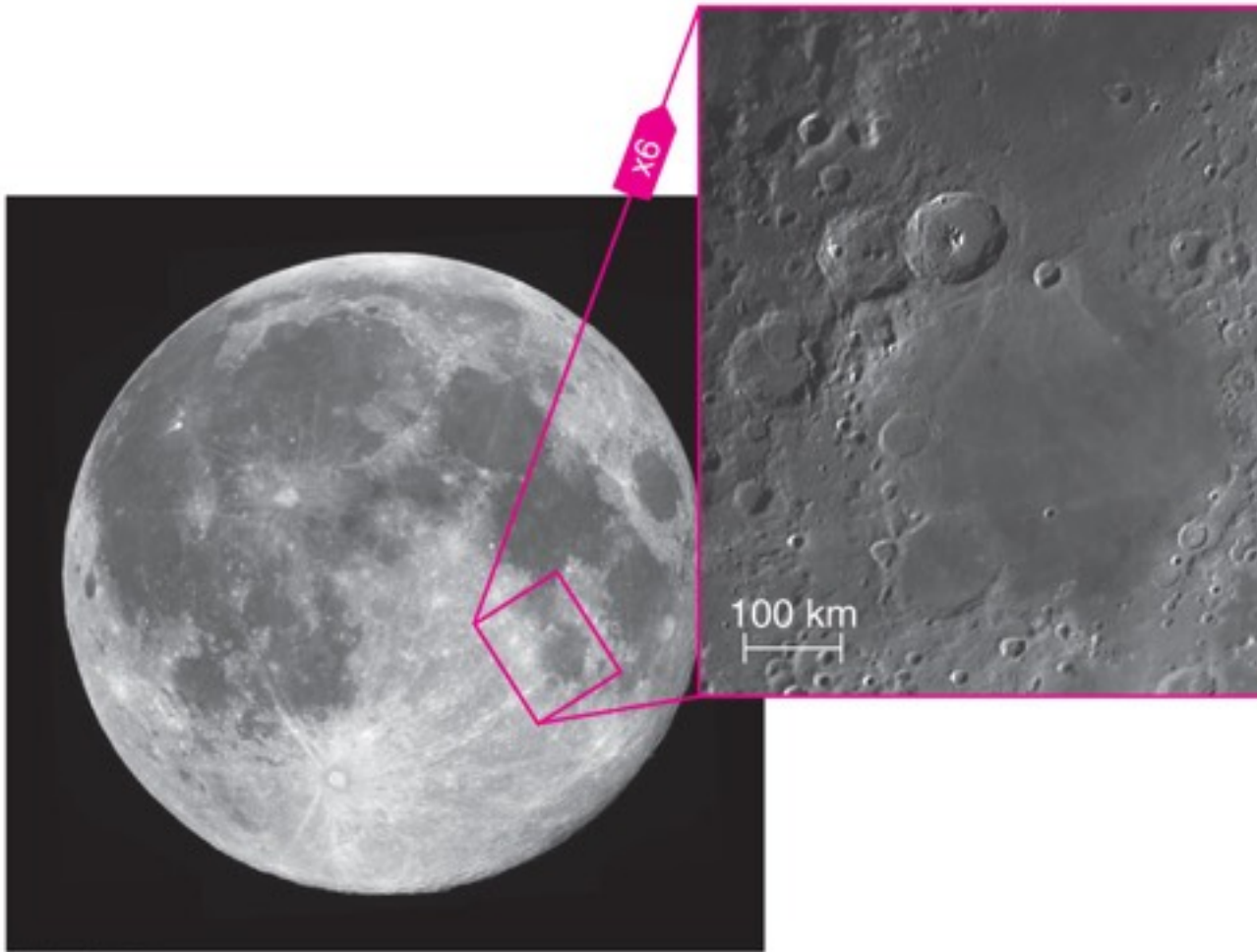


- Planets with slower rotation have less weather, less erosion, and a weak magnetic field.
- Planets with faster rotation have more weather, more erosion, and a stronger magnetic field.

What 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.

<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

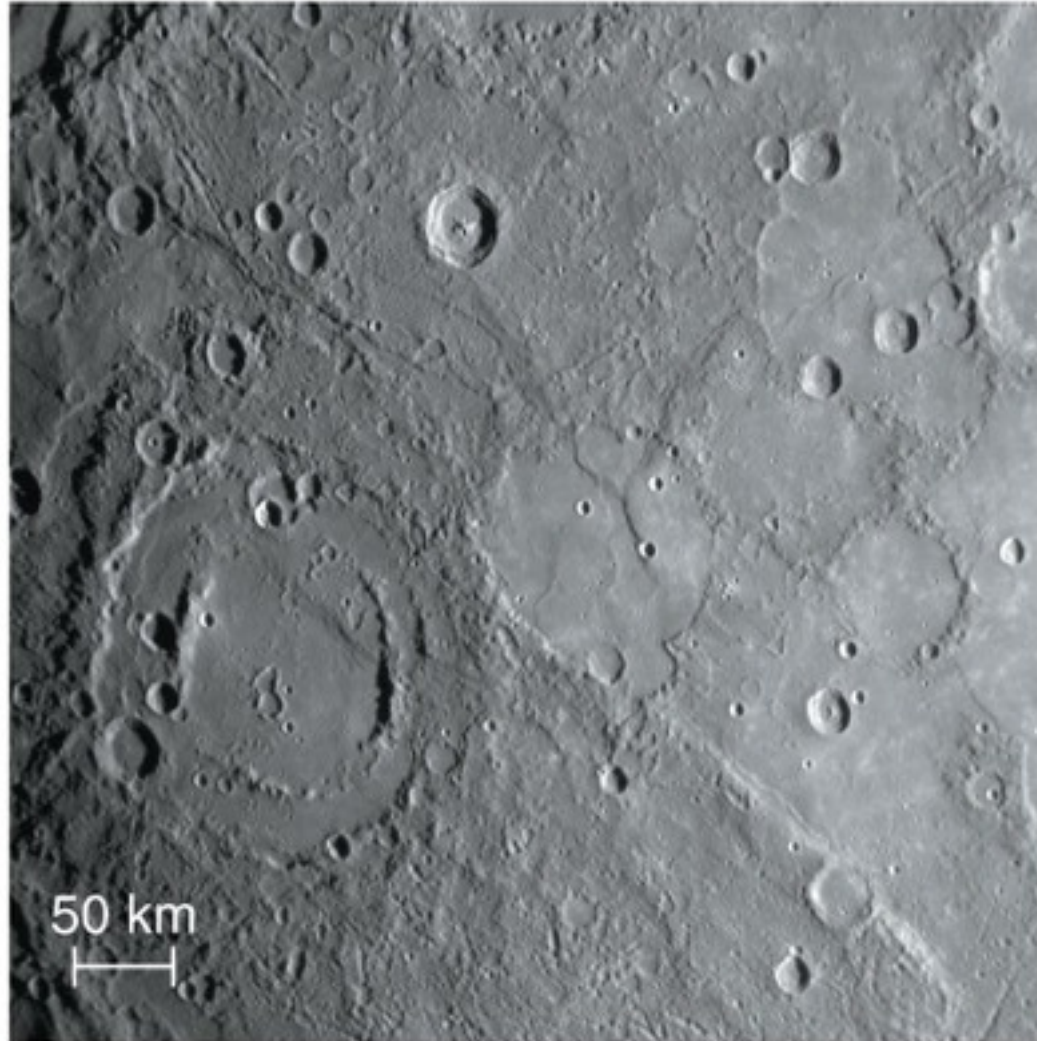
- Moon is considered geologically "dead" because geological processes have virtually stopped.
- Cooling process essentially complete
 - no more geology because there isn't any interior heat to drive it



Mercury

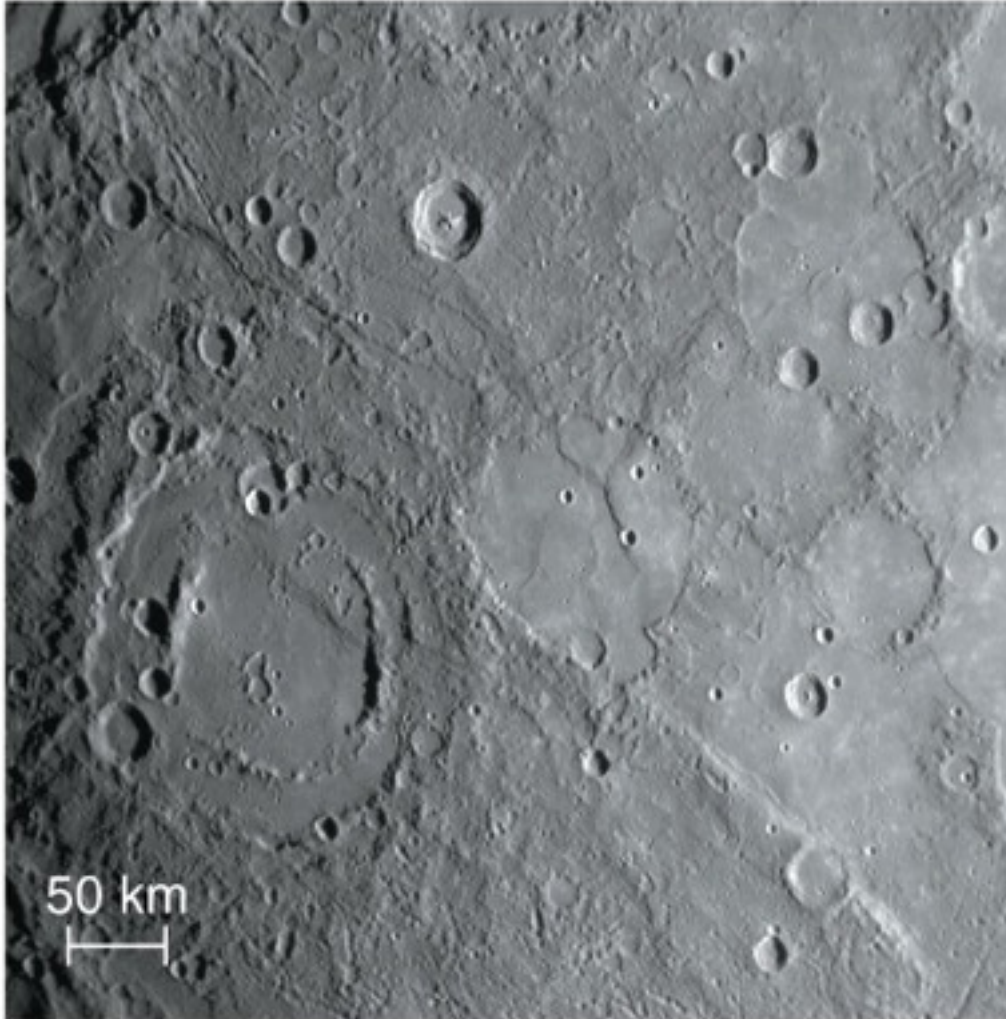


What geological processes shaped Mercury?



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.

