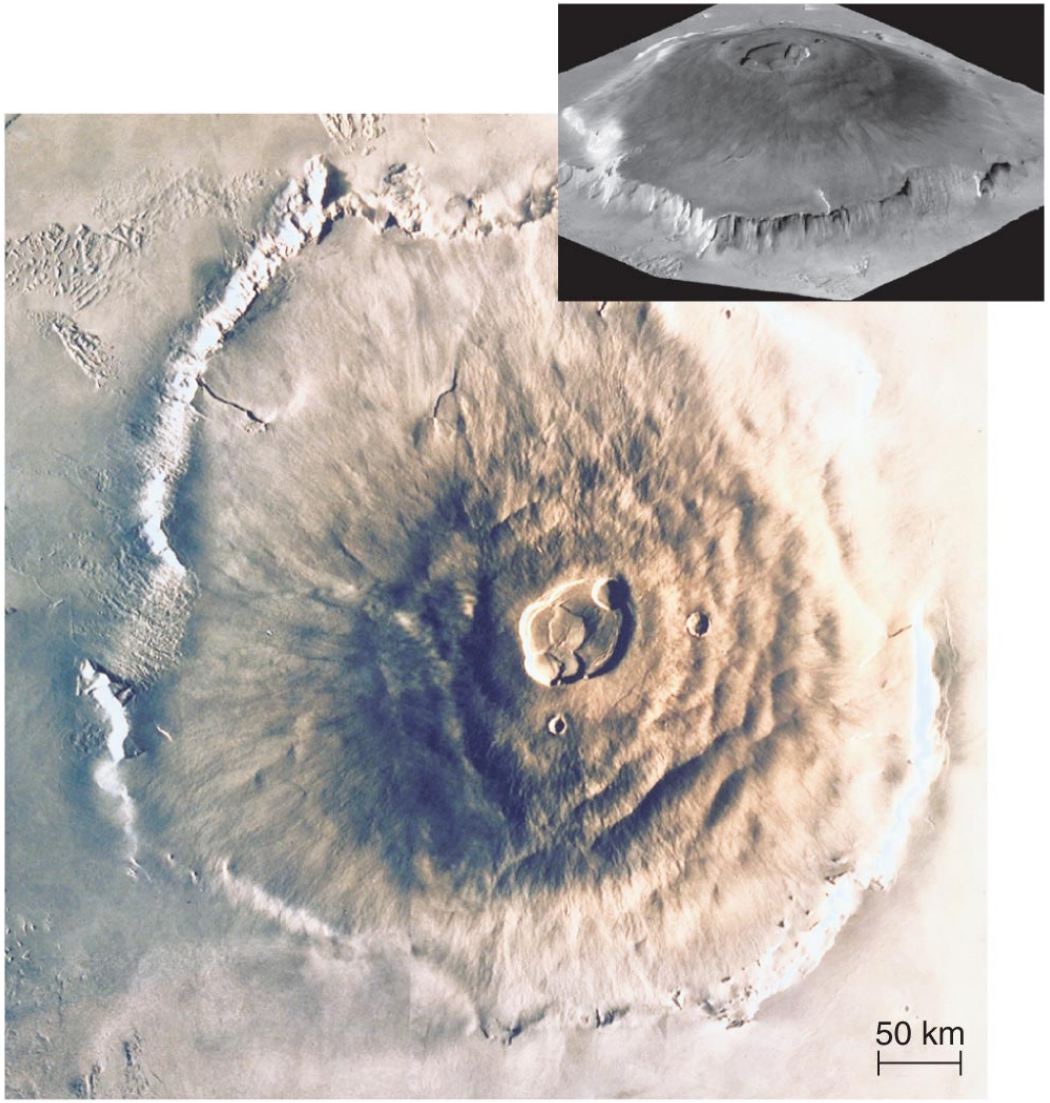
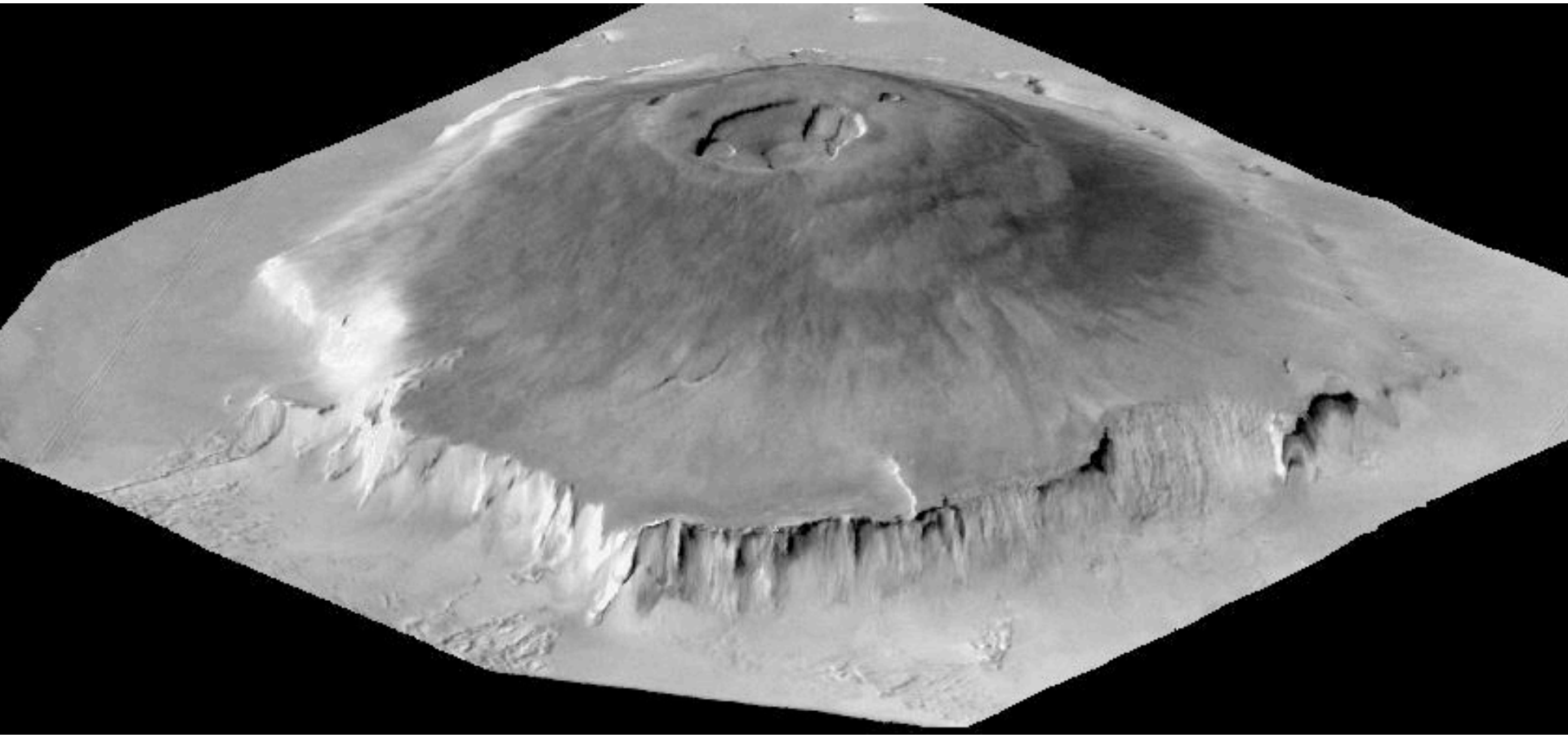
# Volcanism on Mars

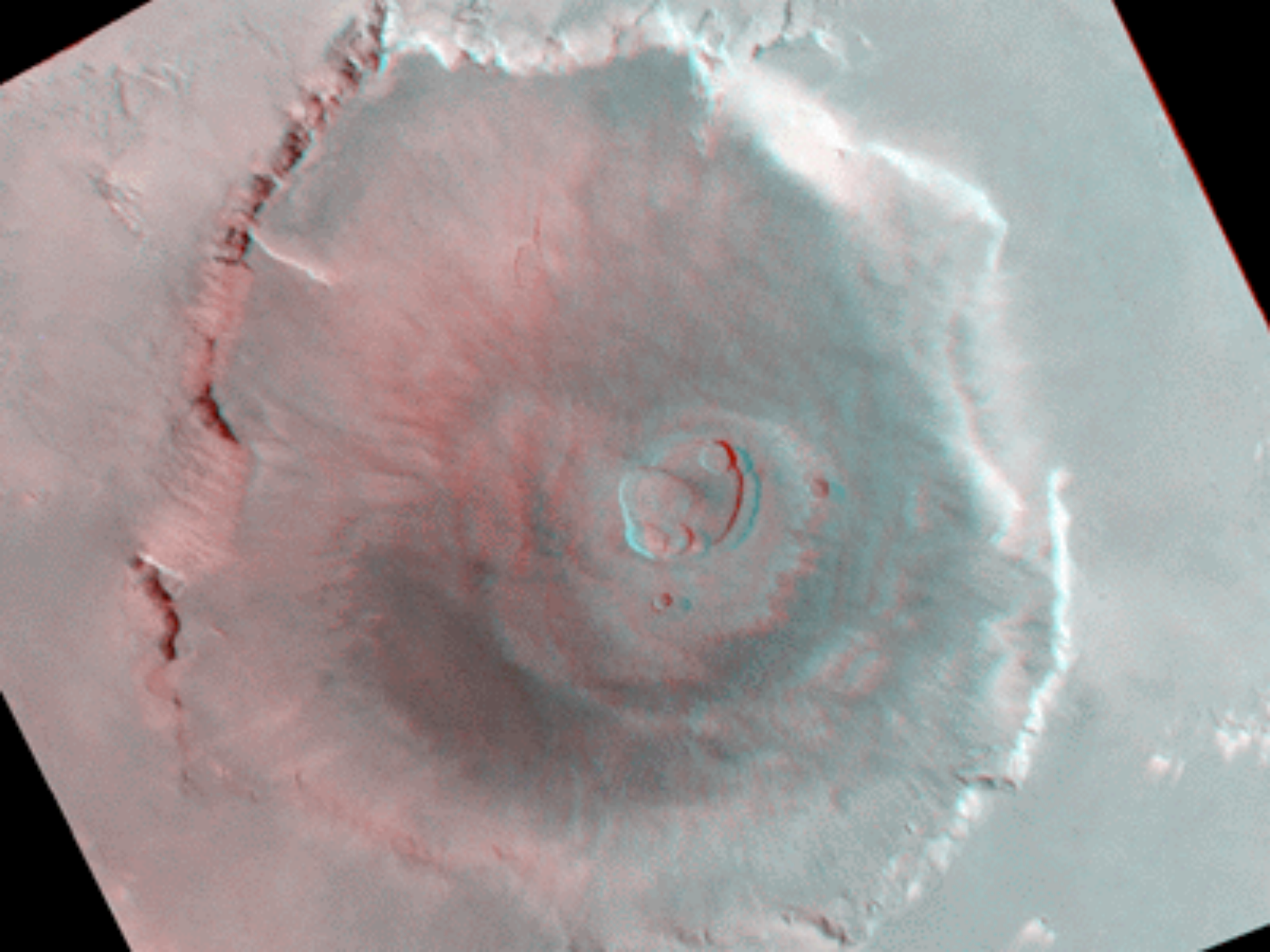



- Mars has many large shield volcanoes.
- Olympus Mons is largest volcano in solar system.

*Olympus Mons: Extinct Volcano (largest in the solar system!)*

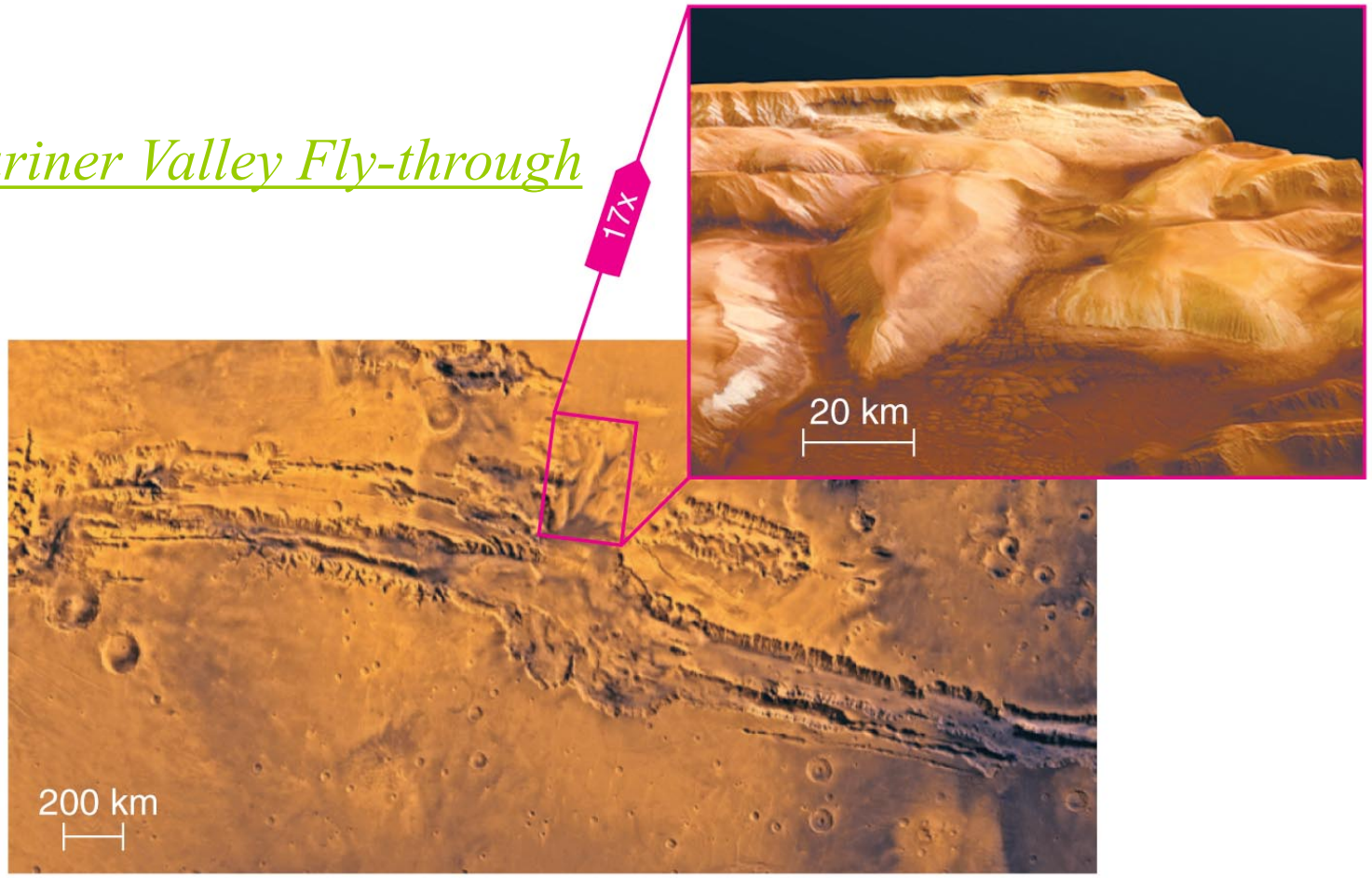
- *26 km high, 600 km across*
- *scarps are 6 km high*
- *compare to Mt Everest: 8 km high*