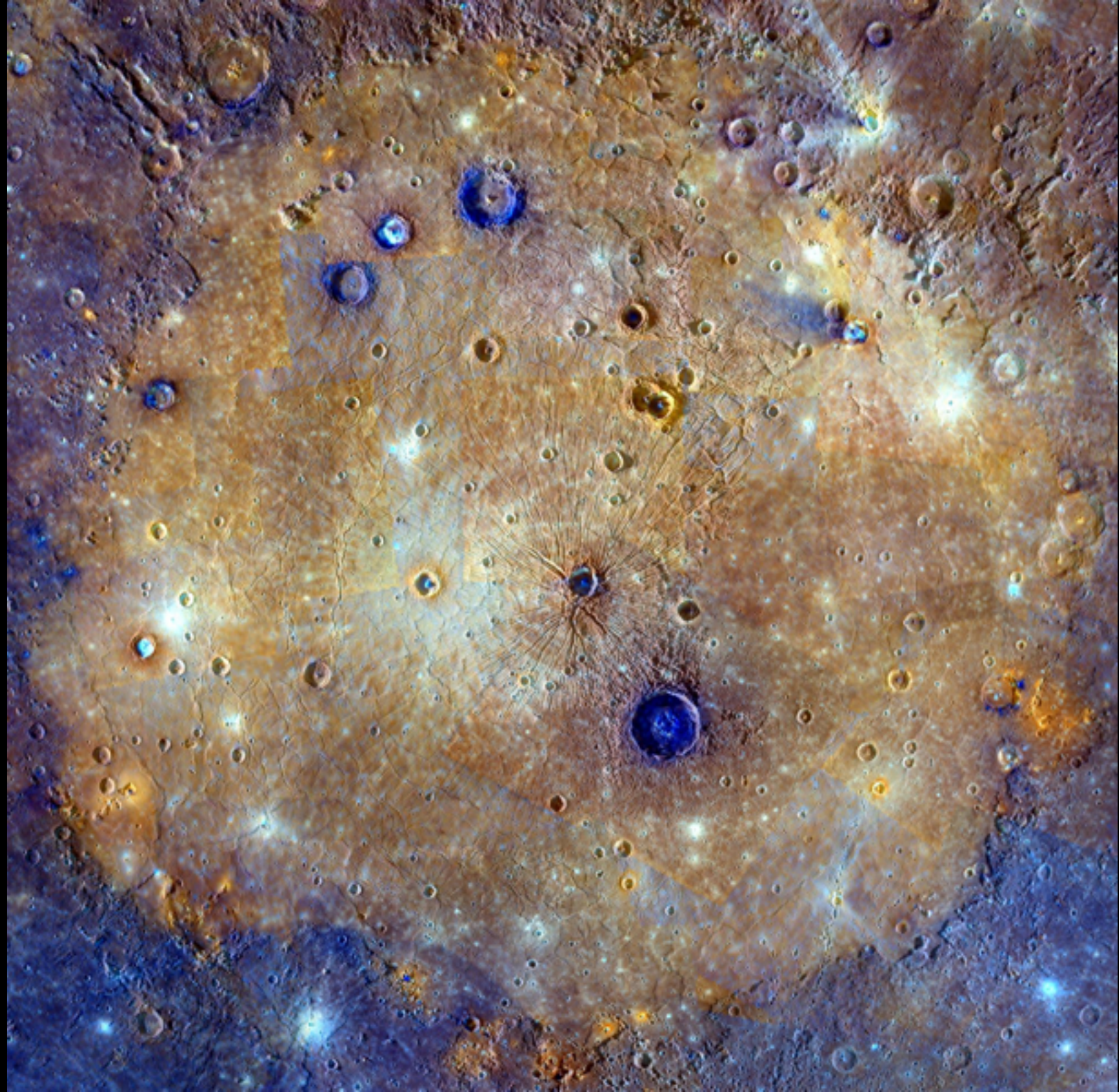
Caloris
basin

largest
crater in
Solar
system

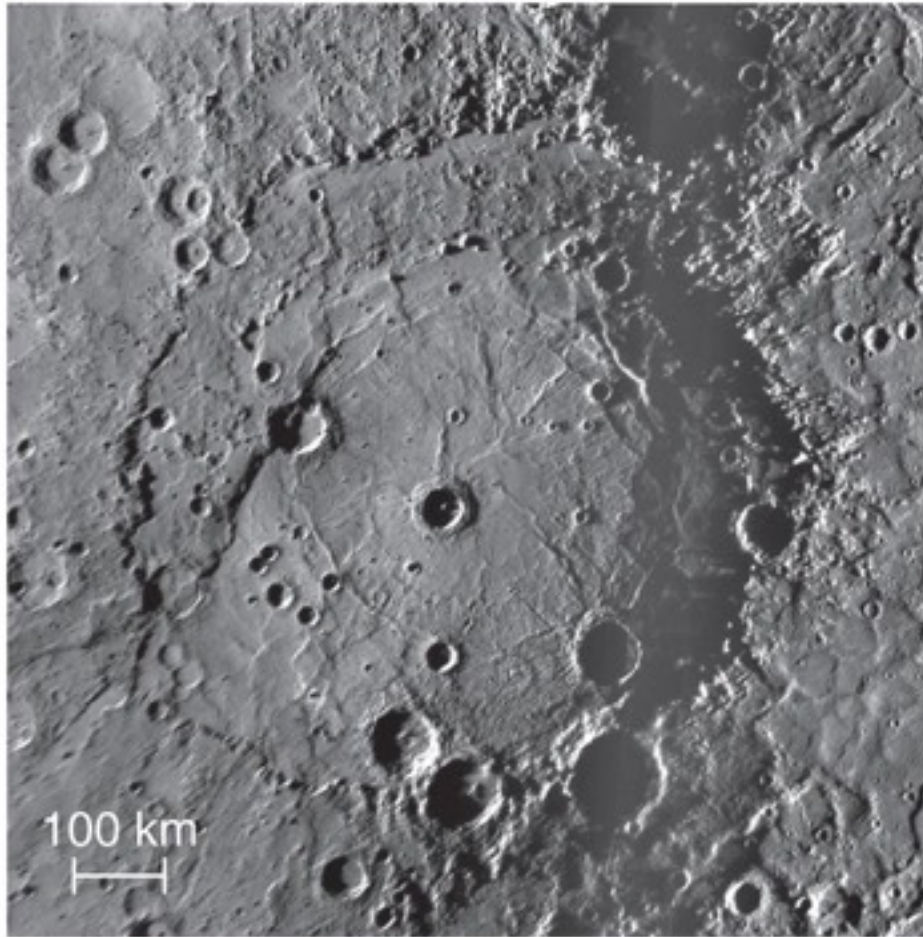
lava
(orange)

older
material
(blue)

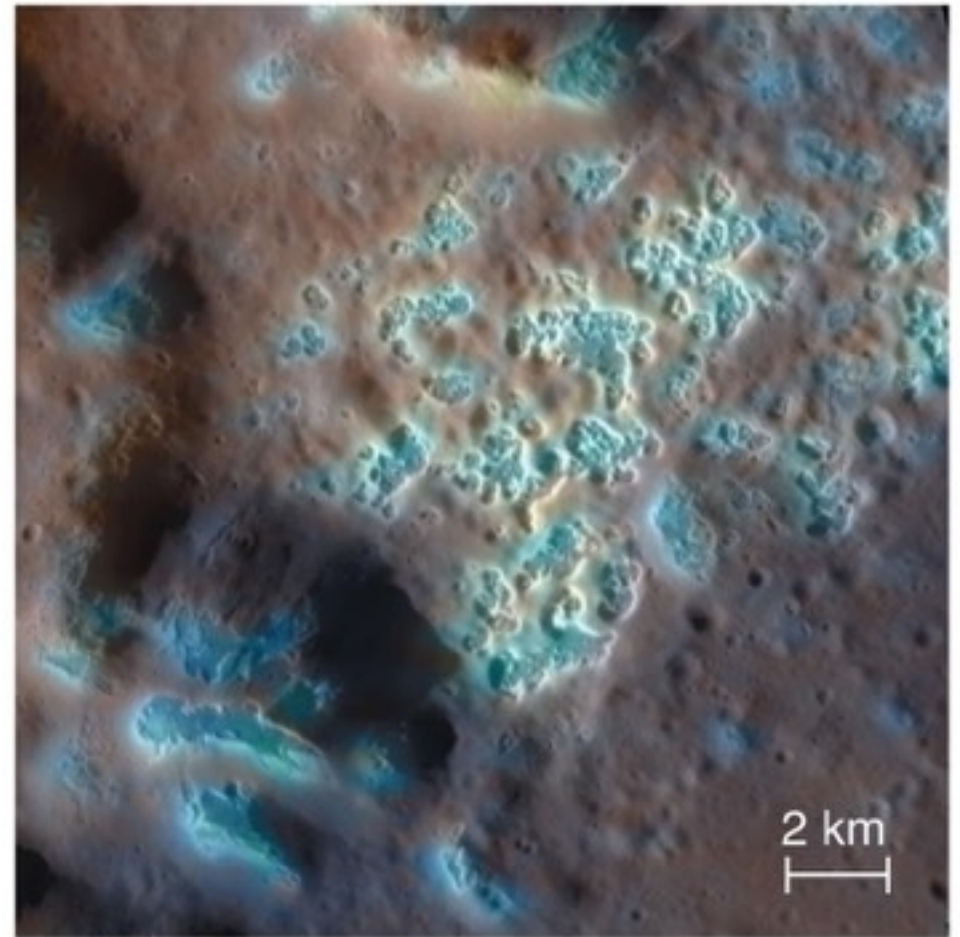
sometimes
excavated by
later impact



Cratering of Mercury



The Rembrandt Basin is a large impact crater on Mercury.



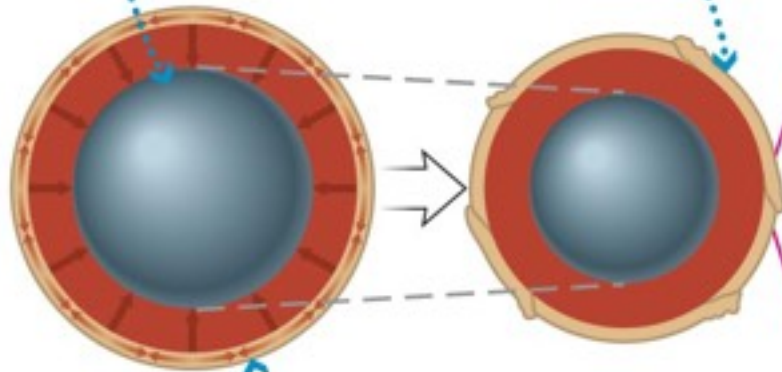
Hollows in a crater floor created by escaping gases.

Tectonics on Mercury

Scarps

Mercury's core and mantle shrank ...

Some portions of the crust were forced to slide under others.



Not to scale!

... causing Mercury's crust to contract.

Today we see long, steep cliffs created by this crustal movement.



- Long cliffs (scarps) created when Mercury shrank (about 7 km in diameter) as it cooled.