# Tectonics on Mars

*Mariner Valley Fly-through*



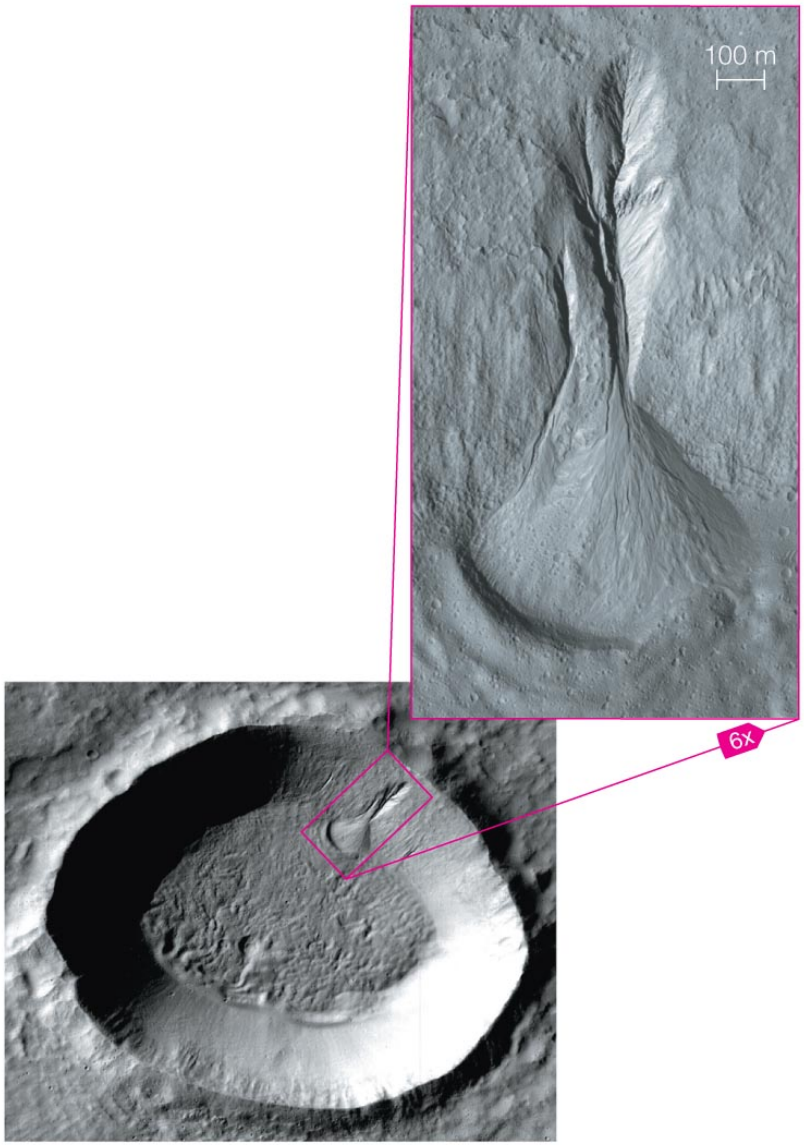

- The system of valleys known as Valles Marineris is thought to originate from tectonics.

*Surface Exploration: Mars Rovers*

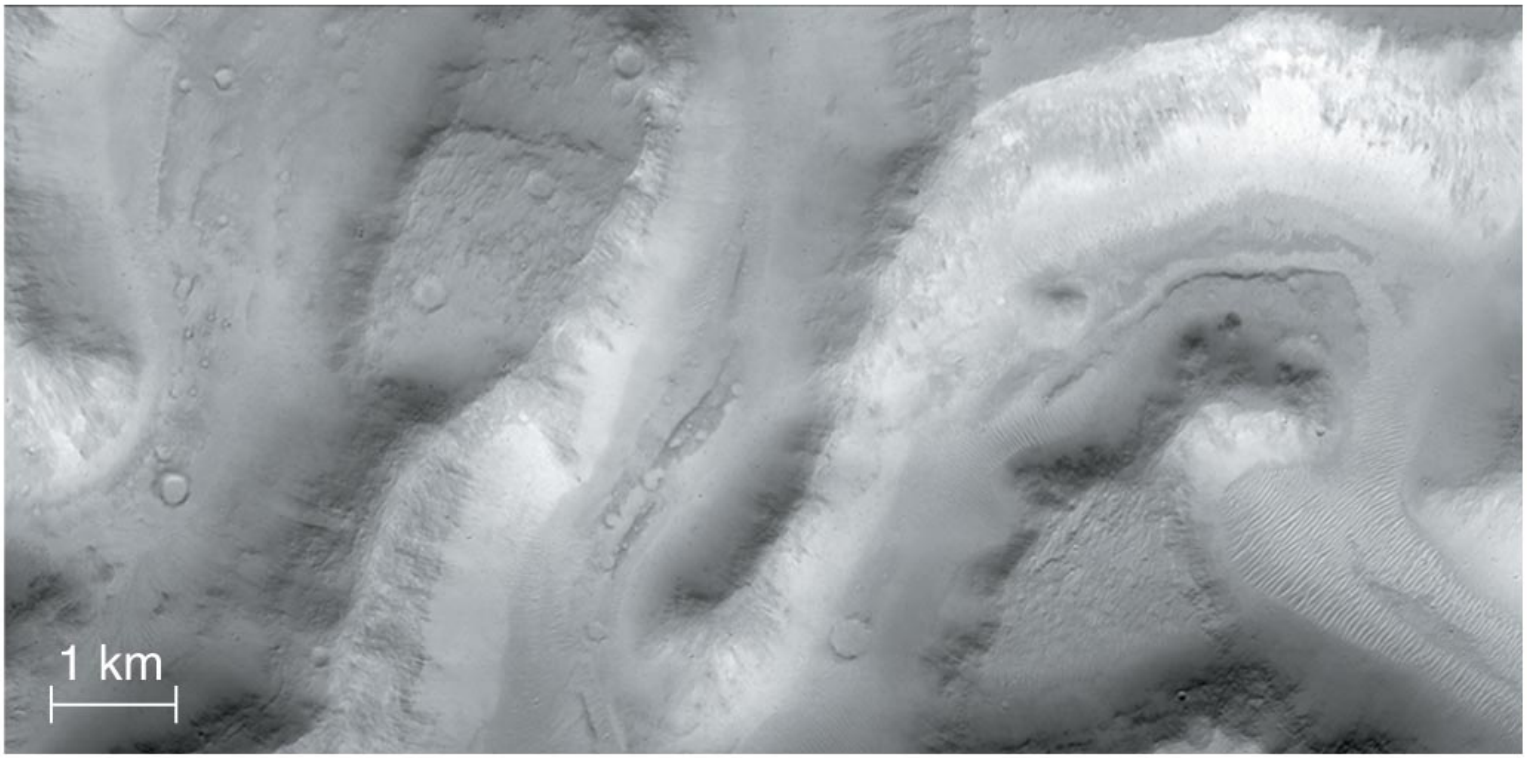
- *Pathfinder (1997)*
- *Spirit (2004-2010)*
- *Opportunity (2004-???)*
- *Curiosity (2012-???)*

*Mars 3D images*

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



# Dry Riverbeds?

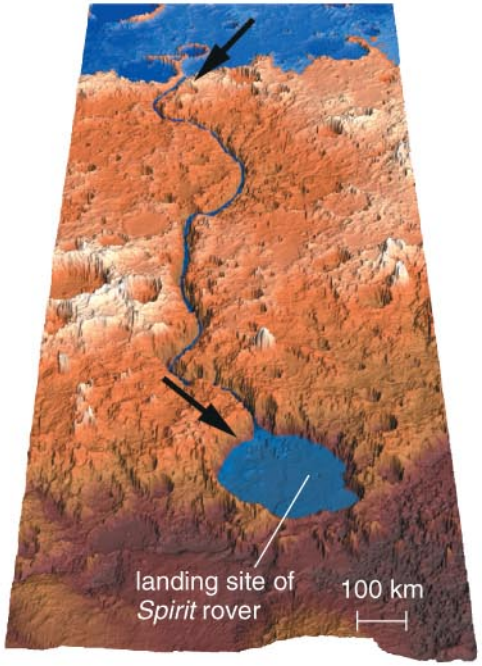



- Close-up photos of Mars show what appear to be dried-up riverbeds.

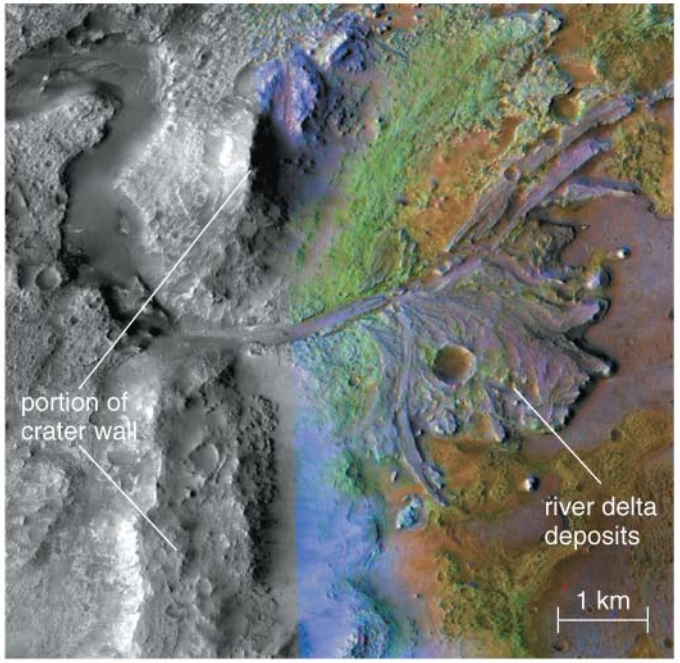
# Erosion of Craters

- 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.

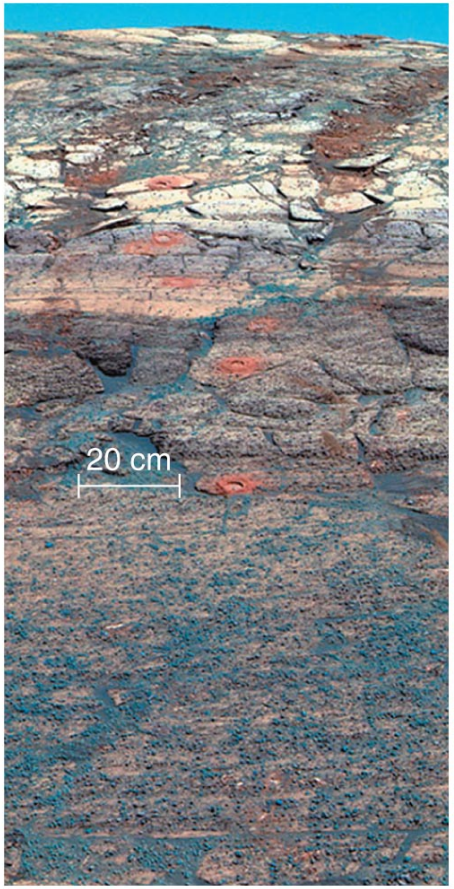



**b** This computer-generated perspective view shows how a Martian valley forms a natural passage between two possible ancient lakes (shaded blue). Vertical relief is exaggerated 14 times to reveal the topography.

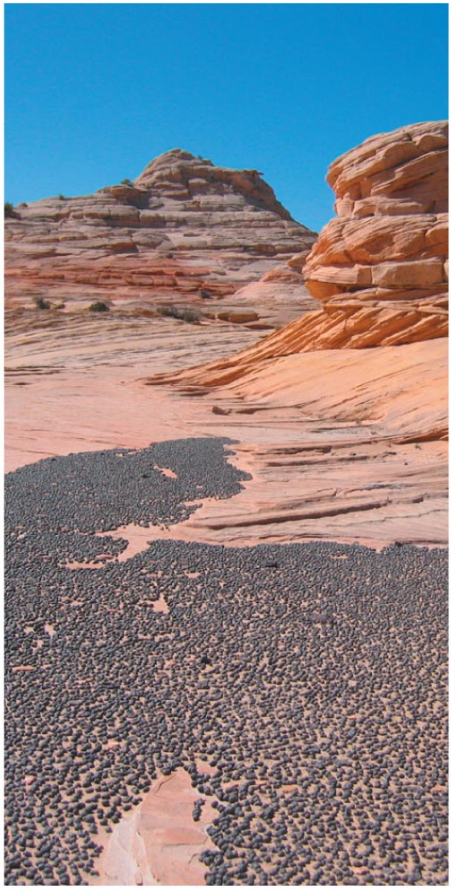



**c** Combined visible/infrared image of an ancient river delta that formed where water flowing down a valley emptied into a lake filling a large crater (portions of the crater wall are identified). Clay minerals are identified in green.