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

3,308
ORBITS

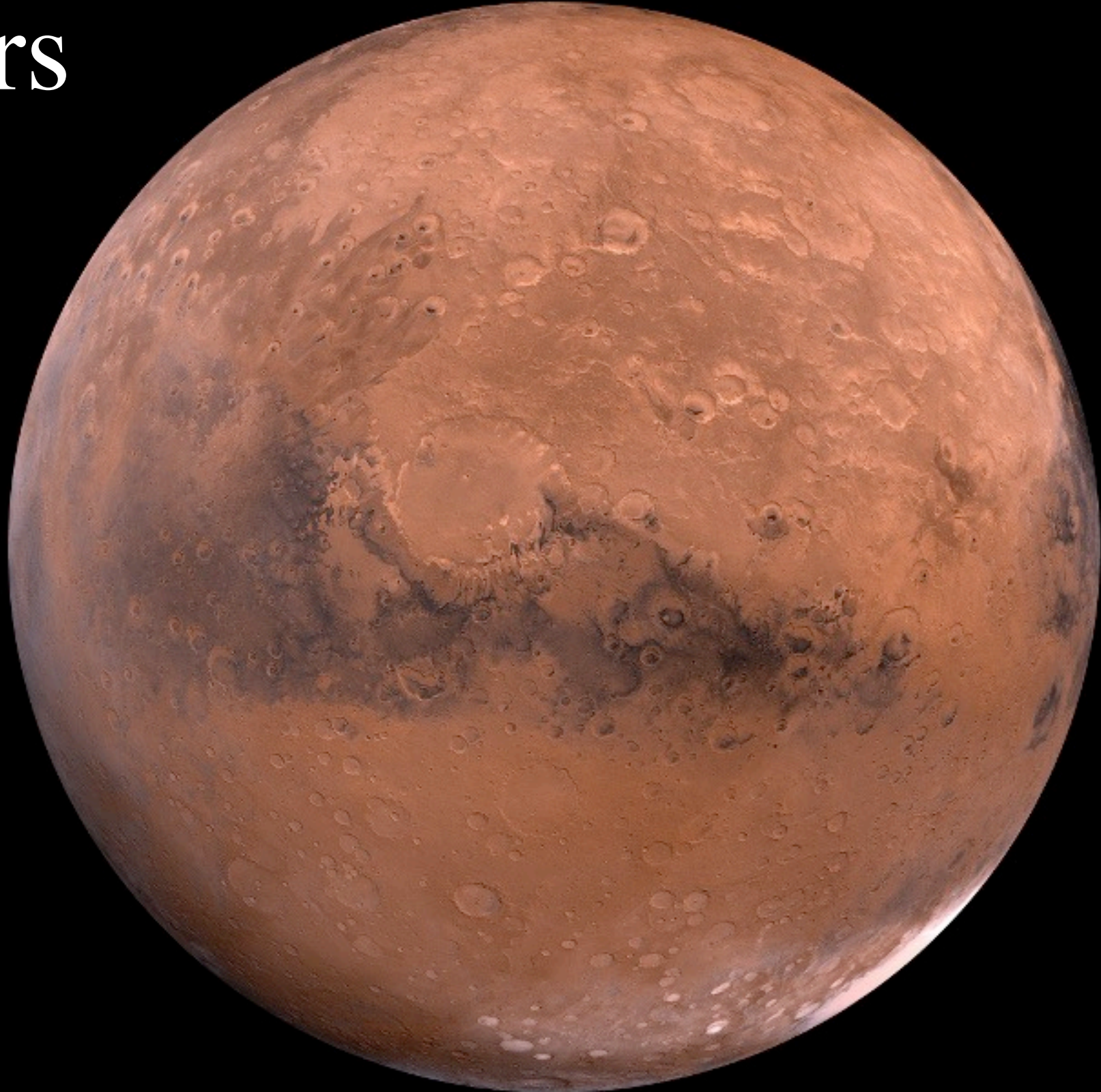


https://www.youtube.com/watch?v=yBF_0wBC_3s

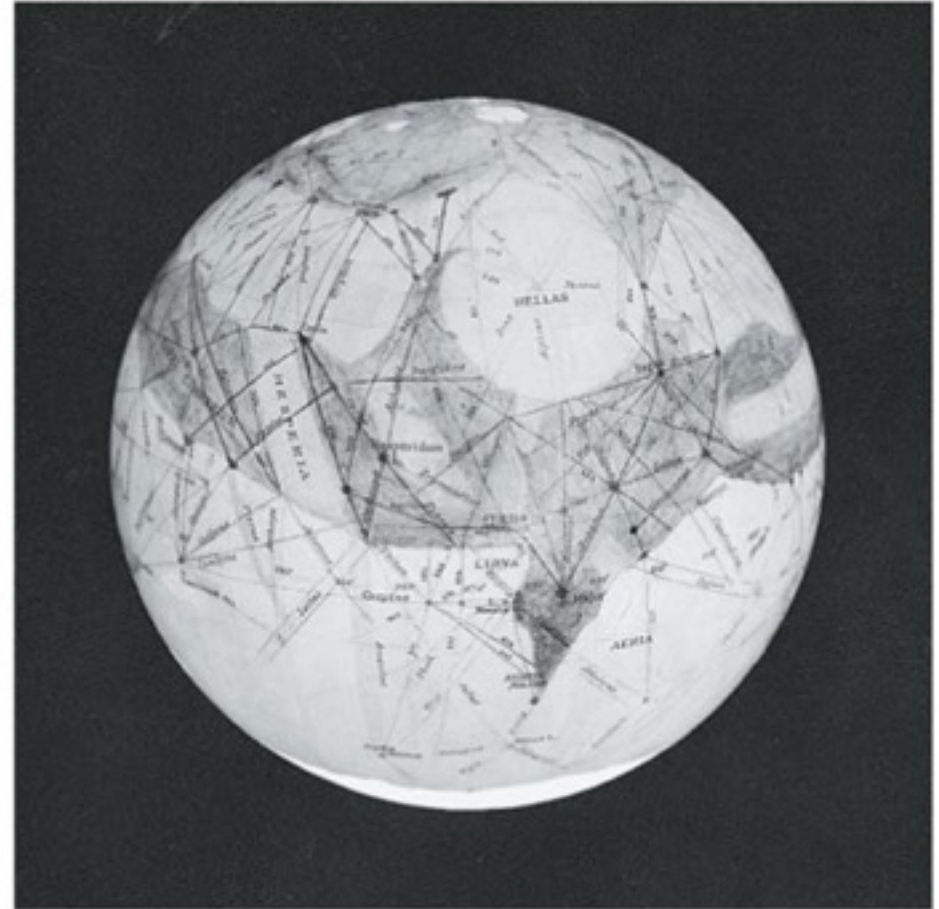
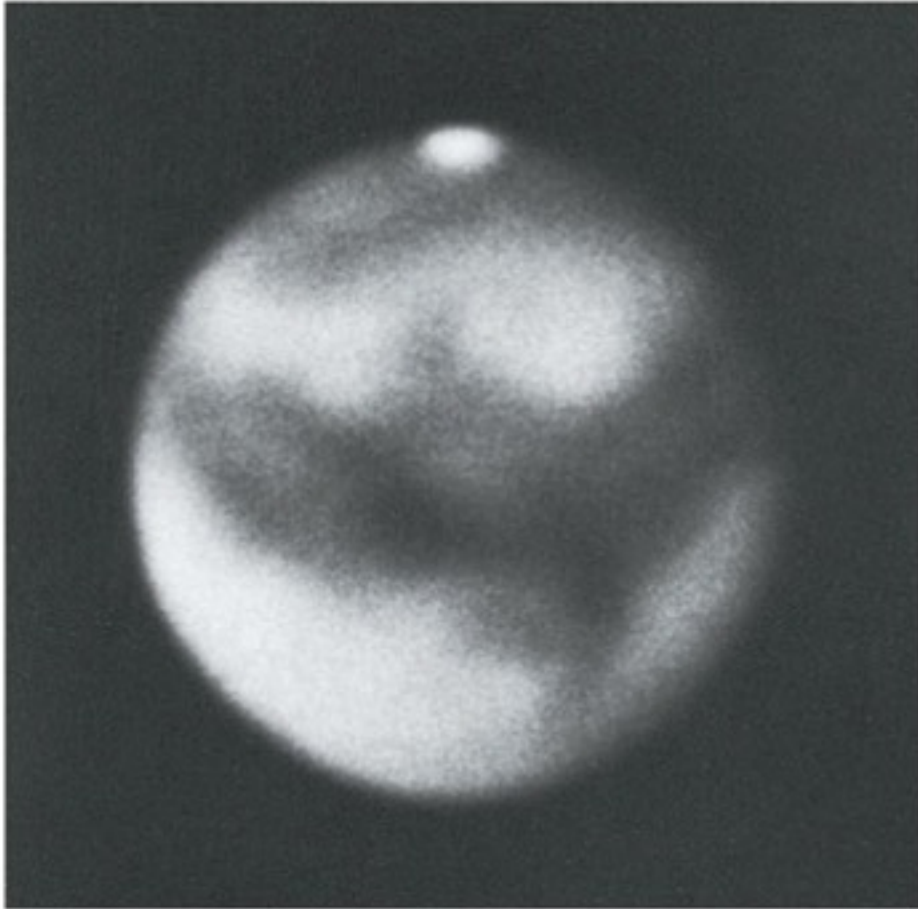
Fly over video

CRASHED 4/30/15

Mars

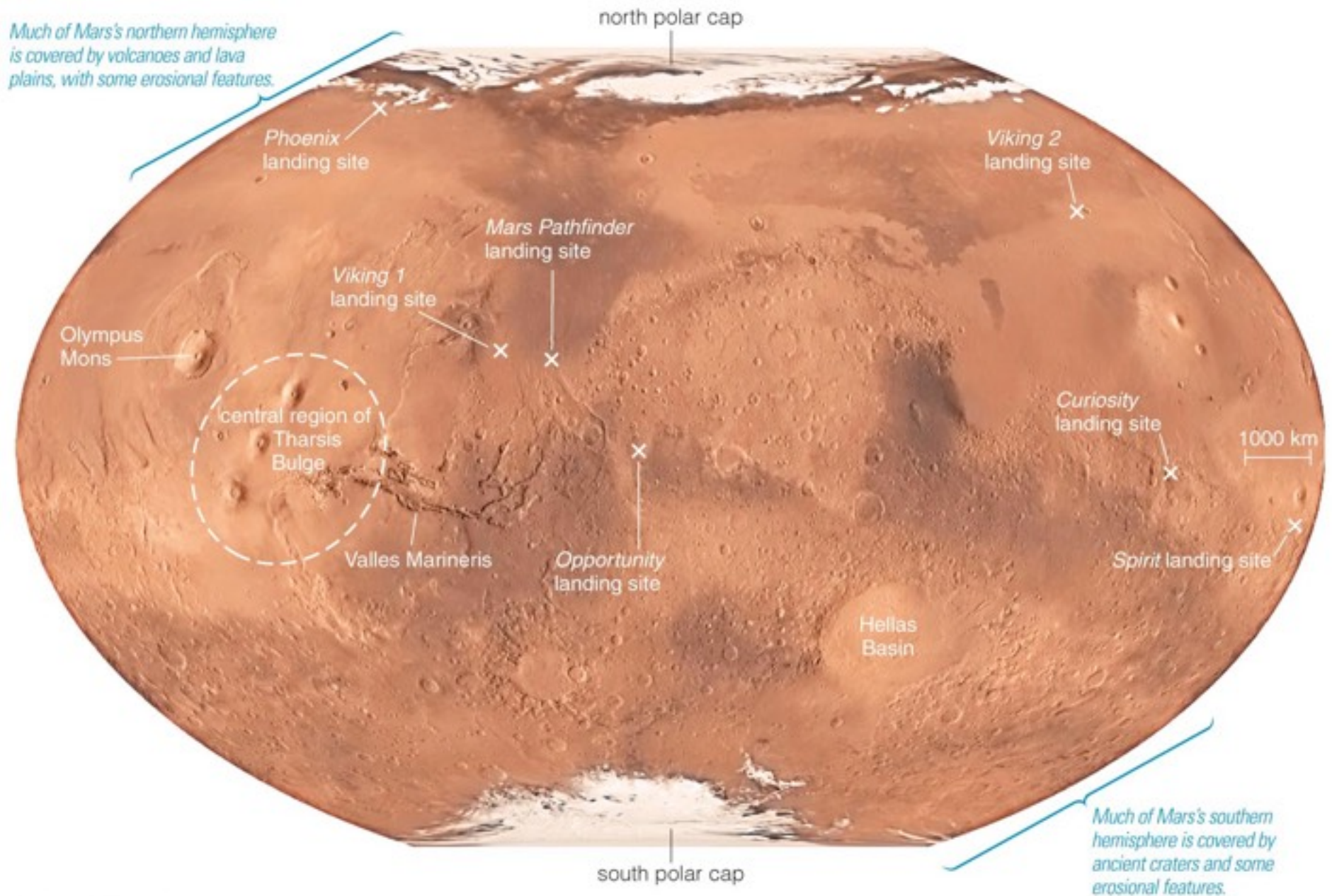


"Canals" on Mars

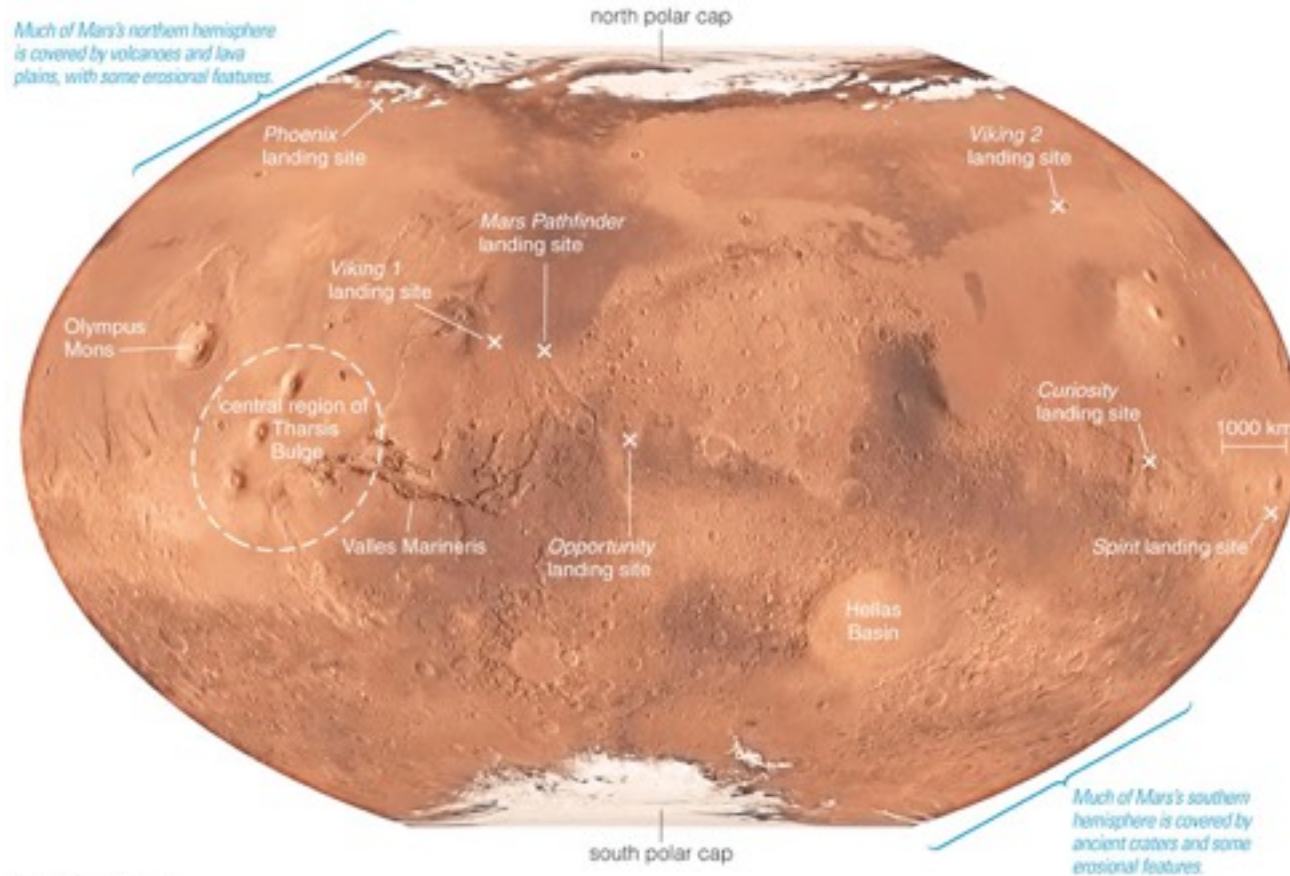


- Percival Lowell misinterpreted surface features seen in telescopic images of Mars.

What geological processes have shaped Mars?



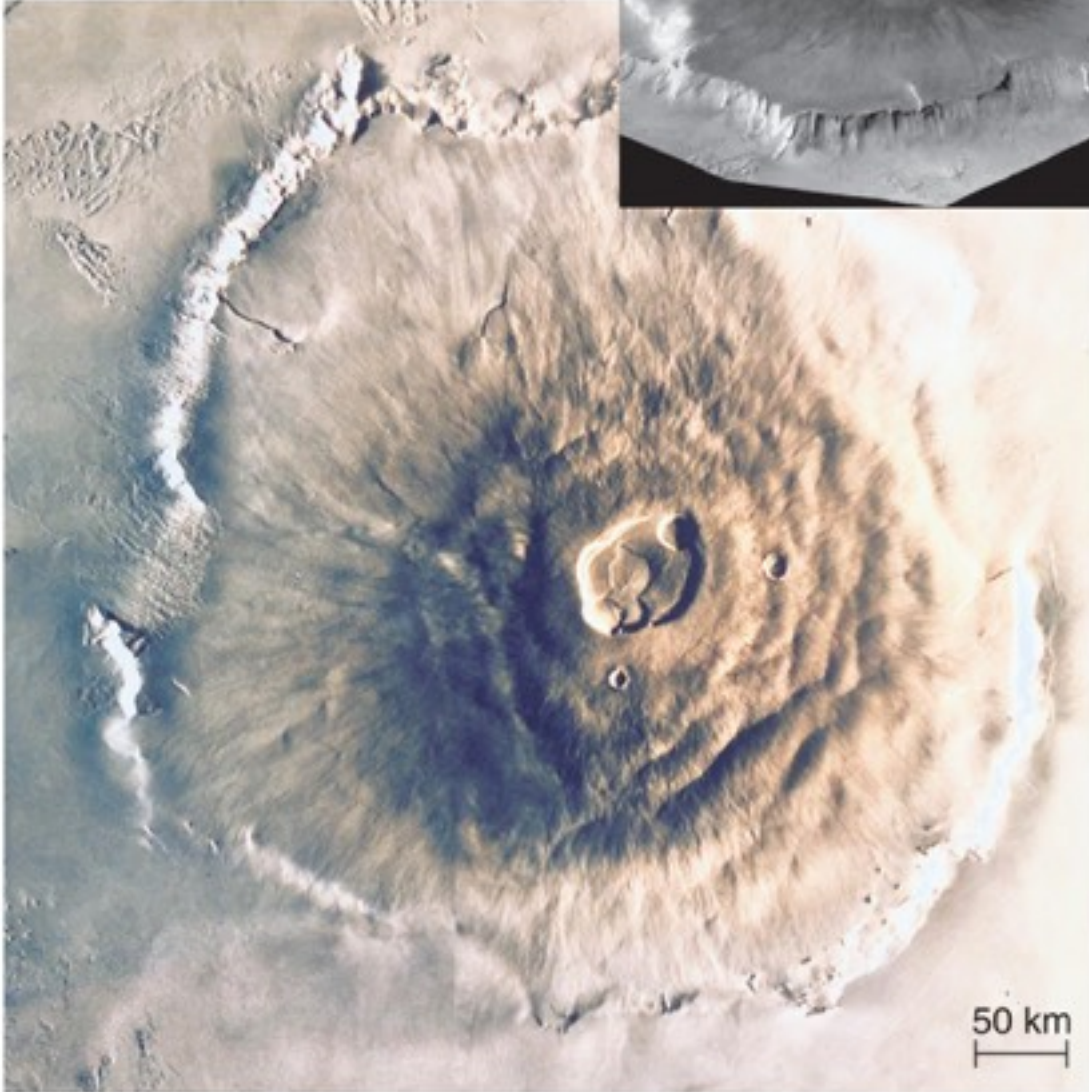
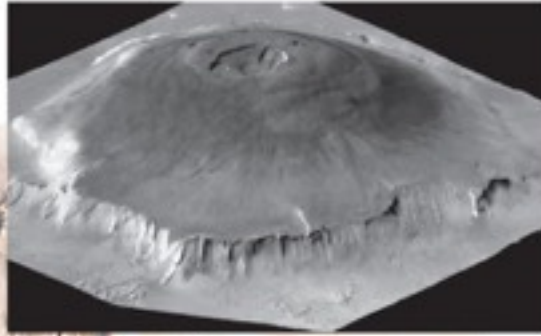
Cratering on Mars



Interactive Figure

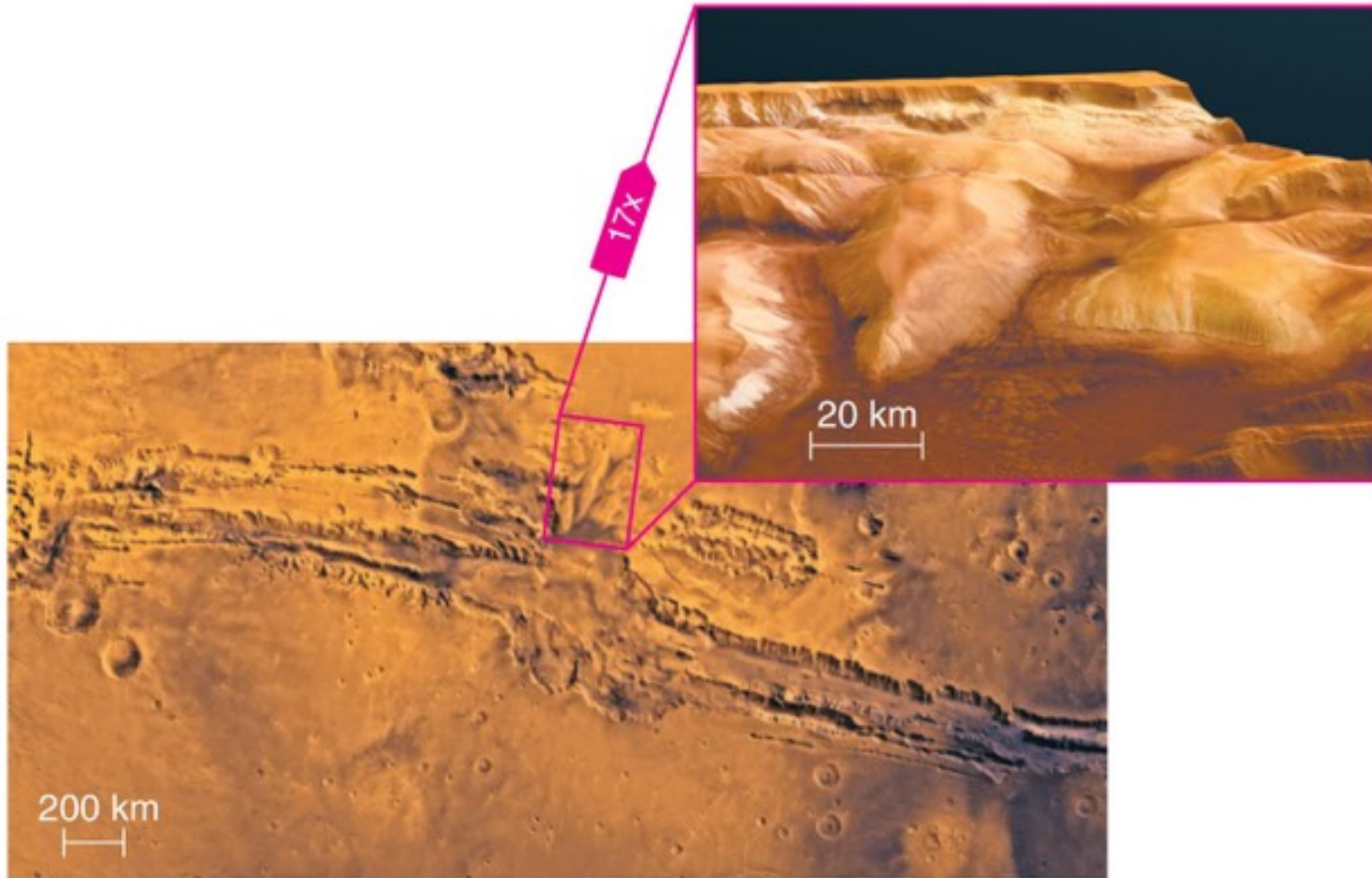
- The amount of cratering differs greatly across Mars's surface.
- Many early craters have been erased.

Volcanism on Mars



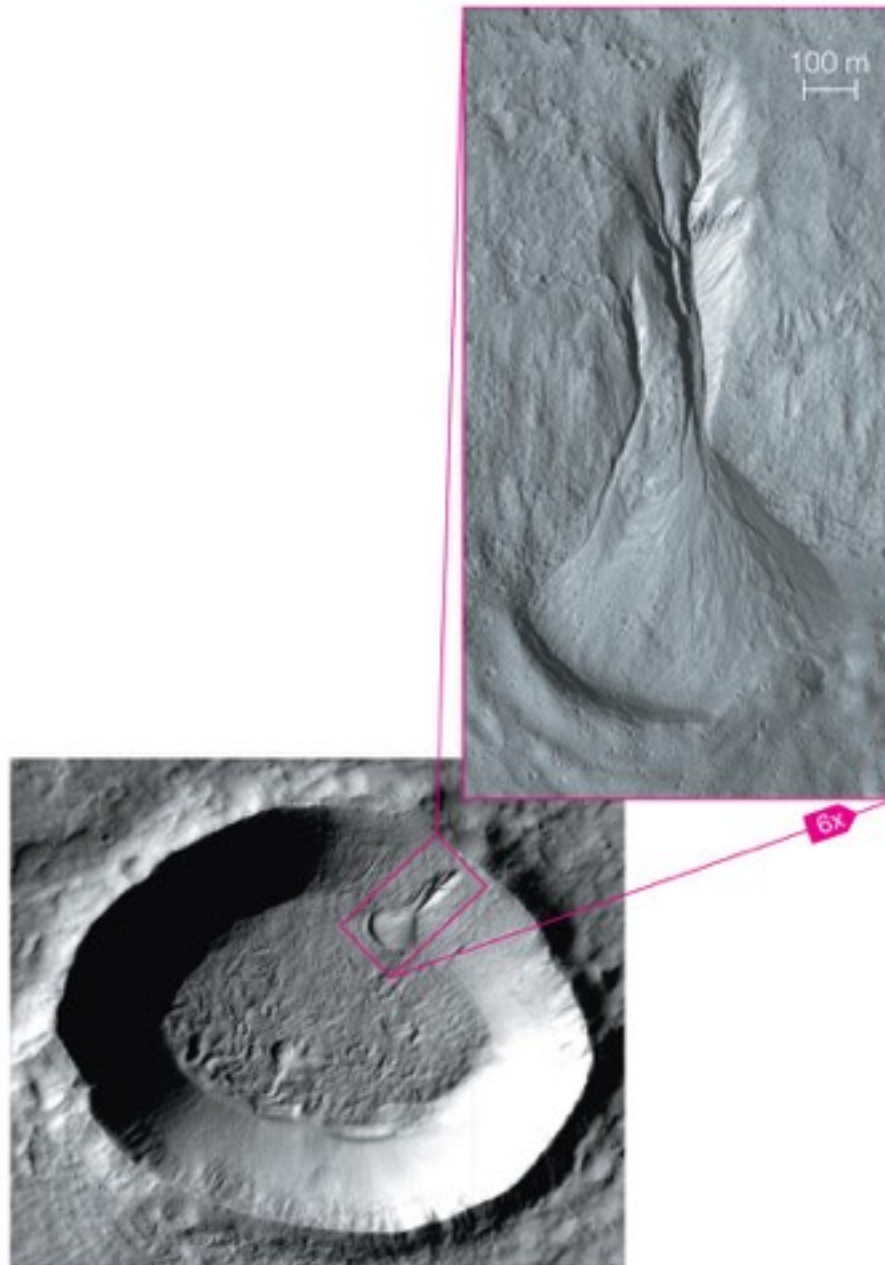
- Mars has many large shield volcanoes.
- Olympus Mons is largest volcano in solar system.