# 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.

# Hydrogen Content

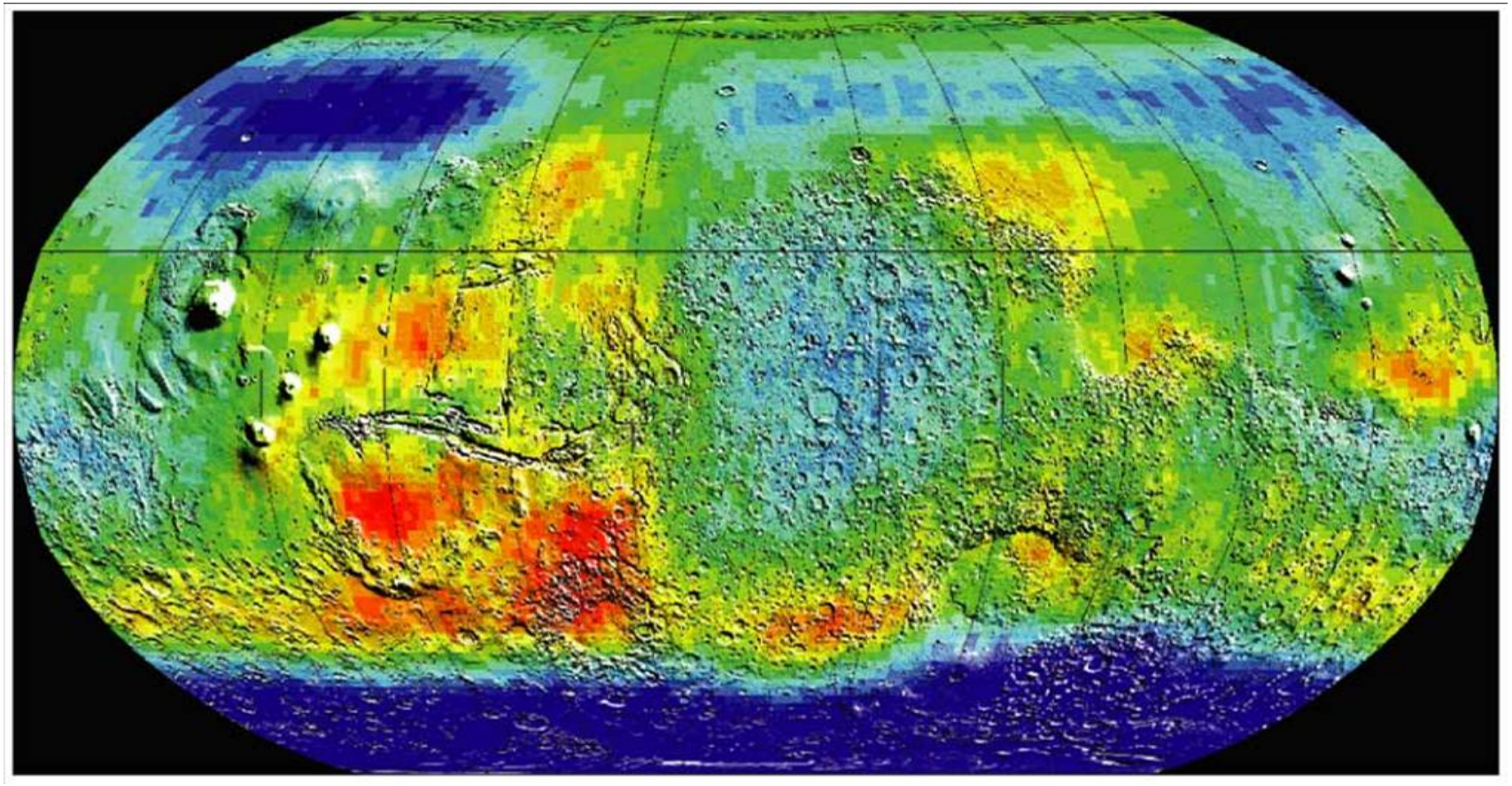


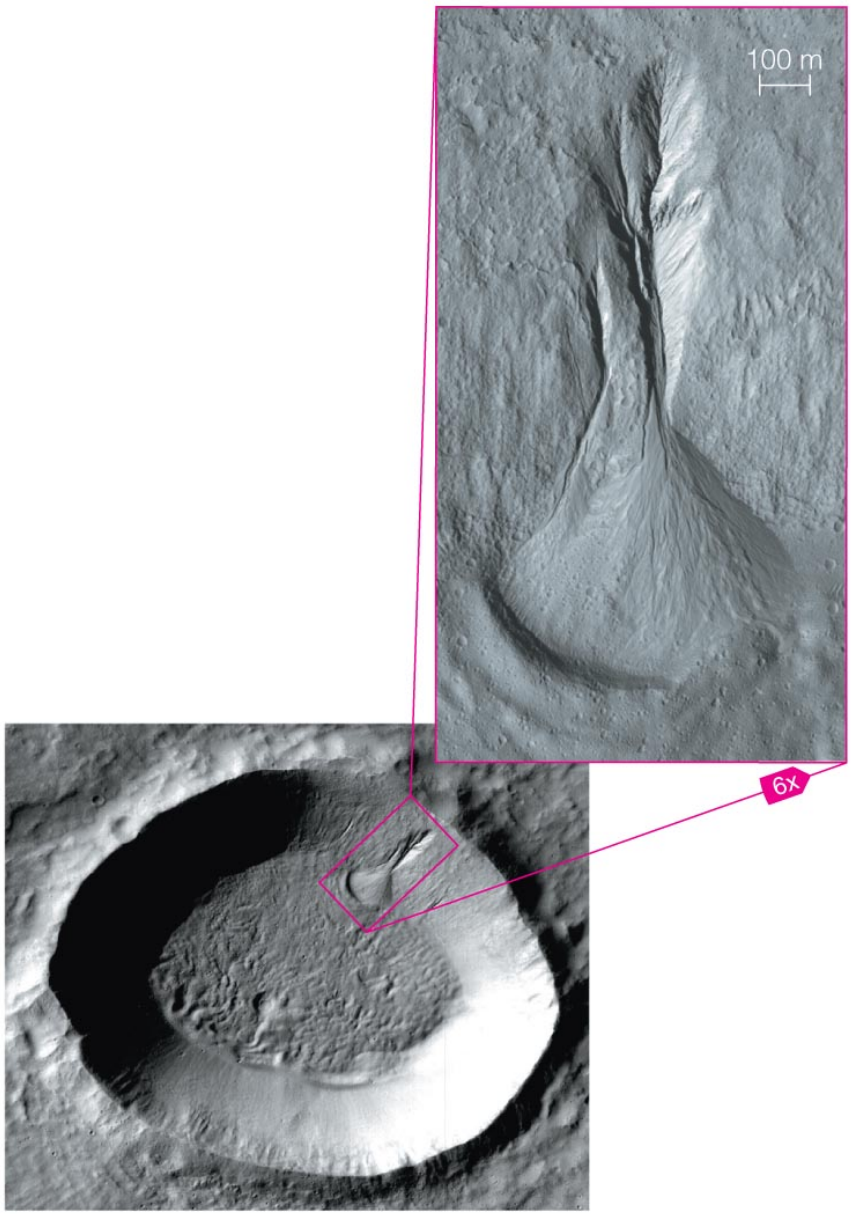
Image Credit: NASA/JPL

- 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.

- Possible seasonal water flows observed today.



# What have we learned?

- **What are the major geological features of Mars?**
  - Differences in cratering across surface
  - Giant shield volcanoes
  - Evidence of tectonic activity

# 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.

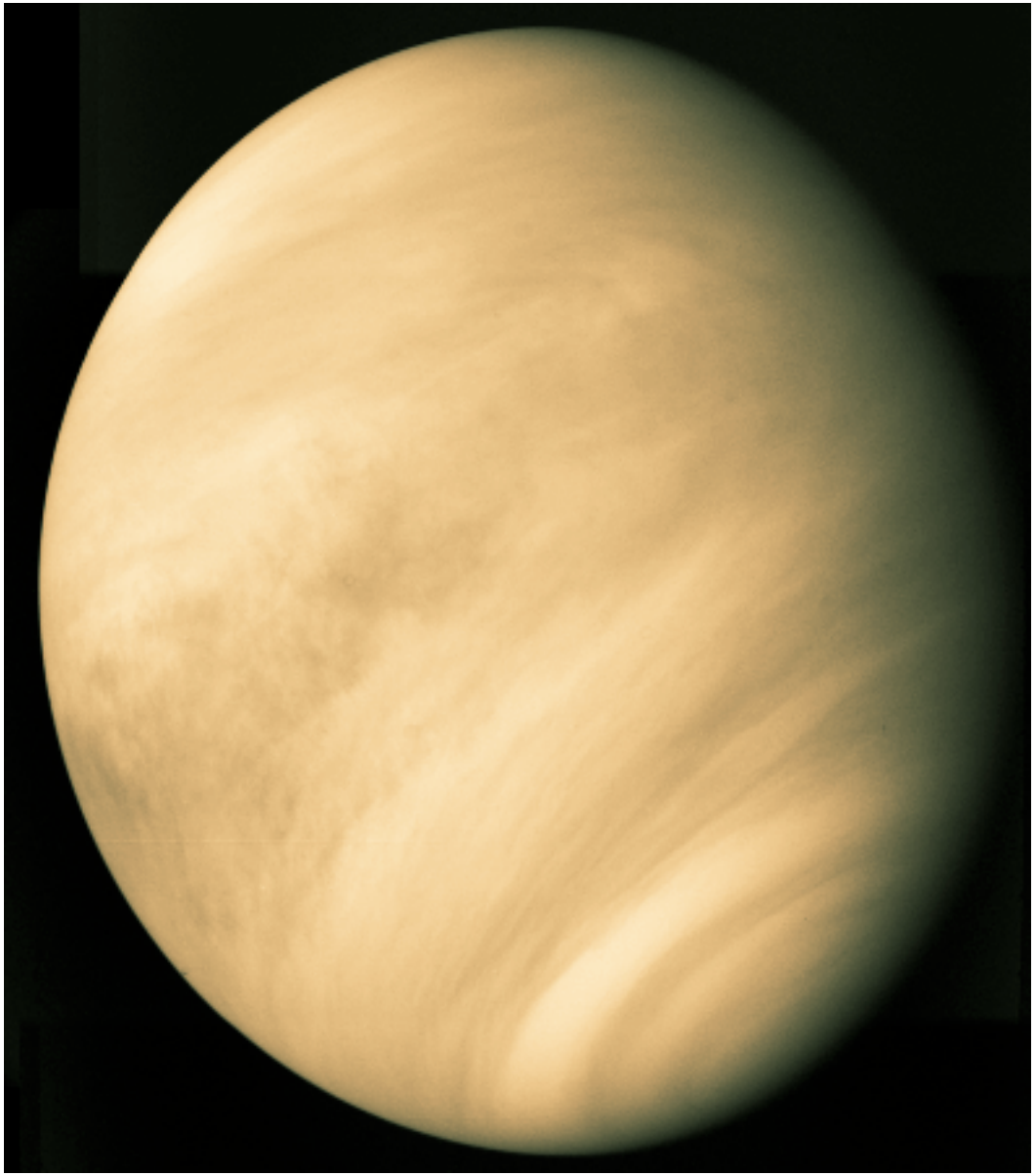
# 9.5 Geology of Venus

- Our goals for learning:
  - **What geological processes have shaped Venus?**
  - **Does Venus have plate tectonics?**

Venus:

- 95% the size of Earth
- 83% the mass of Earth
- Earth's twin?

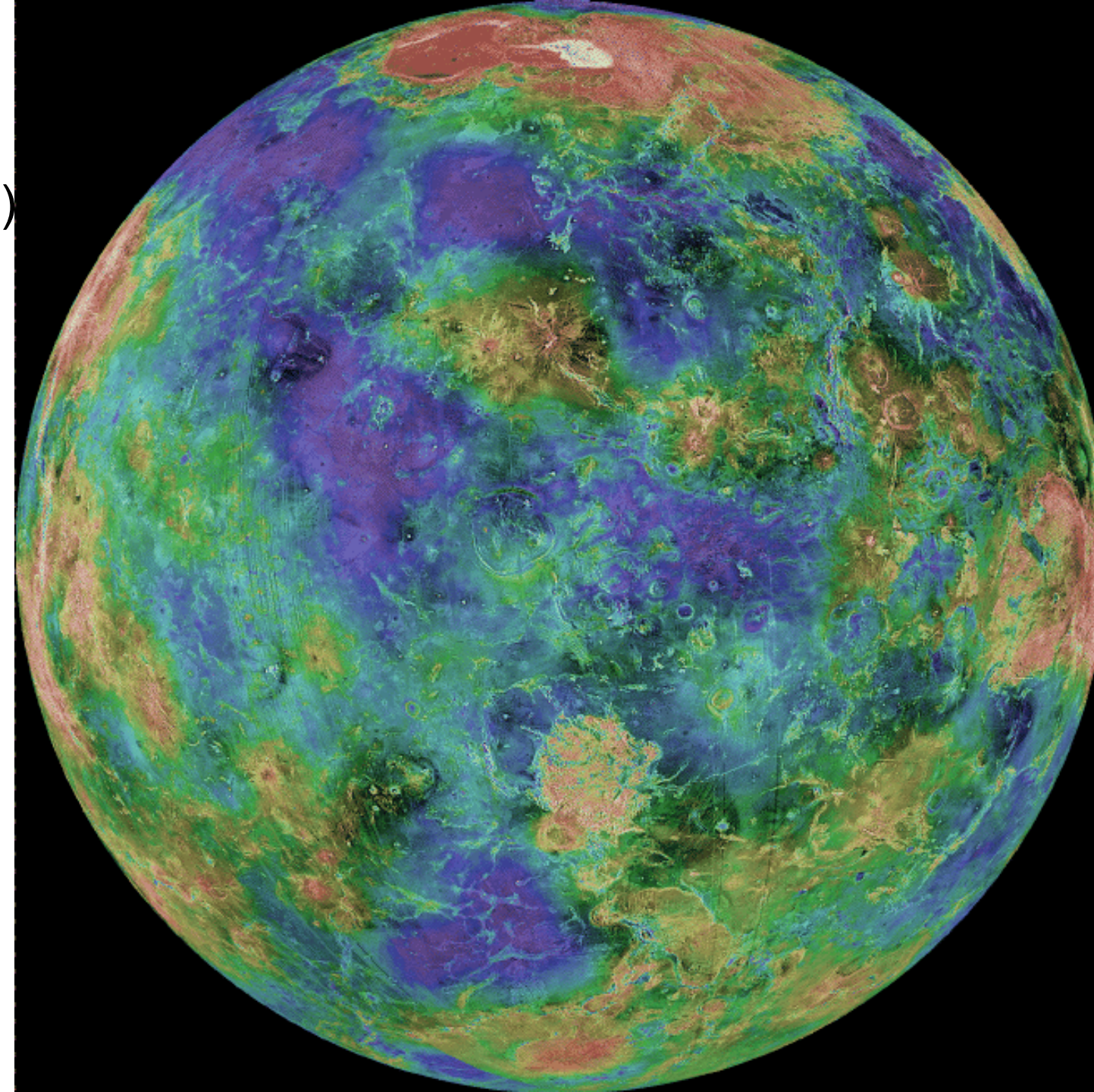
Covered in clouds, how do we figure out what the surface looks like?



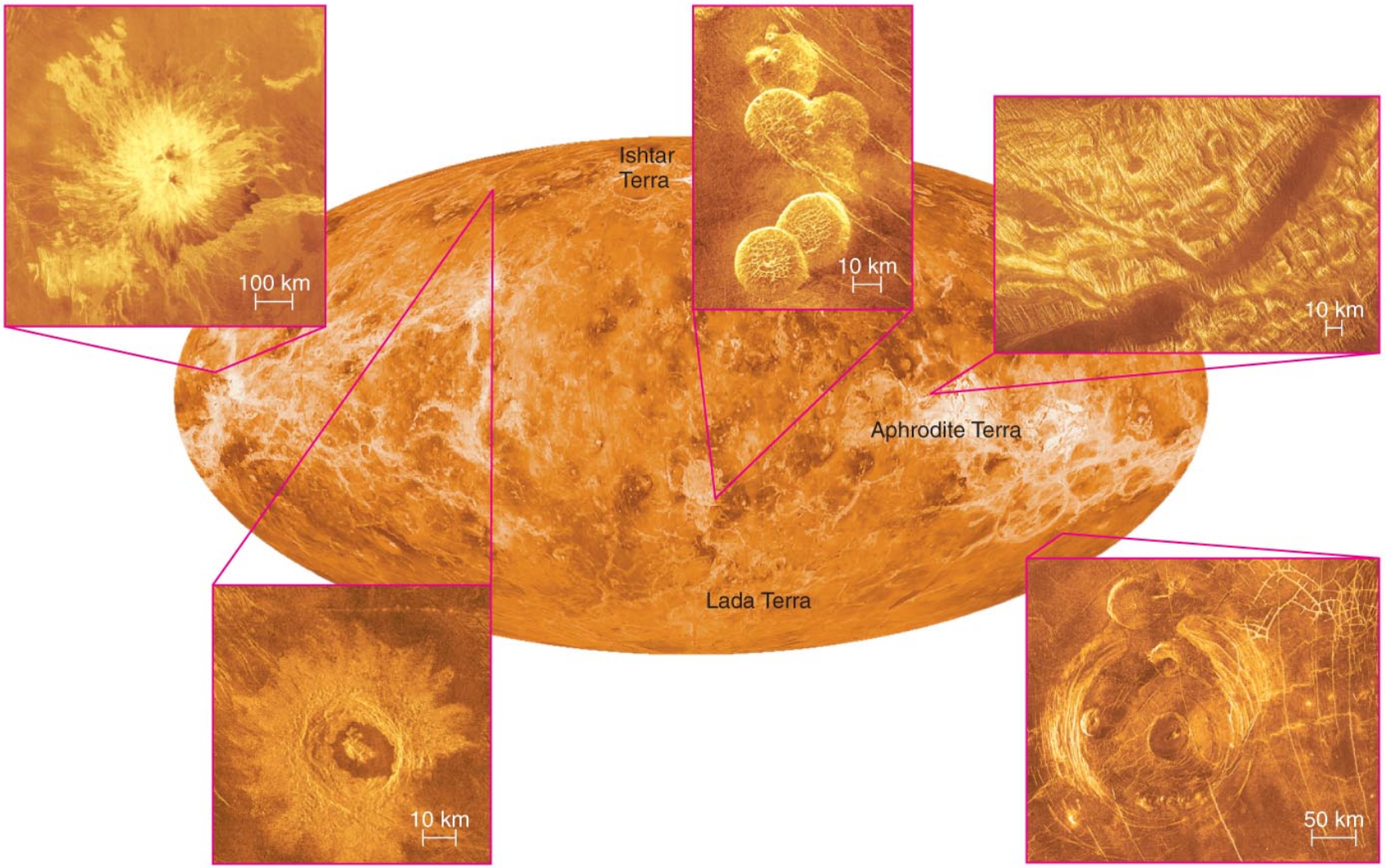
Radar mapping!

Magellan (1990s)