Tectonics on Mars

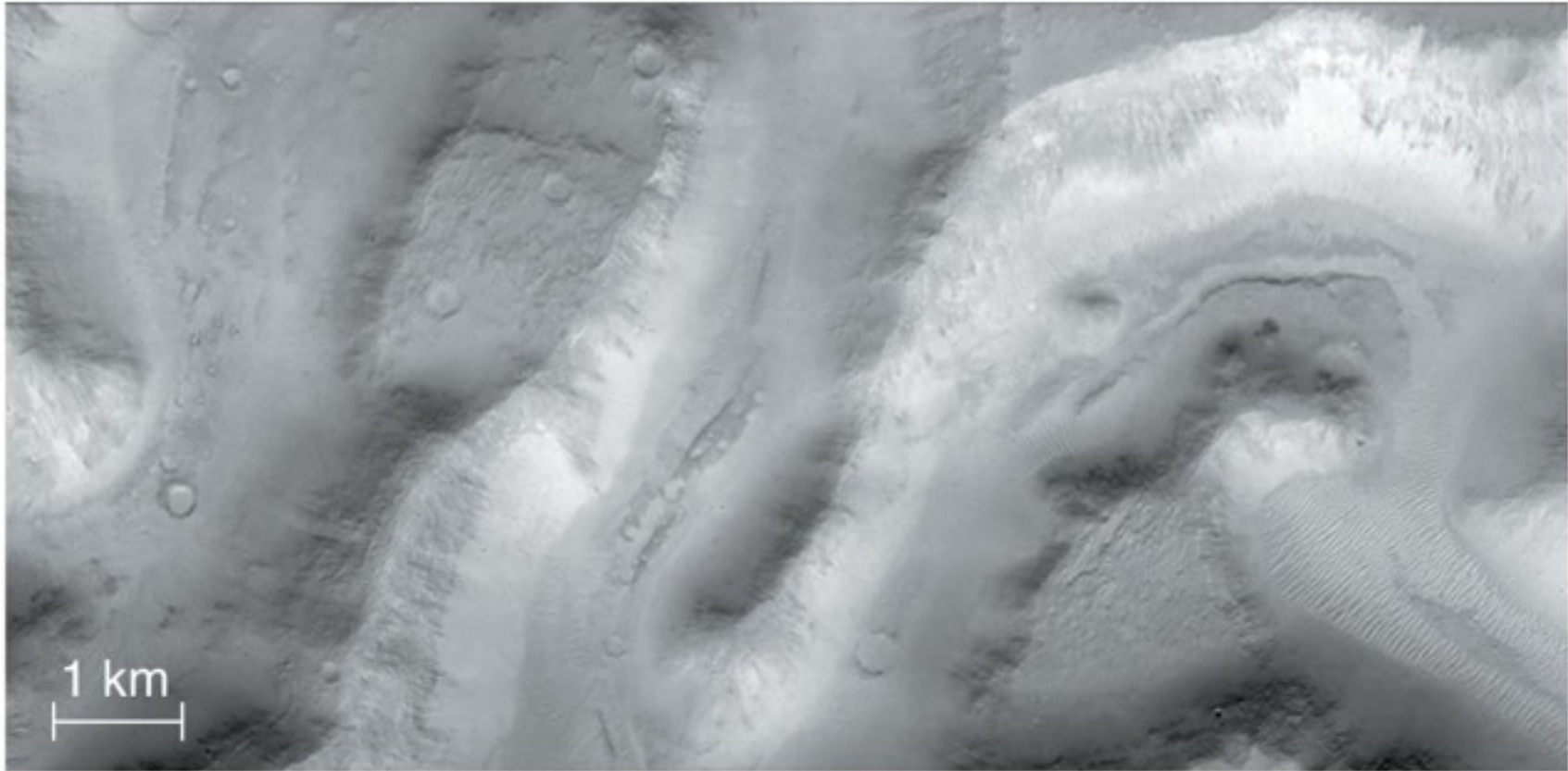


- The system of valleys known as Valles Marineris is thought to originate from tectonics.

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



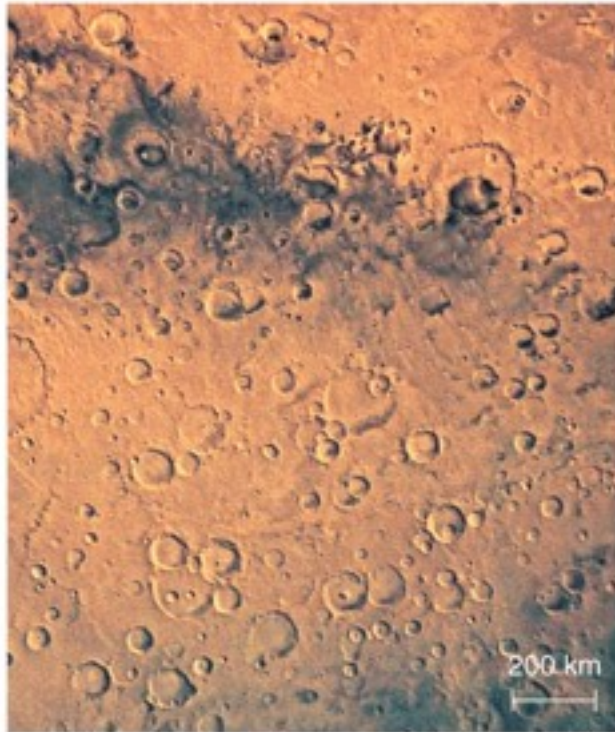
Dry Riverbeds?



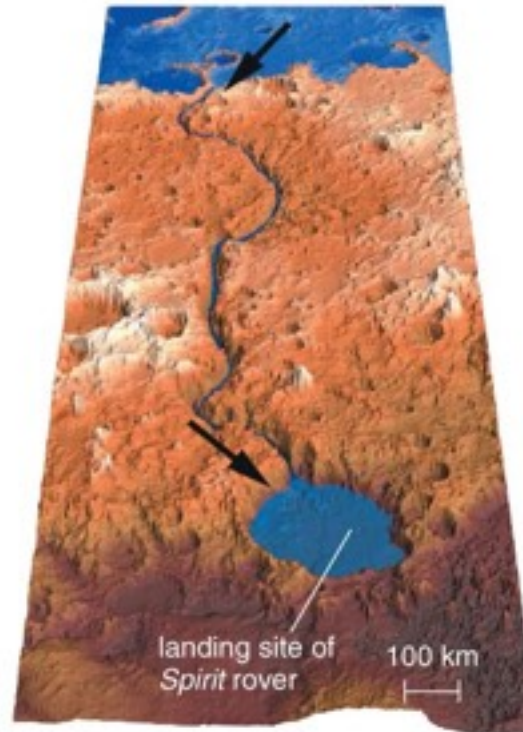
- Close-up photos of Mars show what appear to be dried-up riverbeds.

Erosion of Craters

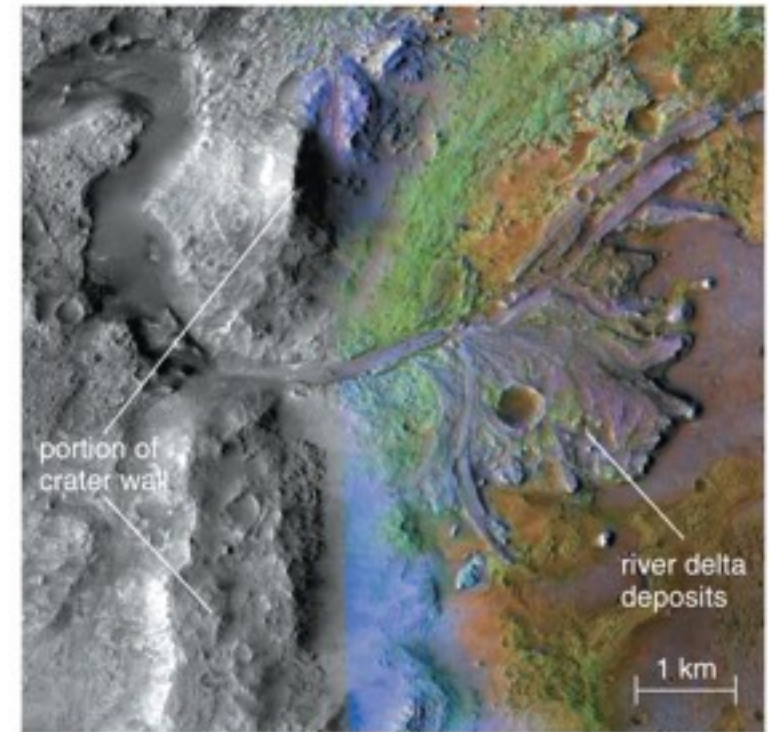
- Details of some craters suggest they were once filled with water.



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.

Spirit & Opportunity (2004) Rovers photoshopped together for scale Curiosity (2012)

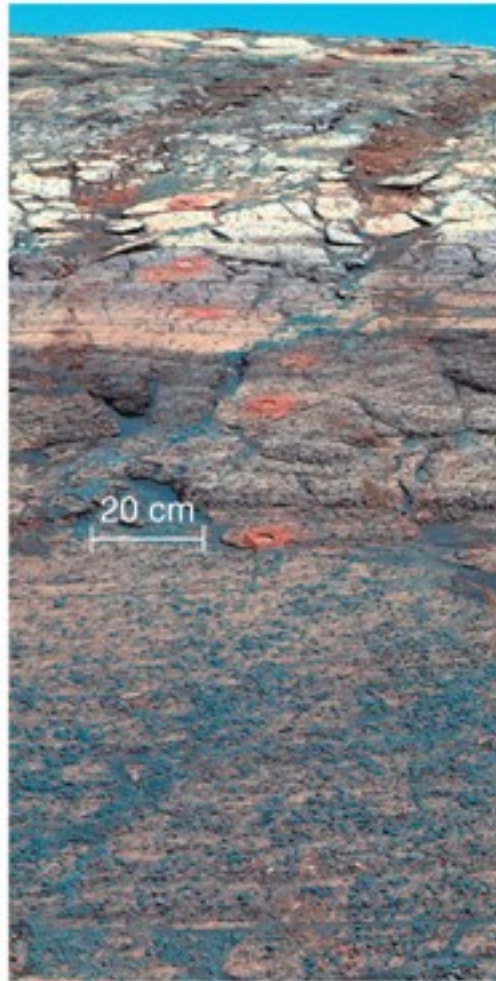


Pathfinder (1997)

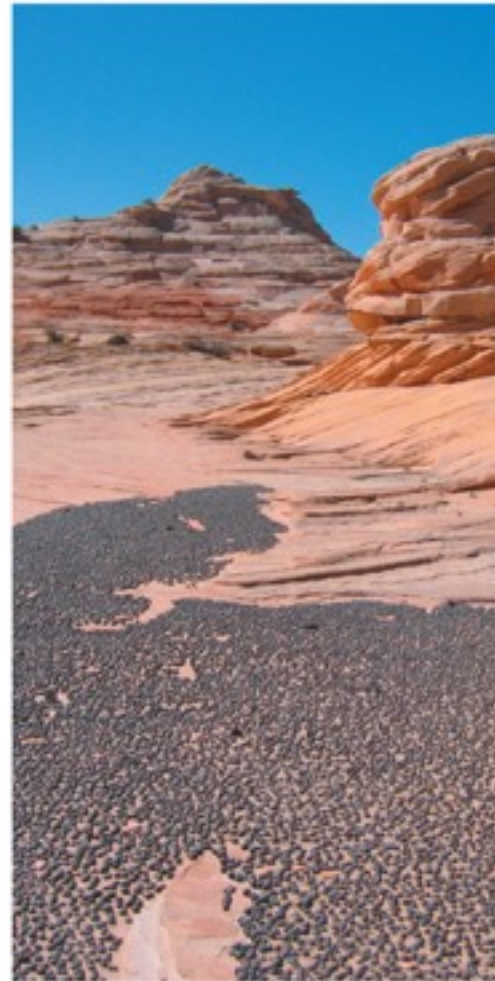
Pathfinder landing video



Martian Rocks



Mars (Endurance Crater)