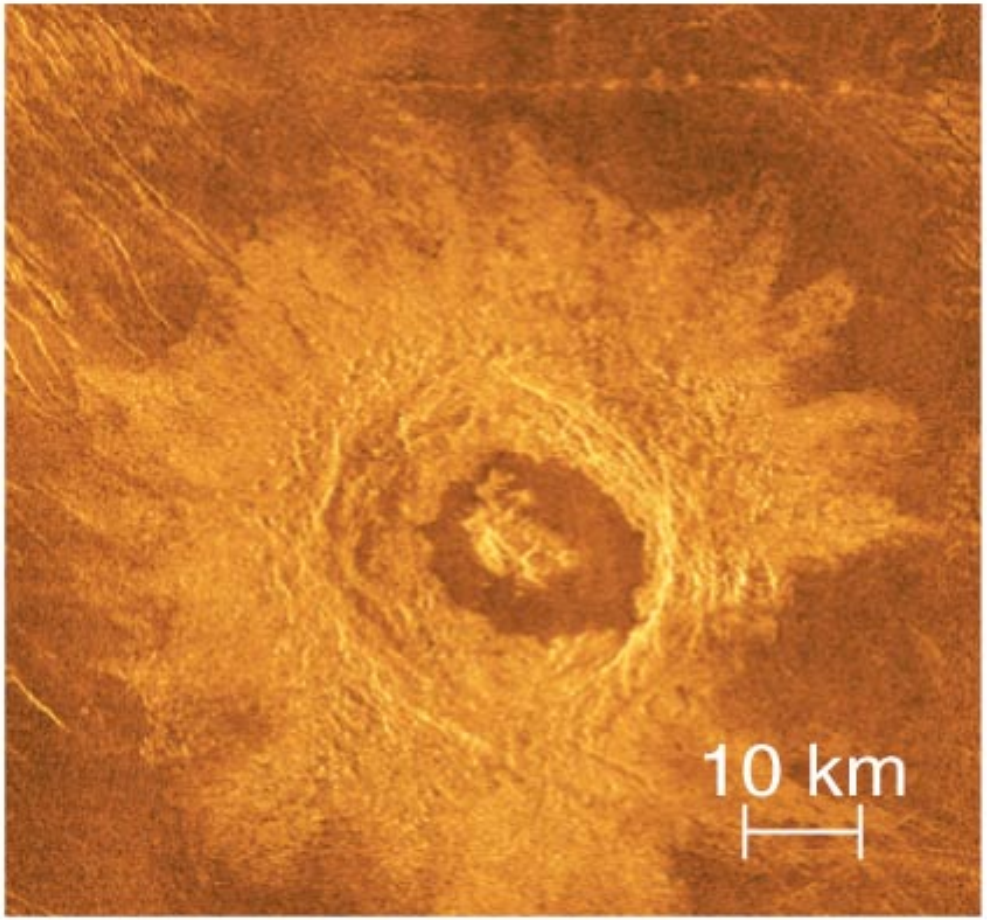
blue ➔ low elev
red ➔ high elev



# What geological processes have shaped Venus?

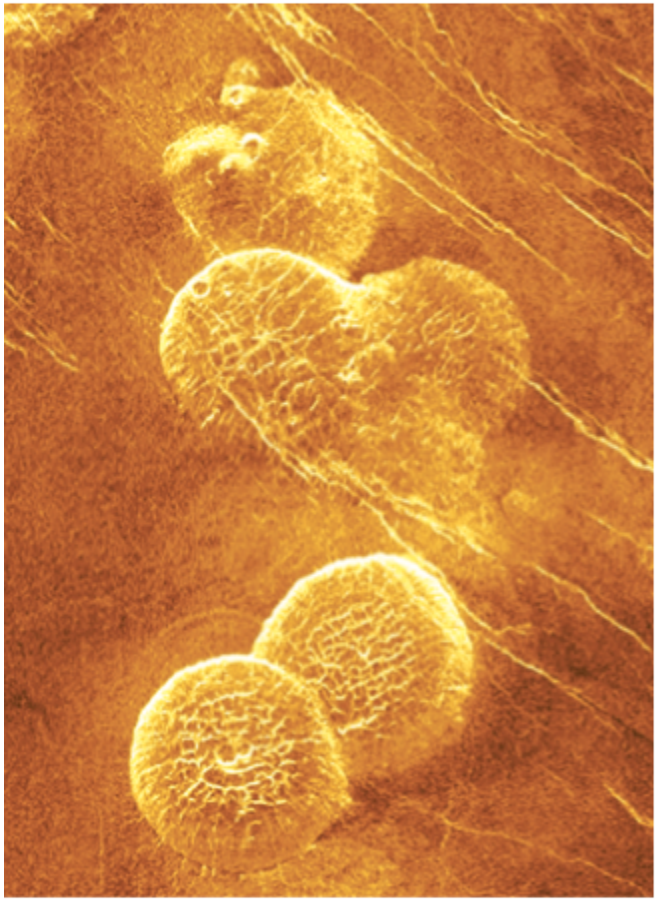


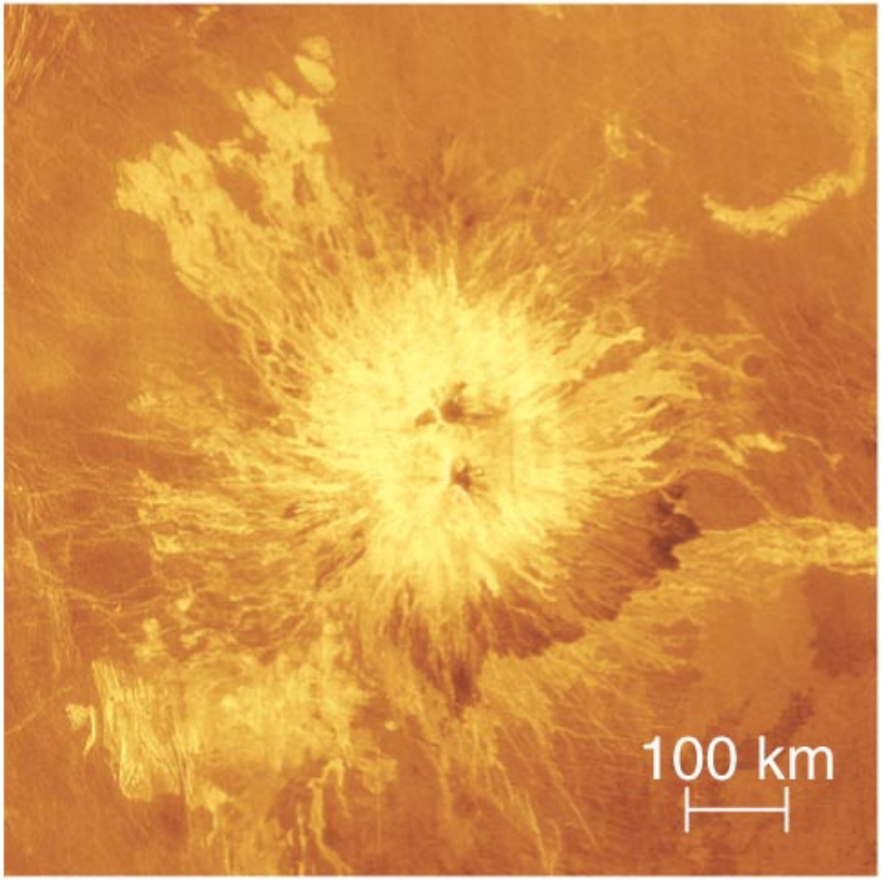
# Cratering on Venus




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

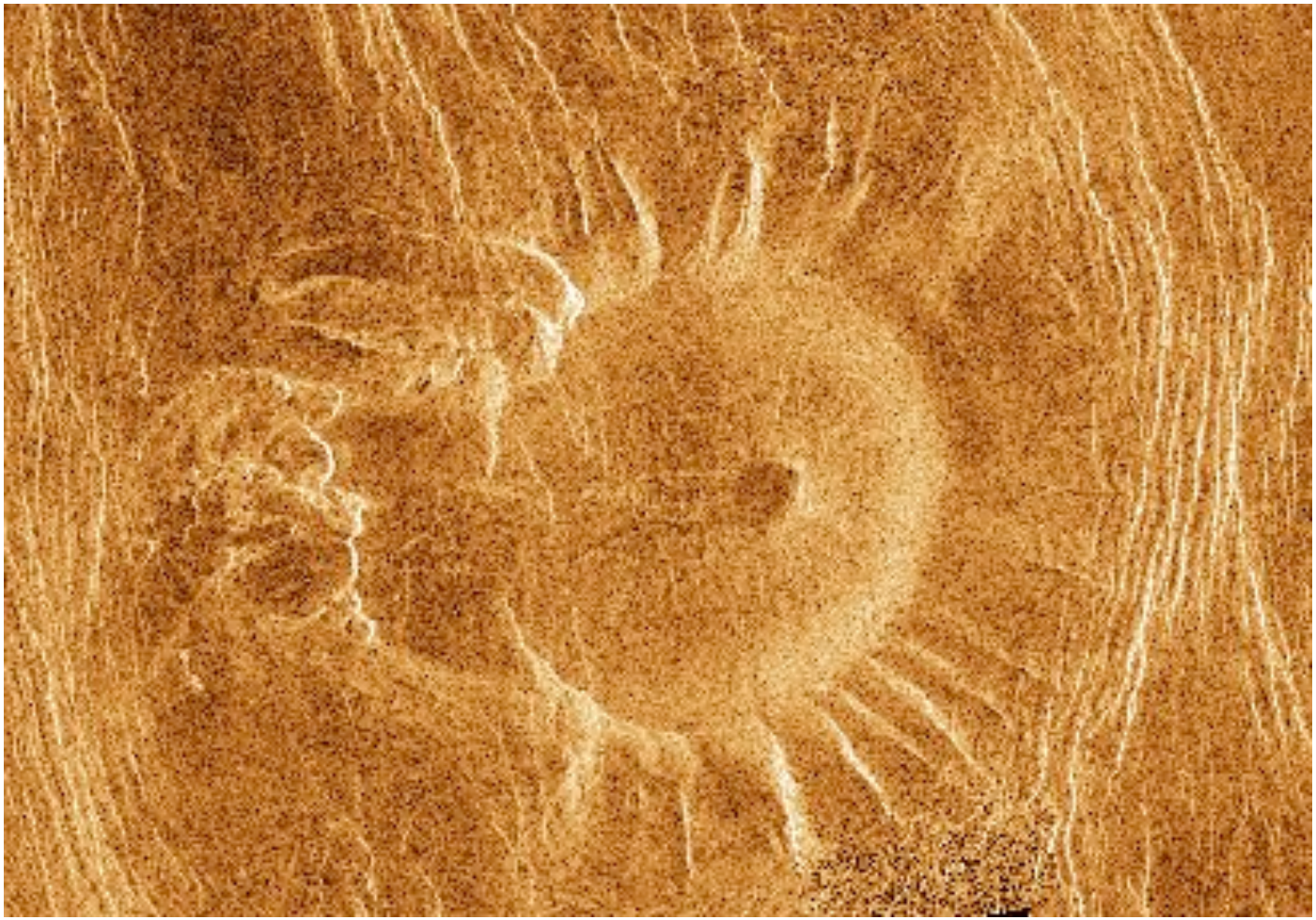
# Volcanoes on Venus





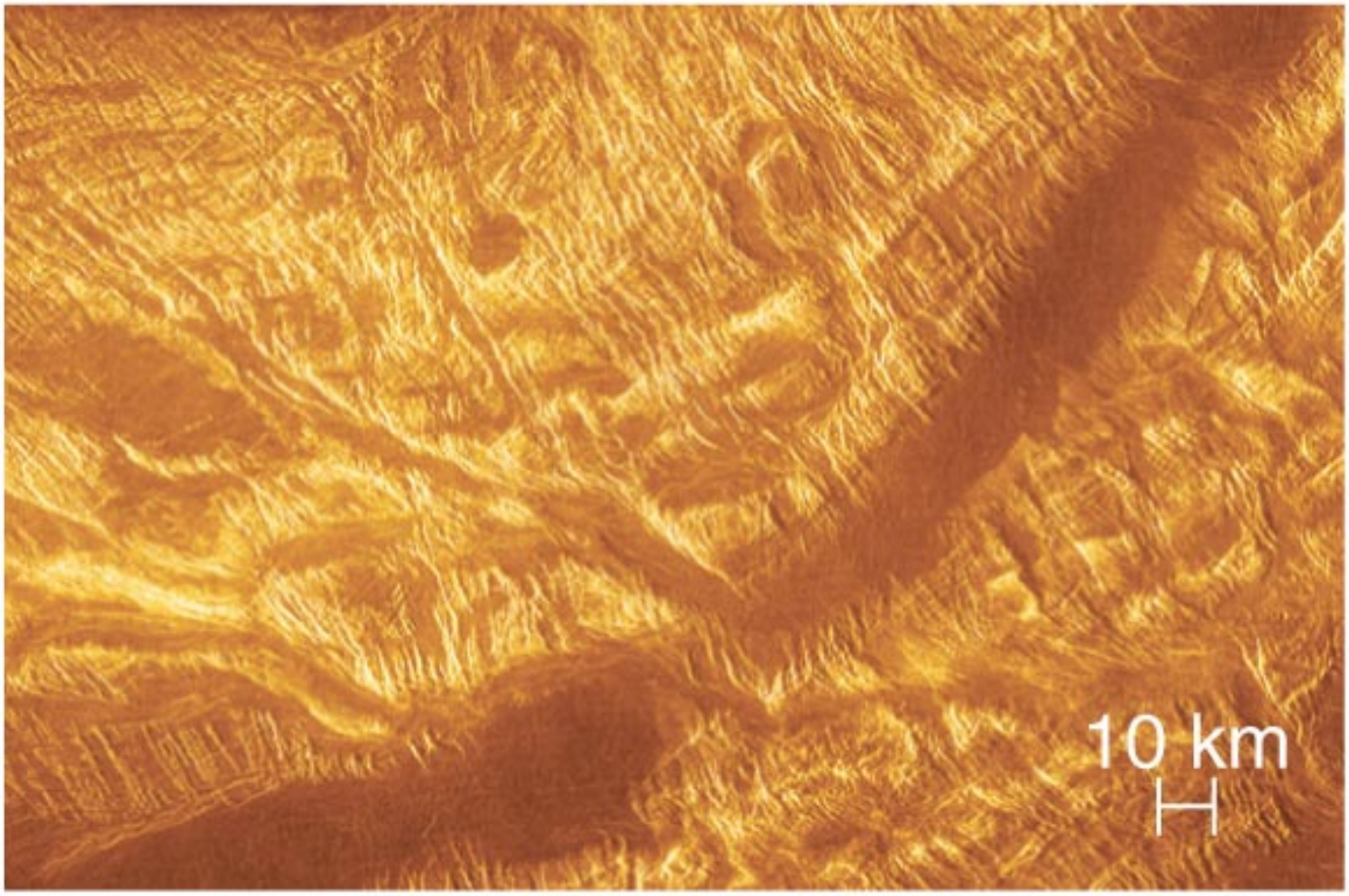

Many volcanoes, including both shield volcanoes and stratovolcanoes.

# Volcanoes on Venus



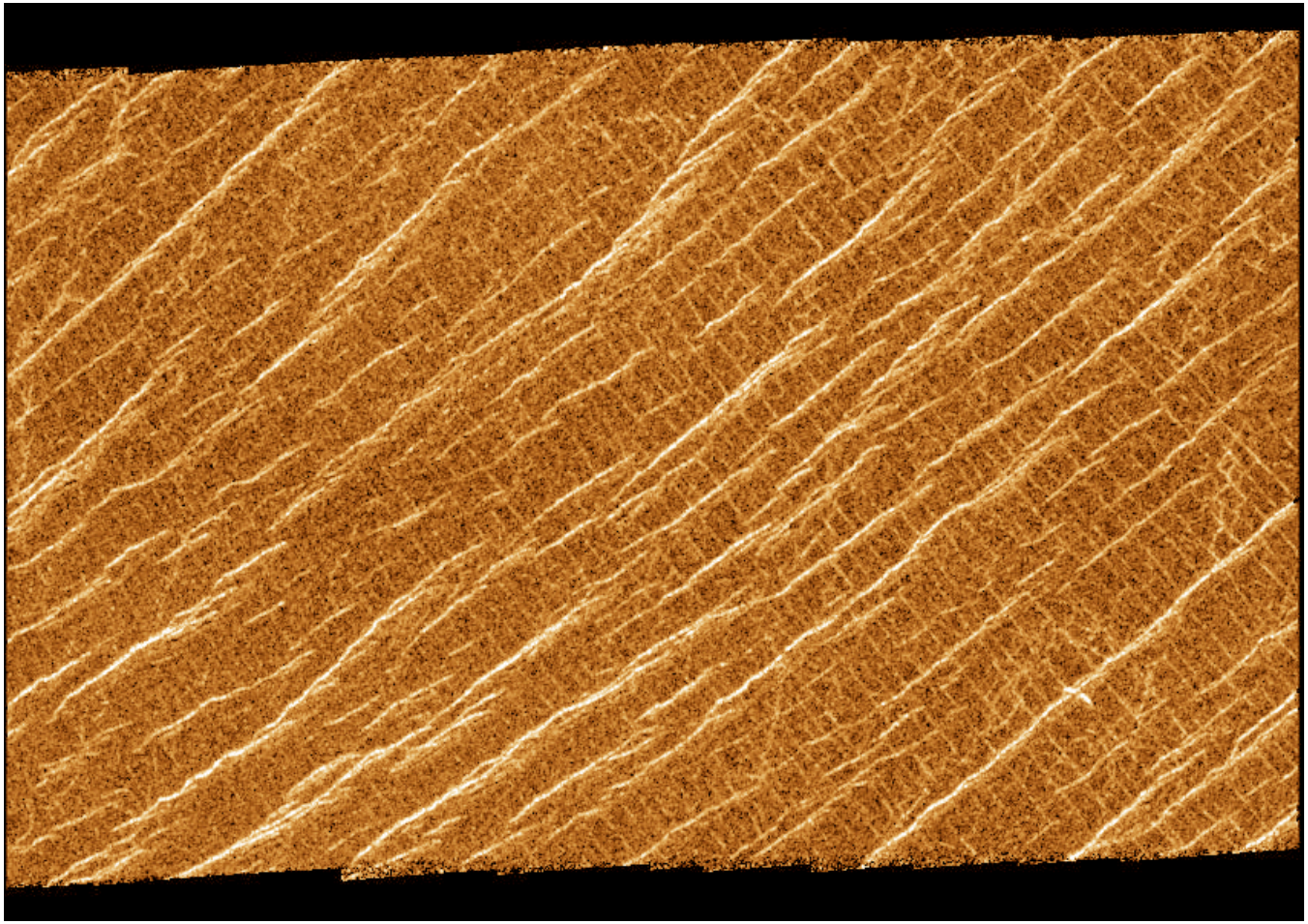
The Tick: another volcano, about 30 km across

# Tectonics on Venus




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

# Tectonics on Venus



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

# What's it like on Venus?

*NASA flyover animation*

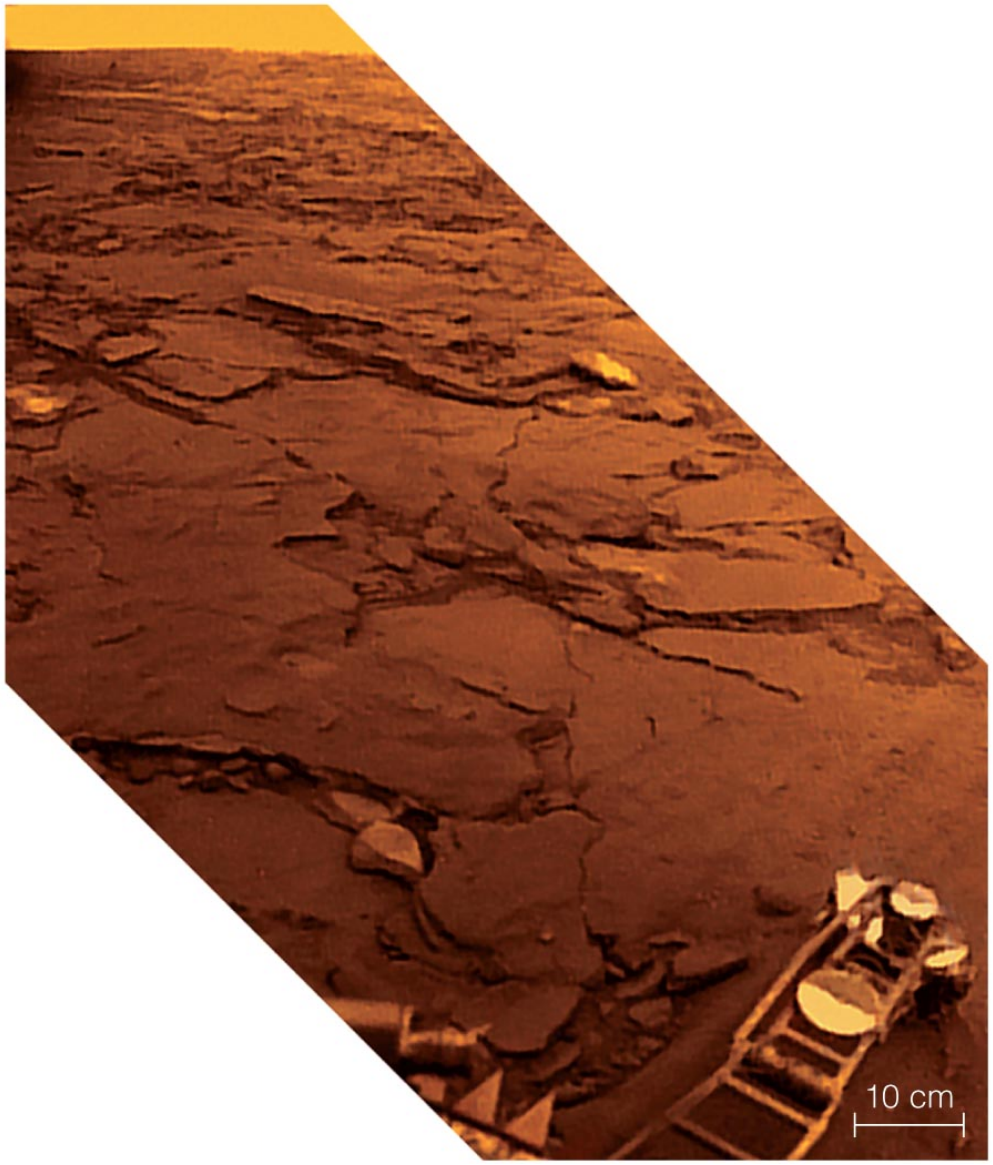
# What's it like on Venus?

Atmosphere:

- Thick carbon-dioxide atmosphere
- Sulfuric acid clouds
- 90 times the atmospheric pressure of Earth
- Hot! 740 K = 870 degrees Fahrenheit
- Little wind due to planet's slow rotation

The only surface data we have comes from Soviet-era (1970/80s) Venera missions, which each survived ~ 1 hr on the surface.

# Erosion on Venus




Photos of rocks taken by landers show little erosion.

More photos from Soviet Venera probes.

# 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. *(How do we know this?)*

- Weaker convection?
- Thicker or more rigid lithosphere?

This is unlike the Earth, where the crust is always in motion. *Why the difference?*

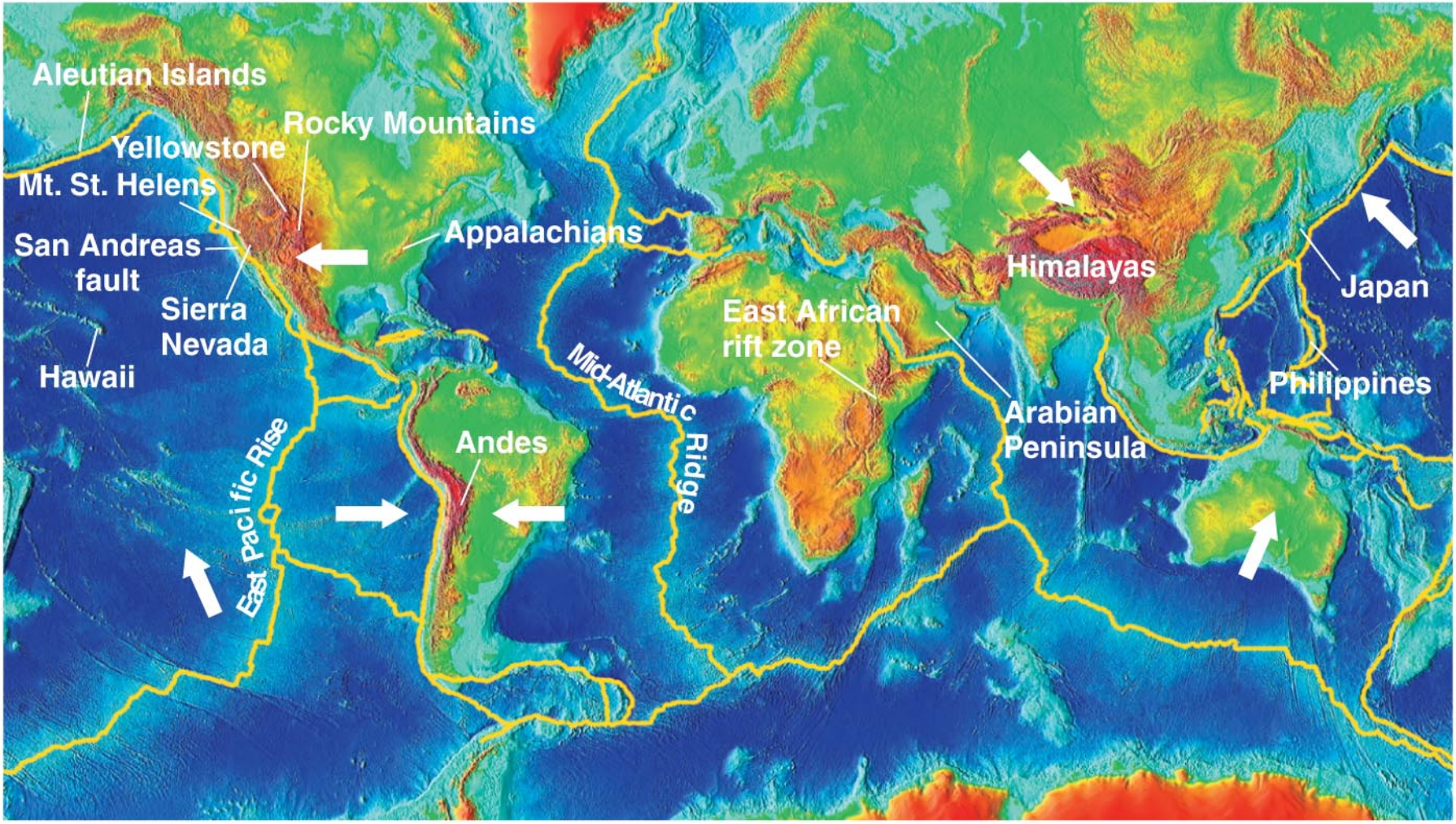
# What have we learned?

- **What geological processes have shaped 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.

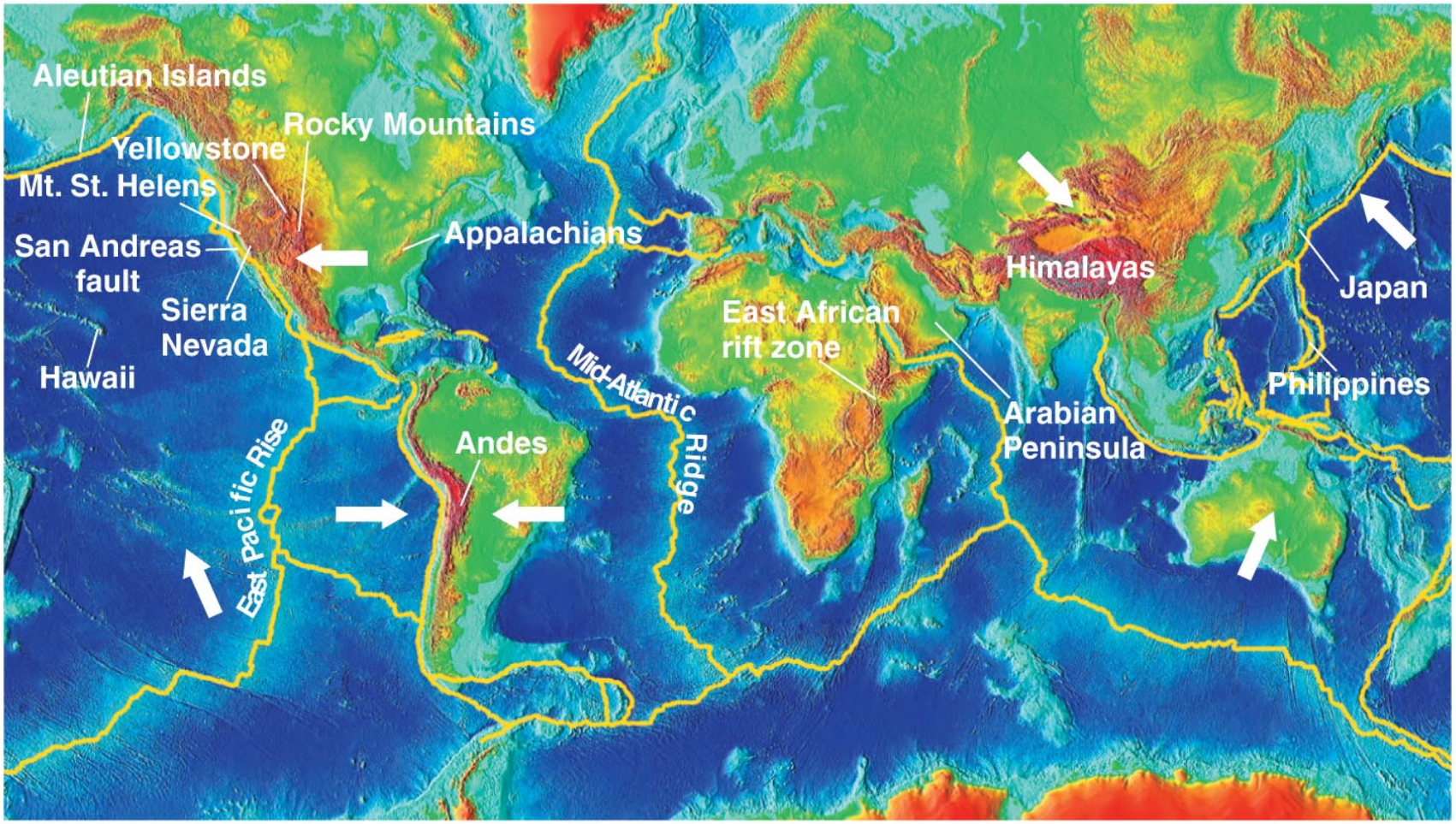
# 9.6 The Unique Geology of Earth

- Our goals for learning:
  - **How is Earth's surface shaped by plate tectonics?**
  - **Was Earth's geology destined from birth?**

# How is Earth's surface shaped by plate tectonics?



# Continental Motion

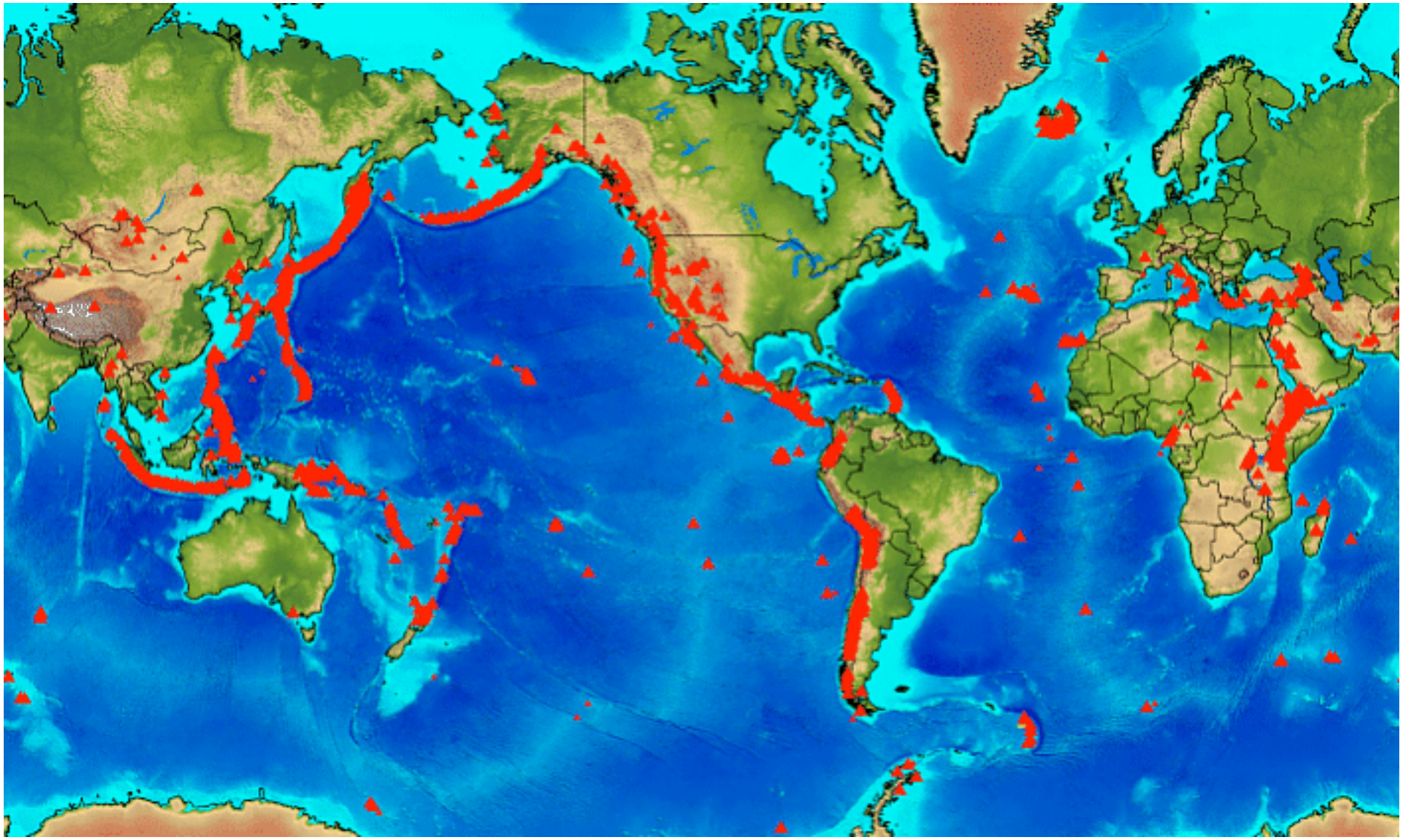



- Motion of the continents can be measured with GPS.

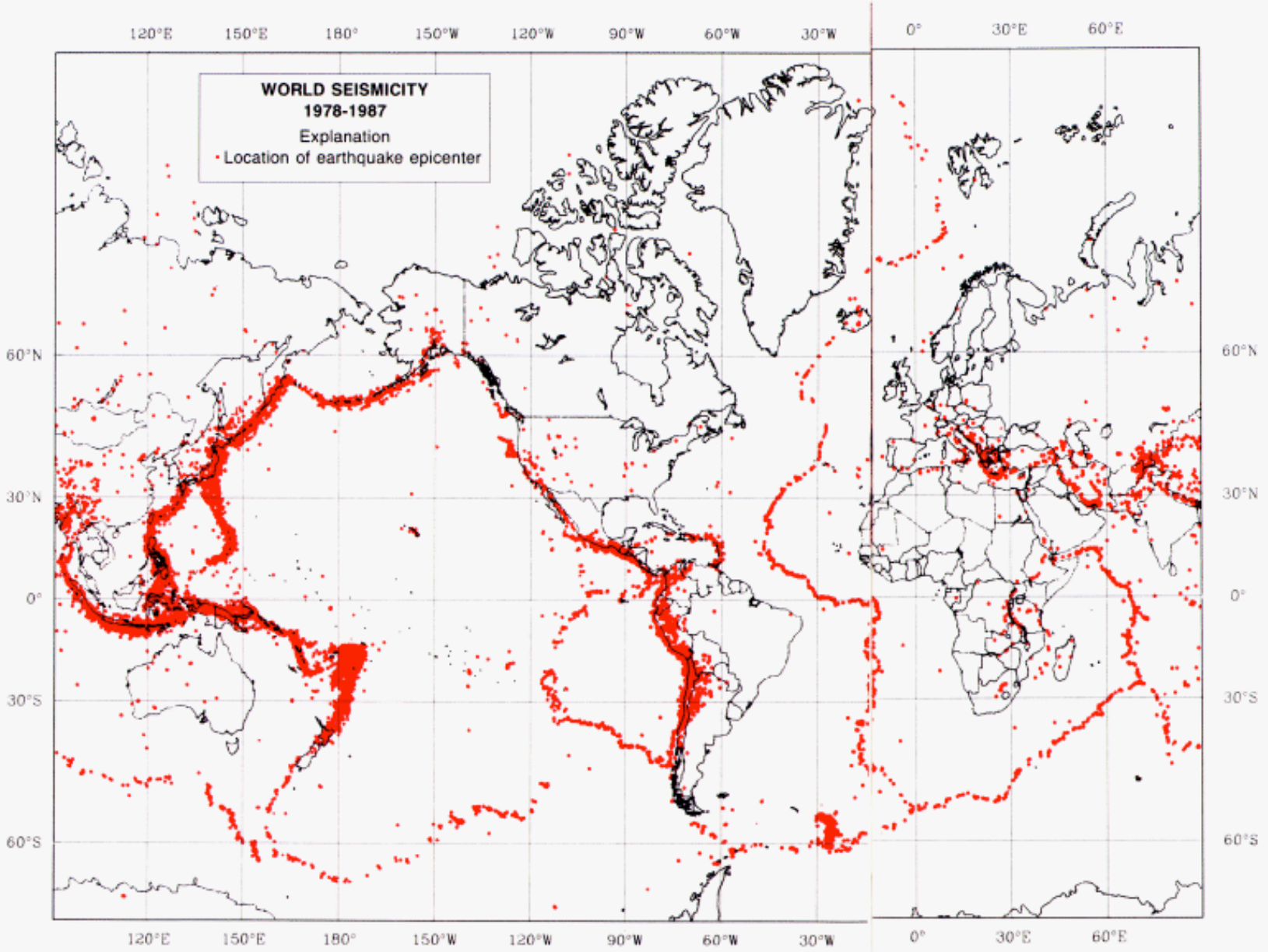
# Continental Motion


- The idea of continental drift was inspired by the puzzle-like fit of the continents.
- Animation (courtesy Caltech Tectonics Observatory)
- Mantle material erupts where the seafloor spreads.