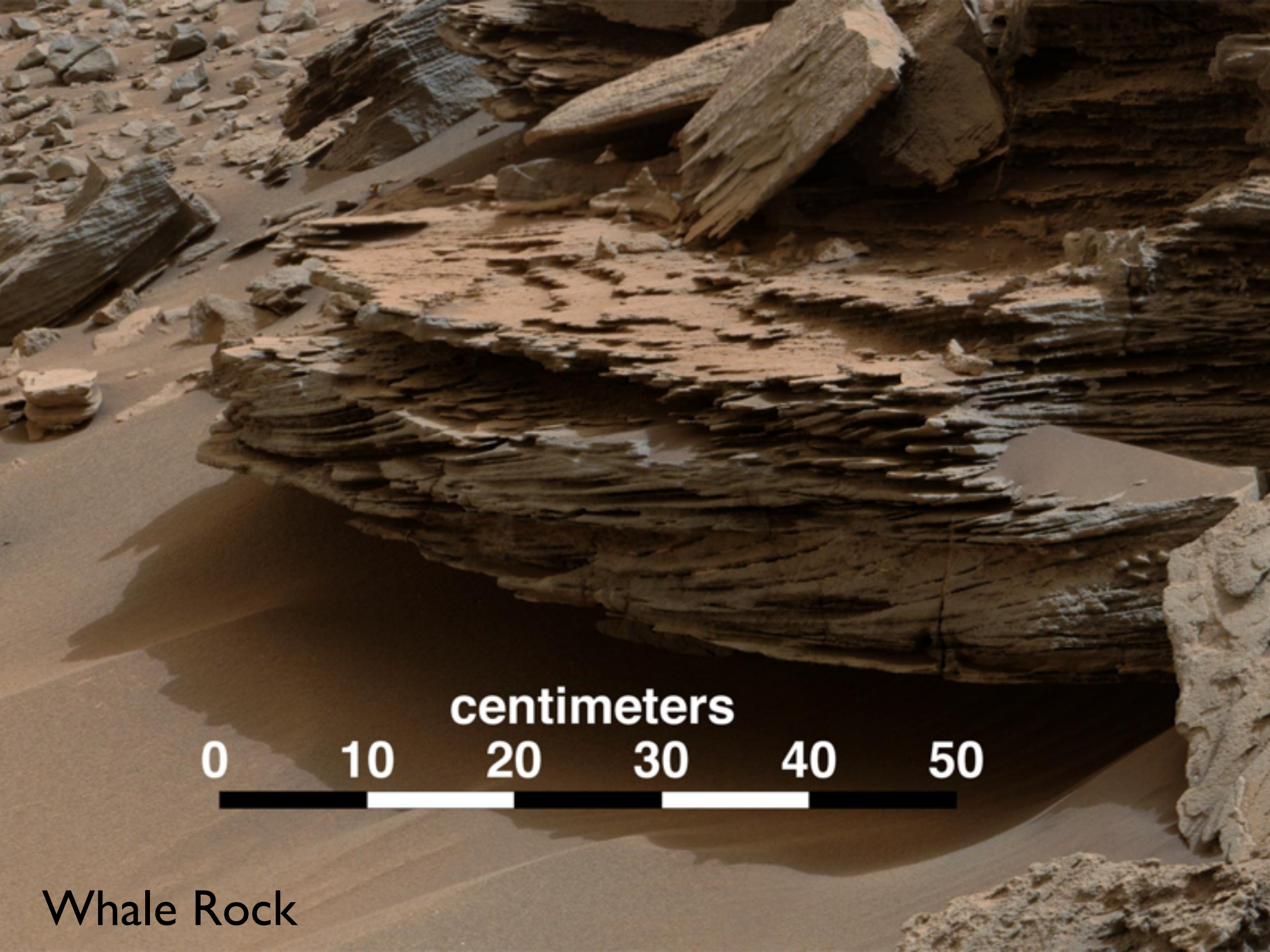
Earth (Utah)

- 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.



centimeters

0

10

20

30

40

50

Whale Rock

Hydrogen Content

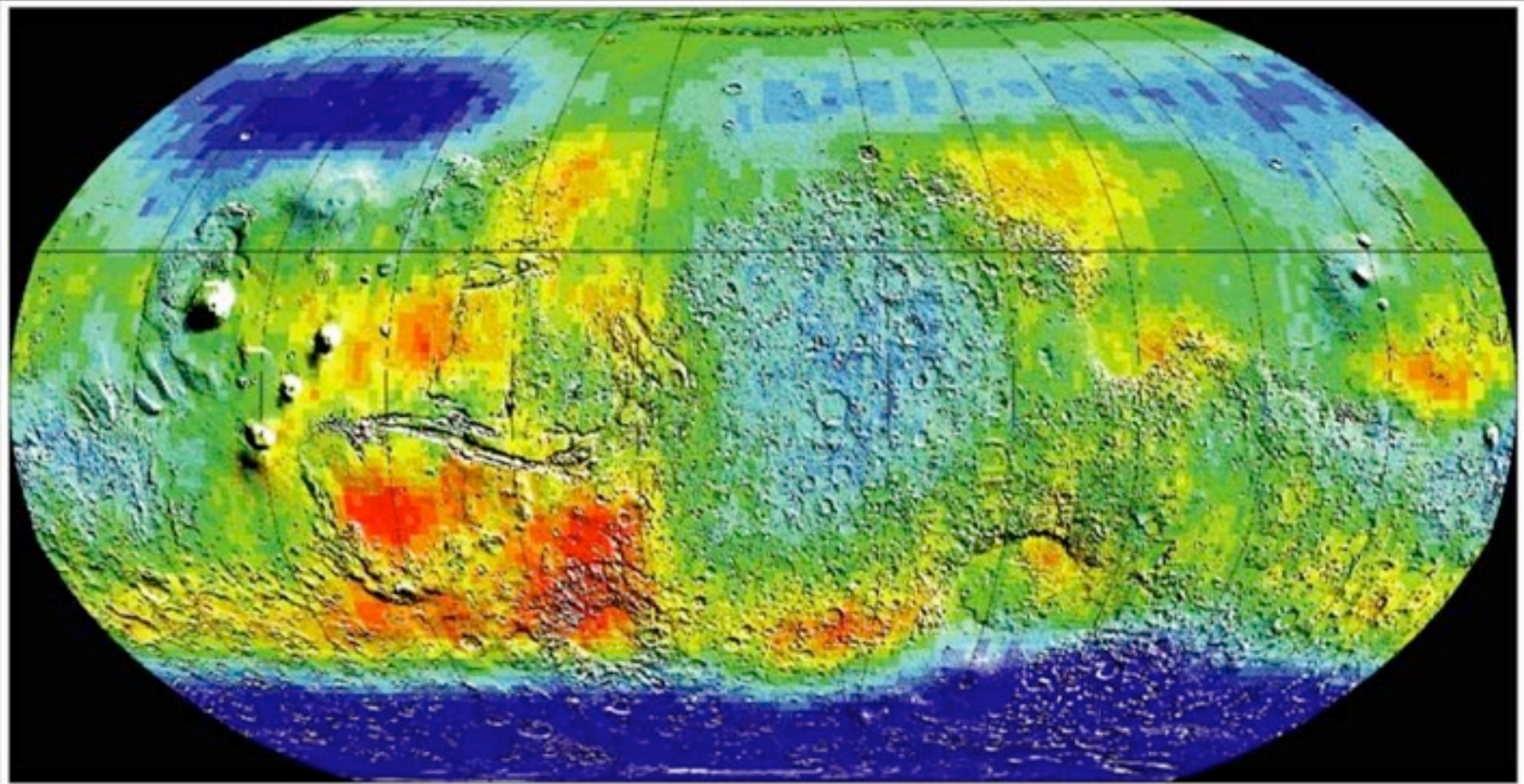
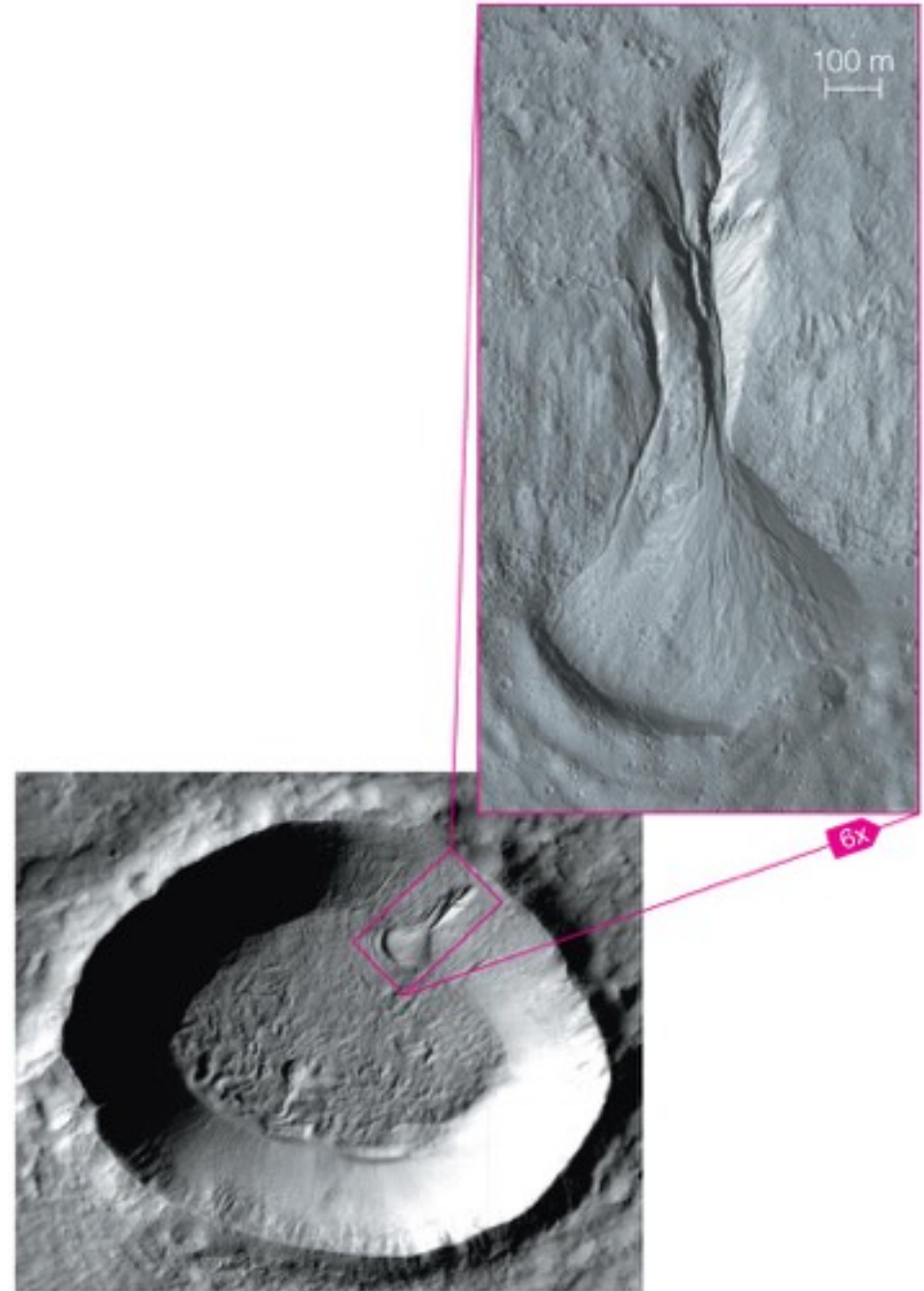