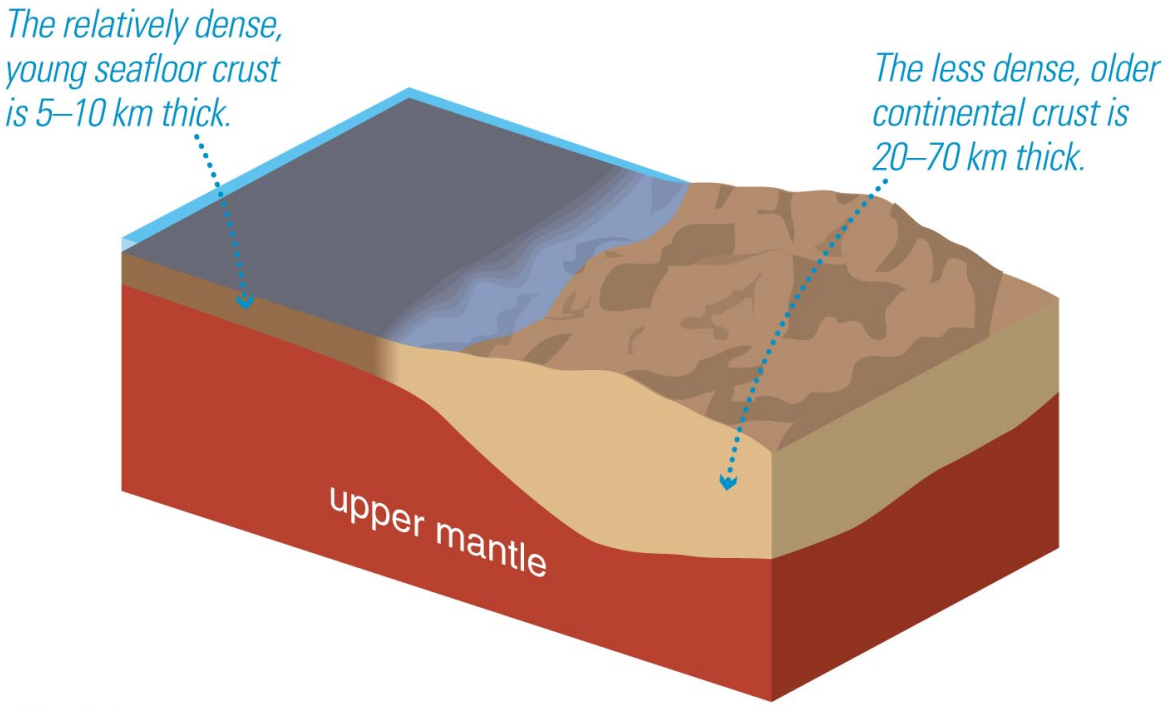
# Volcanoes of the World



# Earthquake Epicenters



# Seafloor Crust

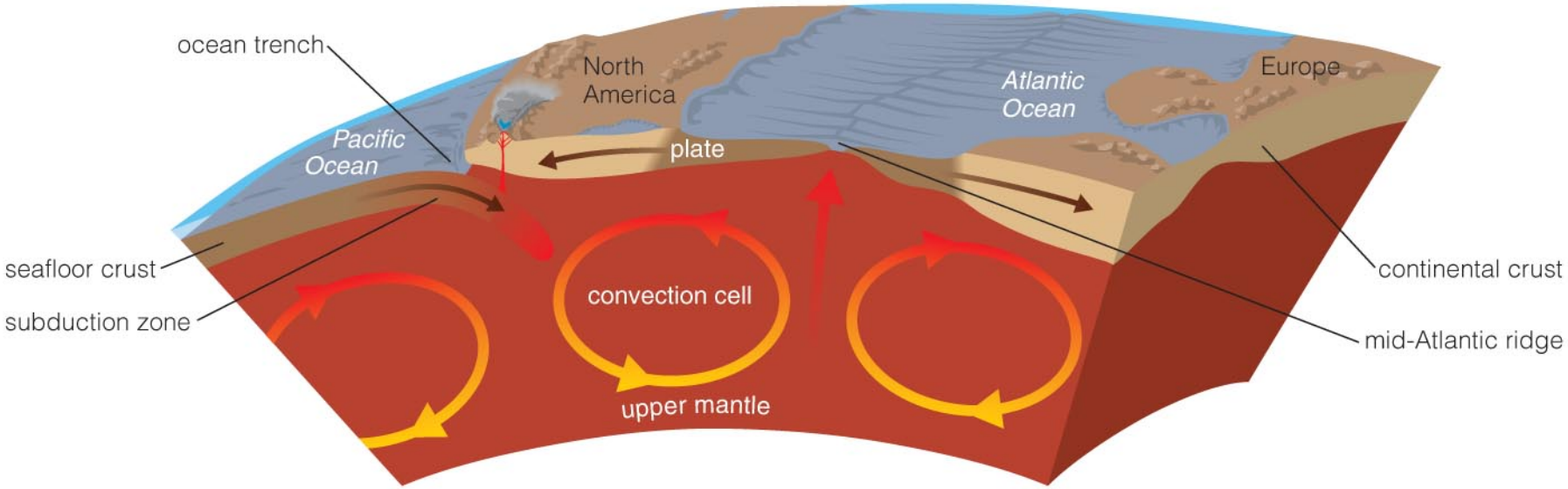



Thin seafloor crust differs from thick continental crust.

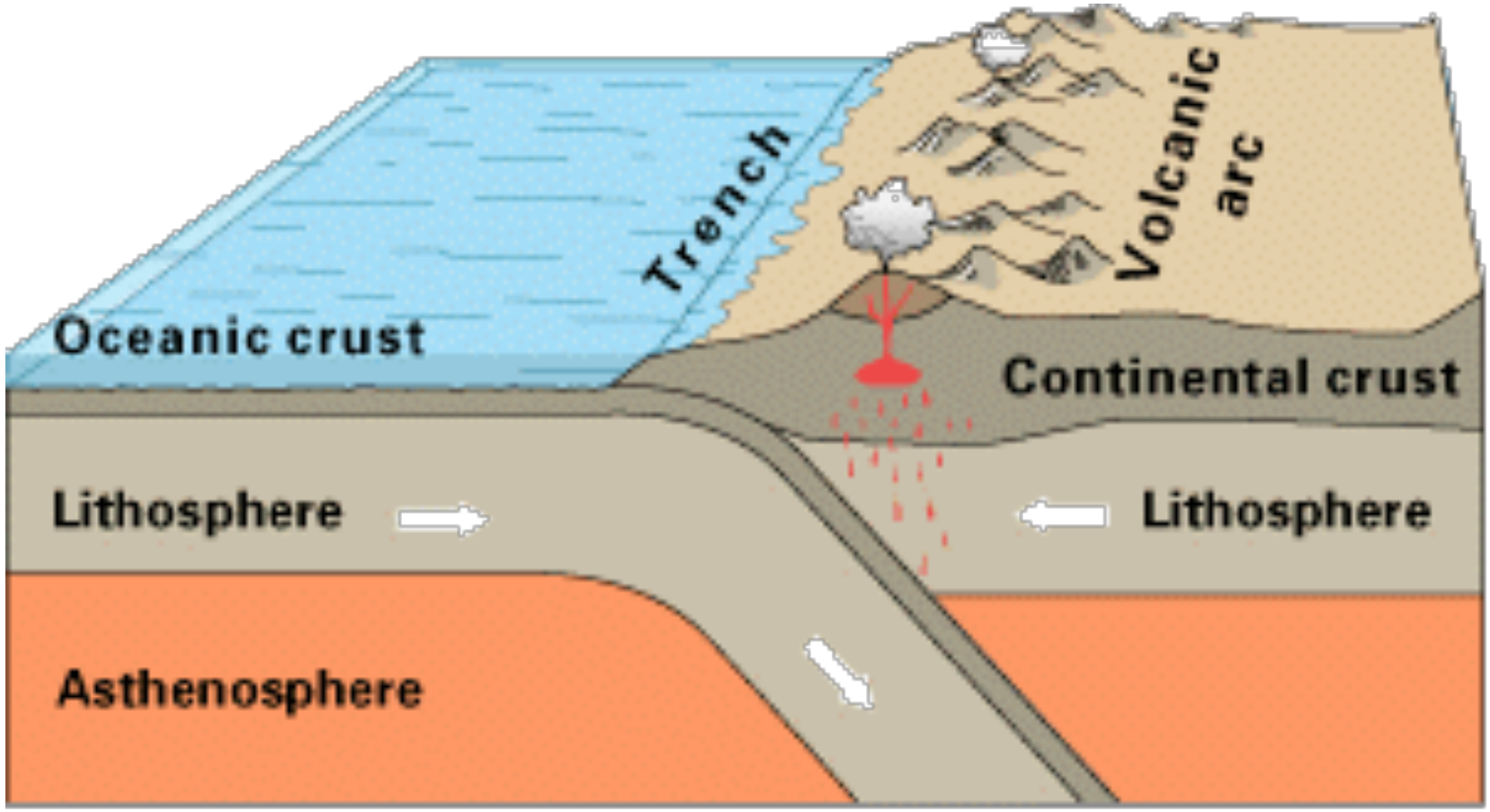
Dating of the seafloor shows that it is usually quite young (200 million years).

Continental crust much older (up to billions of years).