Image Credit: NASA/JPL

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

Crater Walls

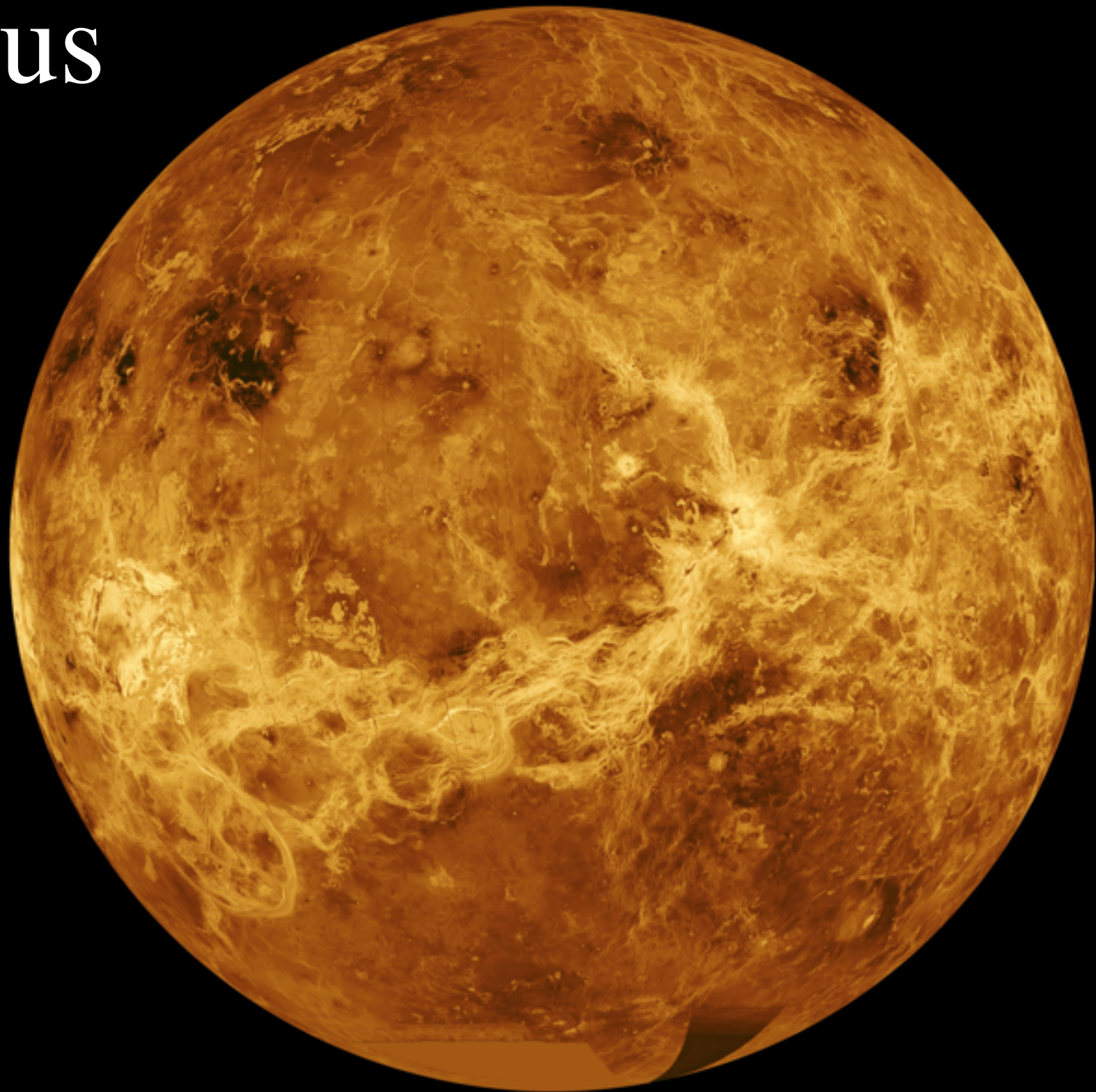
- Gullies on crater walls suggest occasional liquid water flows have happened less than a million years ago.
- or, like, now



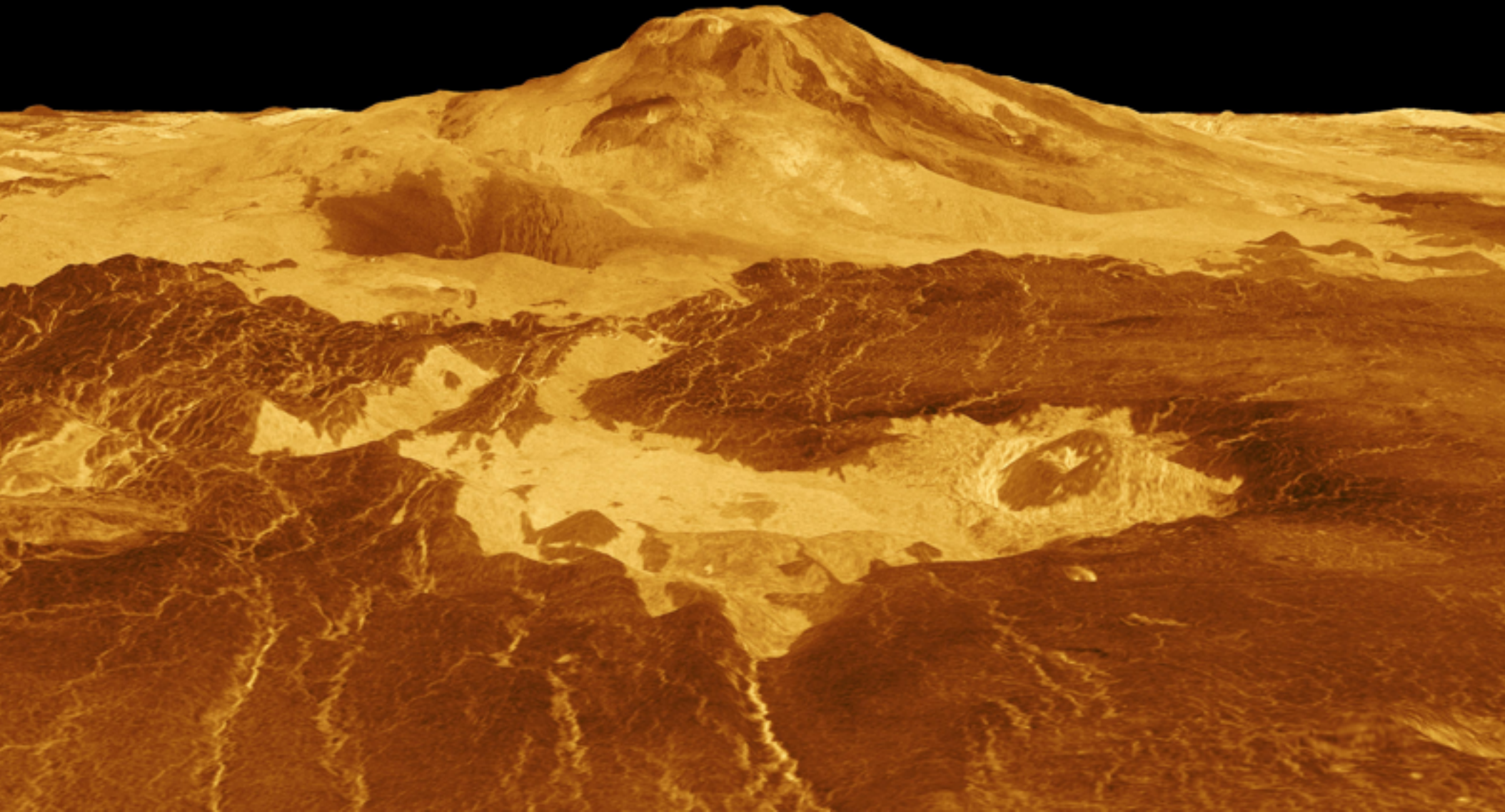


- Major geological features of Mars
 - Differences in cratering across surface
 - Giant shield volcanoes
 - Evidence of tectonic activity
- Evidence that water once flowed on Mars
 - Some surface features look like dry riverbeds.
 - Some craters appear to be eroded.
 - Rovers have found rocks composed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

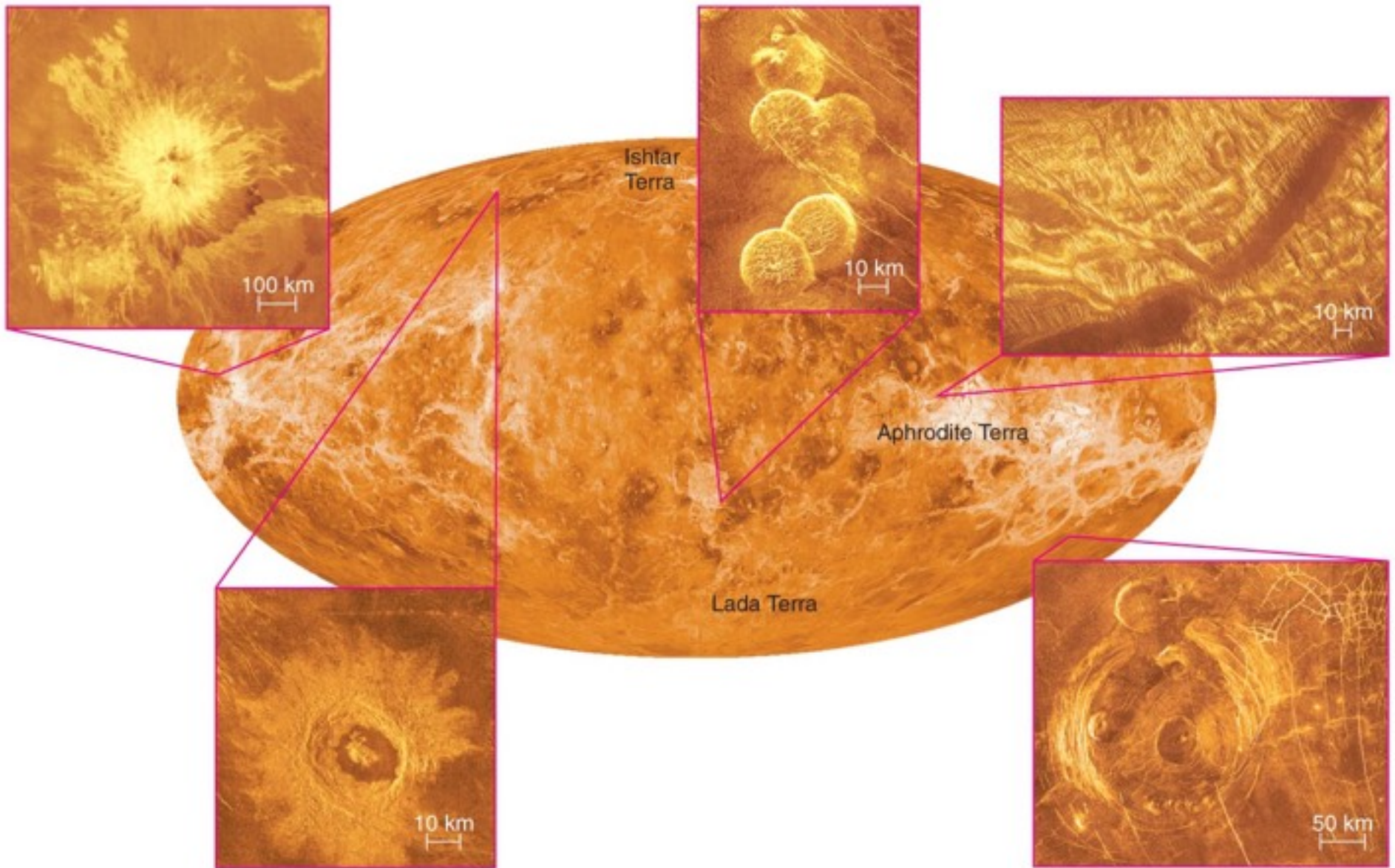
Venus



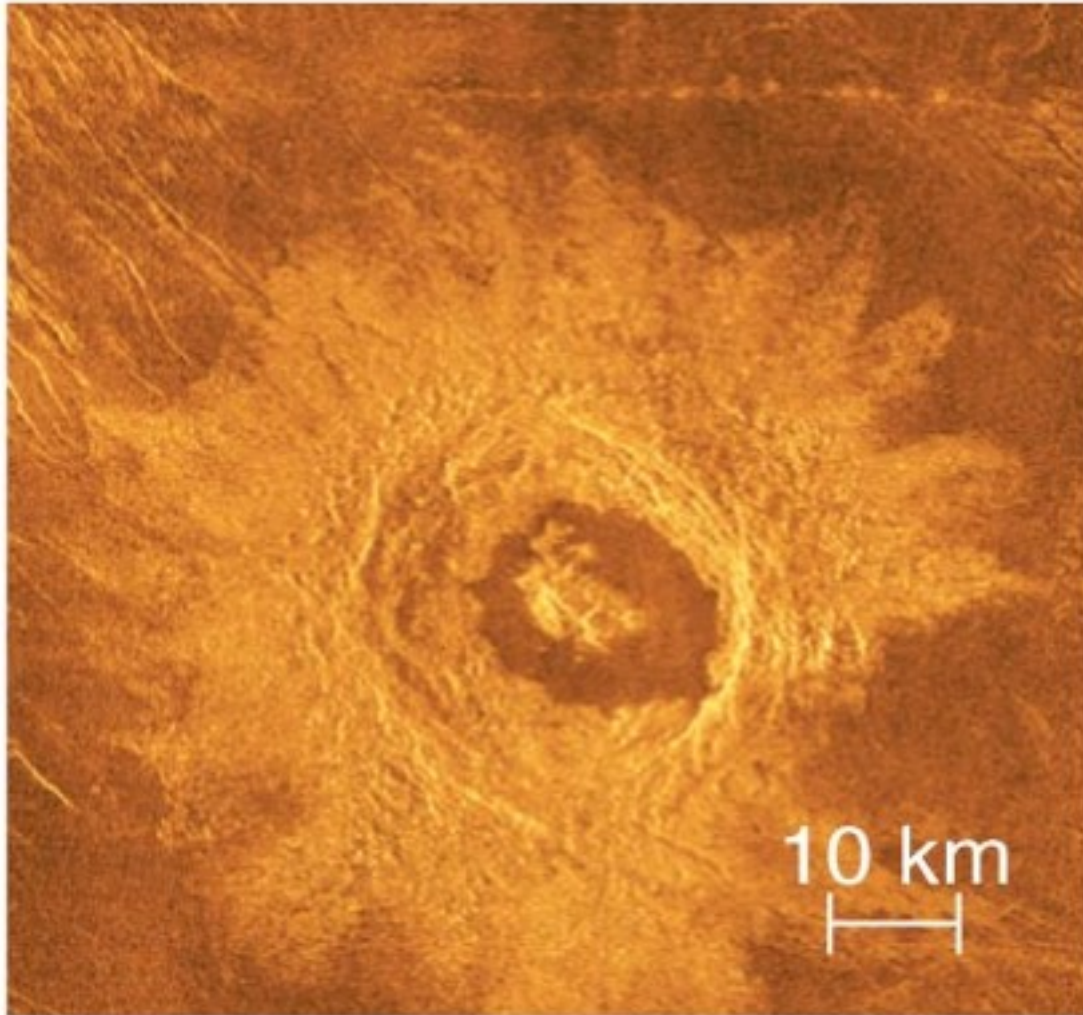
- Surface mapped by radar to penetrate thick clouds
- Magellan orbiter (1990 - 1994)
 - burned up in atmosphere



What geological processes have shaped Venus?

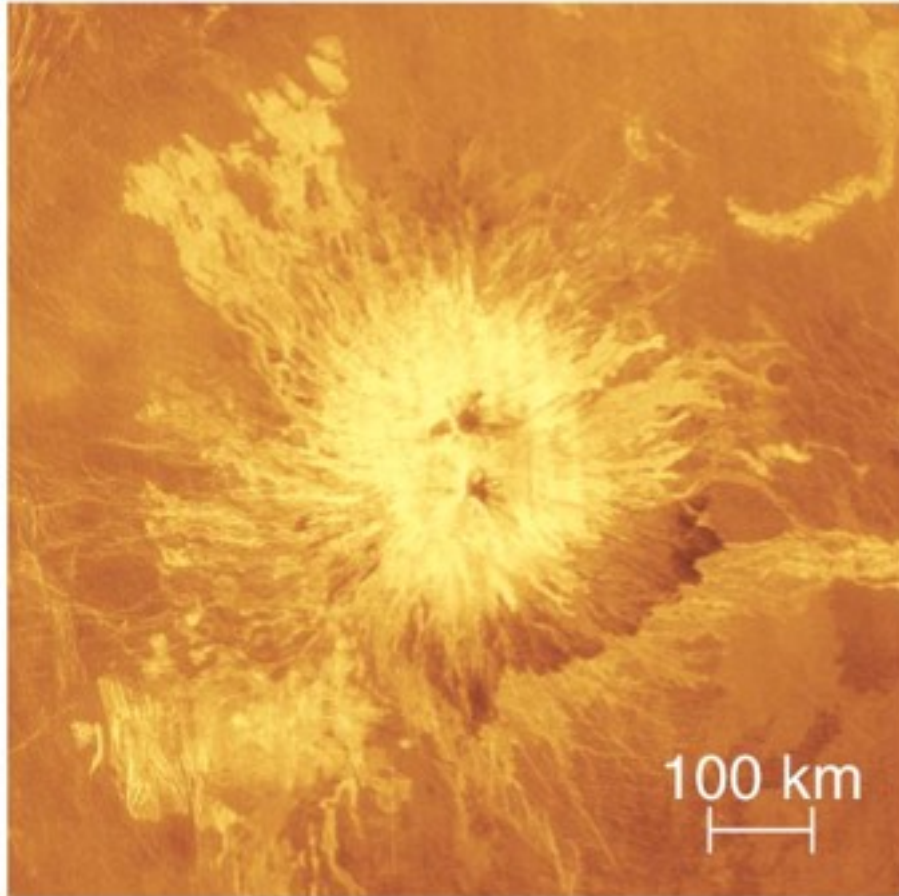


Cratering on Venus

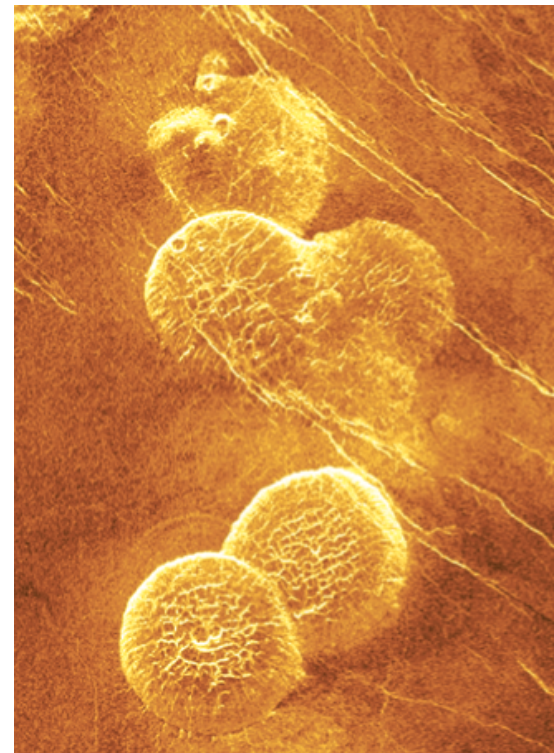


- Venus has impact craters, but fewer than the Moon, Mercury, or Mars.
- Mostly large craters
 - shielded from small impactors by thick atmosphere

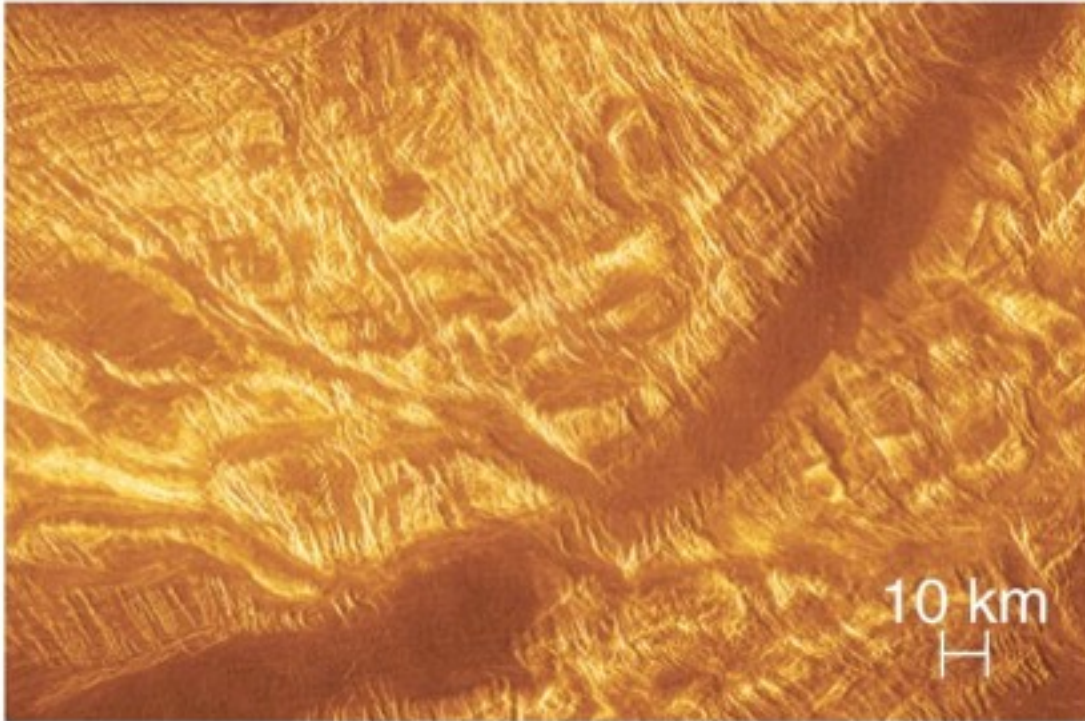
Volcanoes on Venus



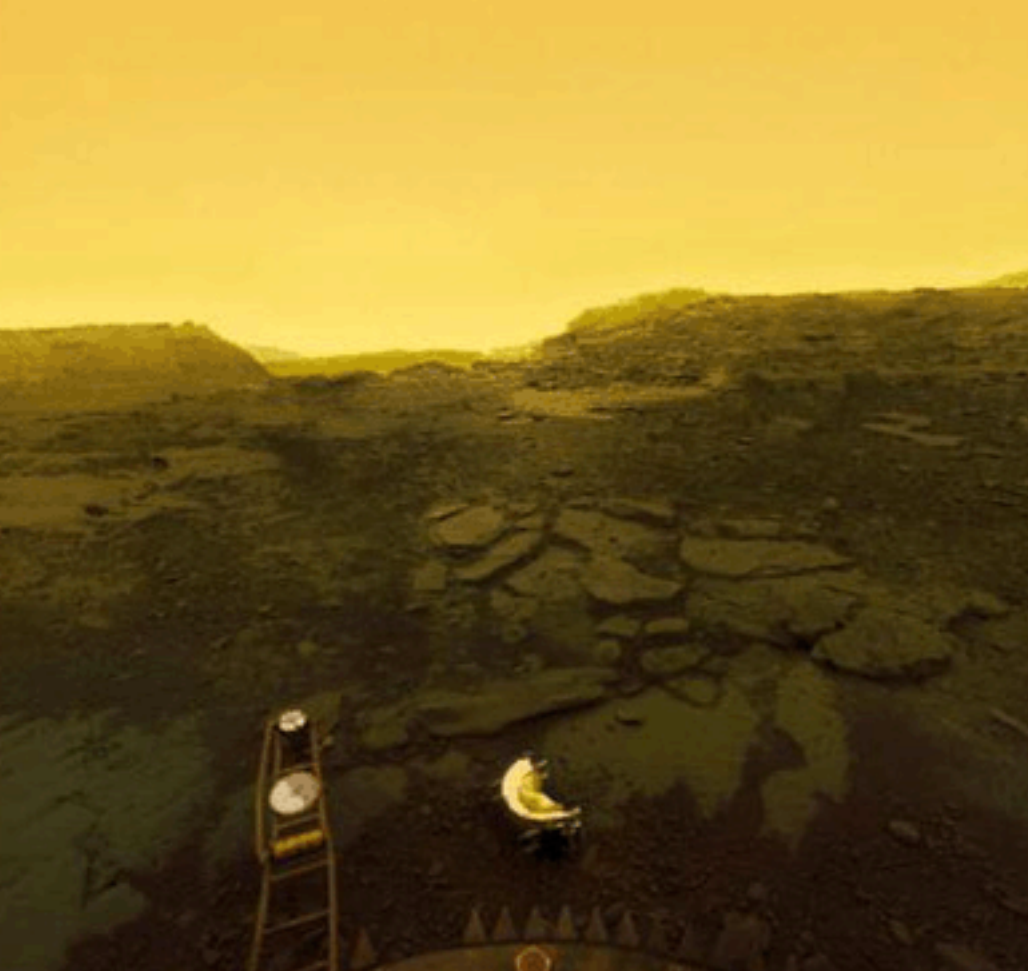
- It has many volcanoes, including both shield volcanoes and stratovolcanoes.



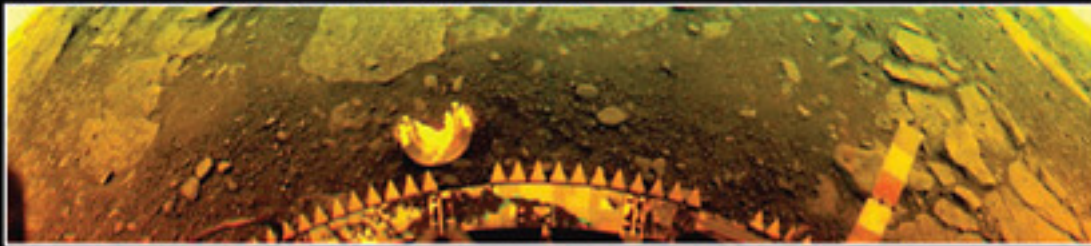
Tectonics on Venus



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



Color as seen on the surface of Venus



Color with atmospheric effects removed



- Photos of rocks taken by landers show little erosion.
- No flowing water
- The Russian lander only lasted a few minutes

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?