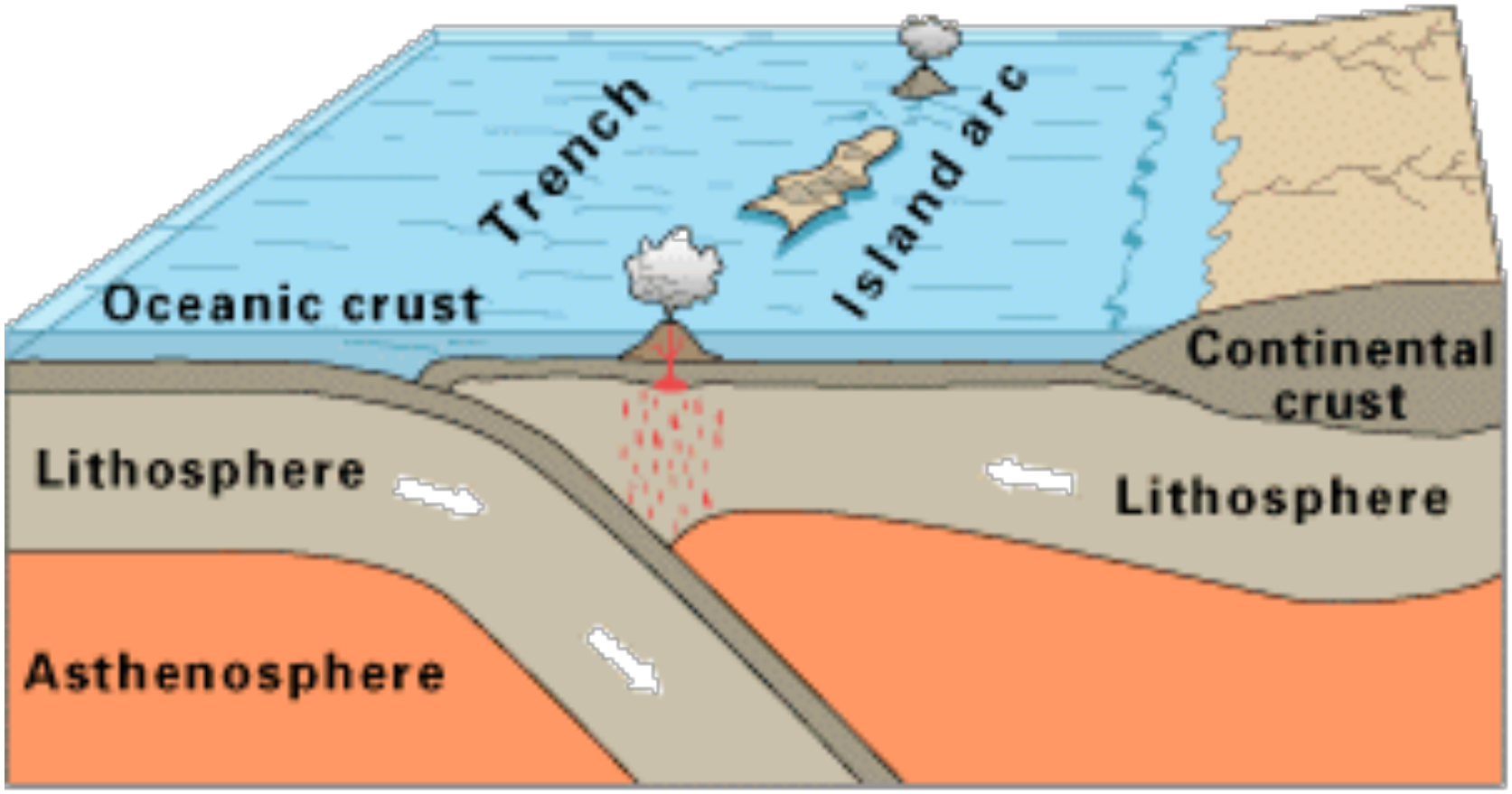
# Seafloor Recycling



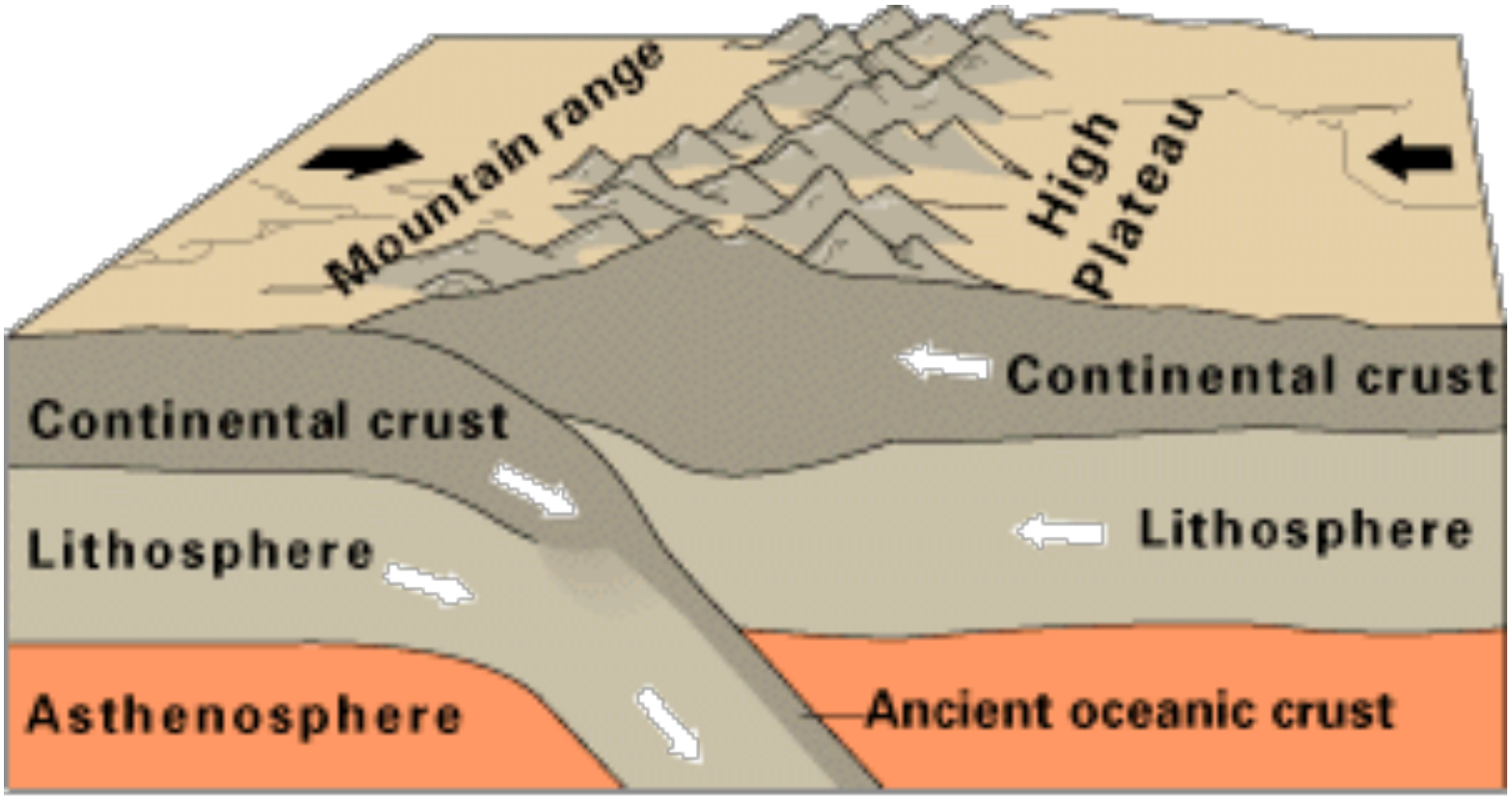

- Seafloor is recycled through a process known as subduction.




Oceanic-continental convergence




Oceanic-oceanic convergence

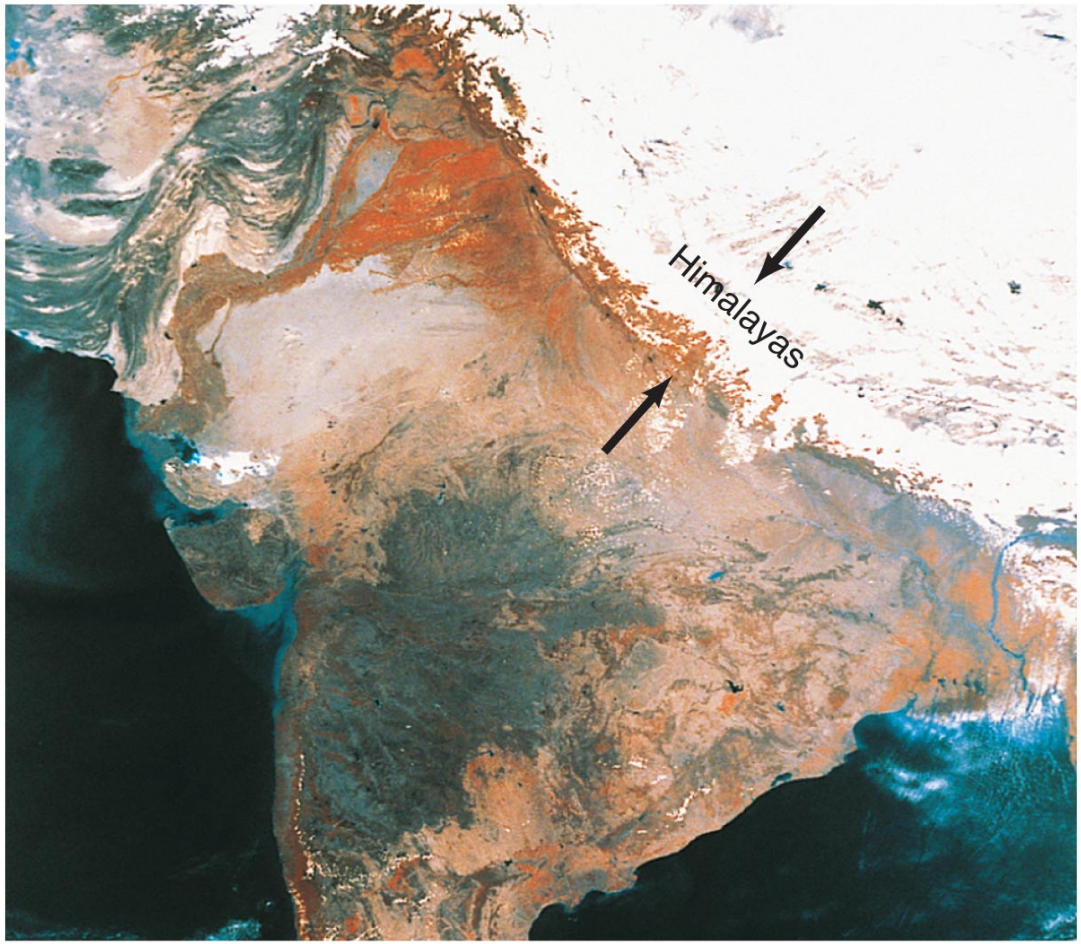



Continental-continental convergence

# Surface Features

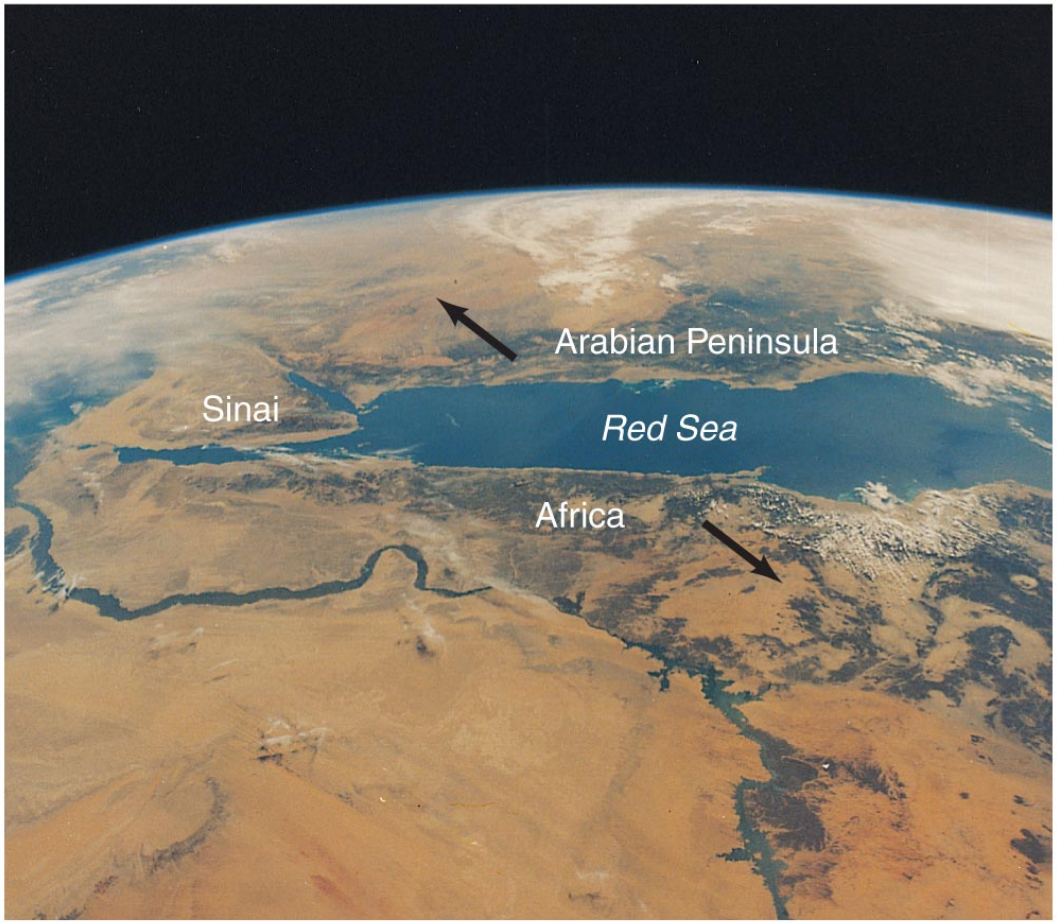

- Major geological features of North America record the history of plate tectonics.

# Surface Features




- The Himalayas formed from a collision between plates.

# Surface Features

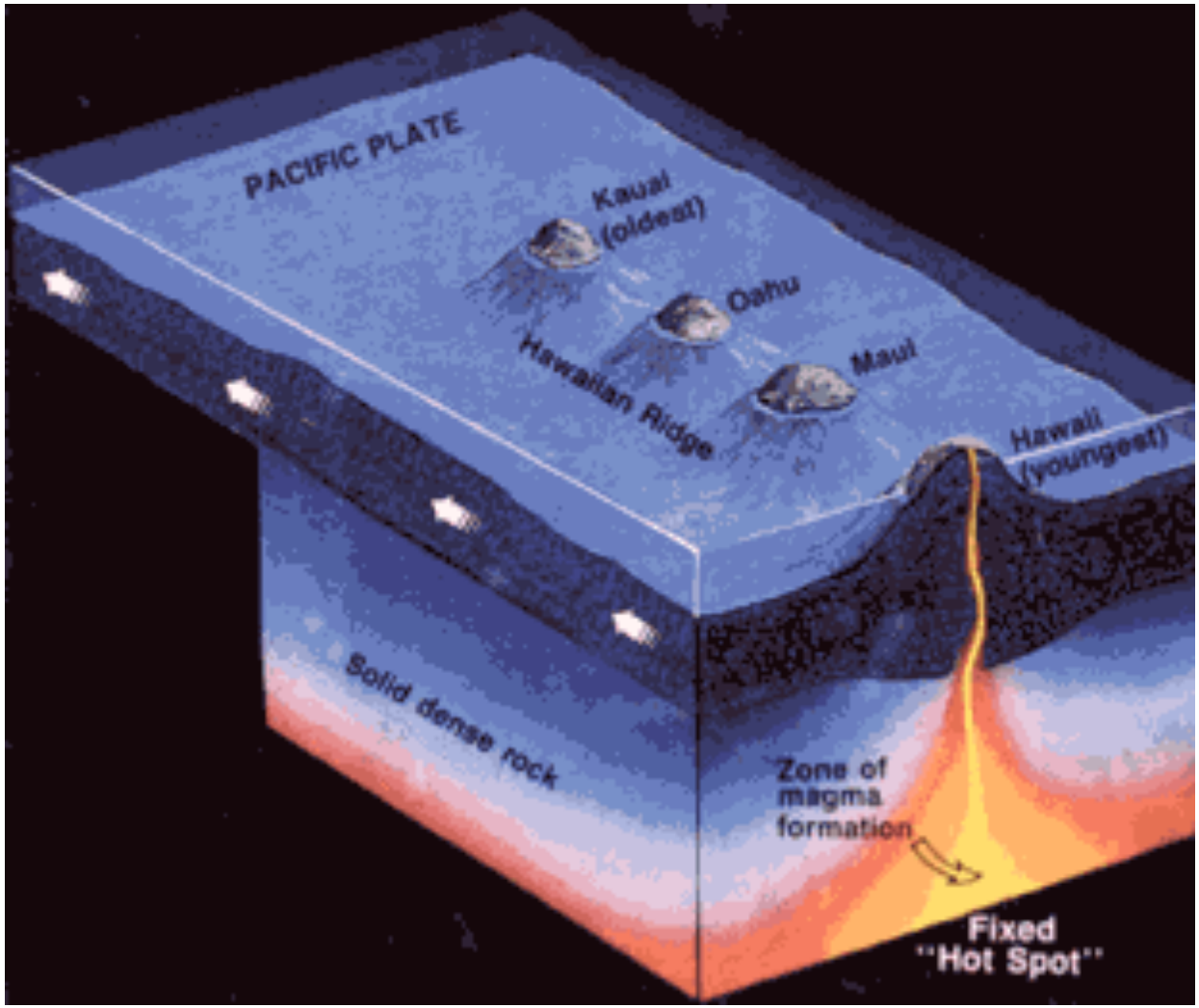



- The Red Sea is formed where plates are pulling apart.

# Rifts, Faults, Earthquakes

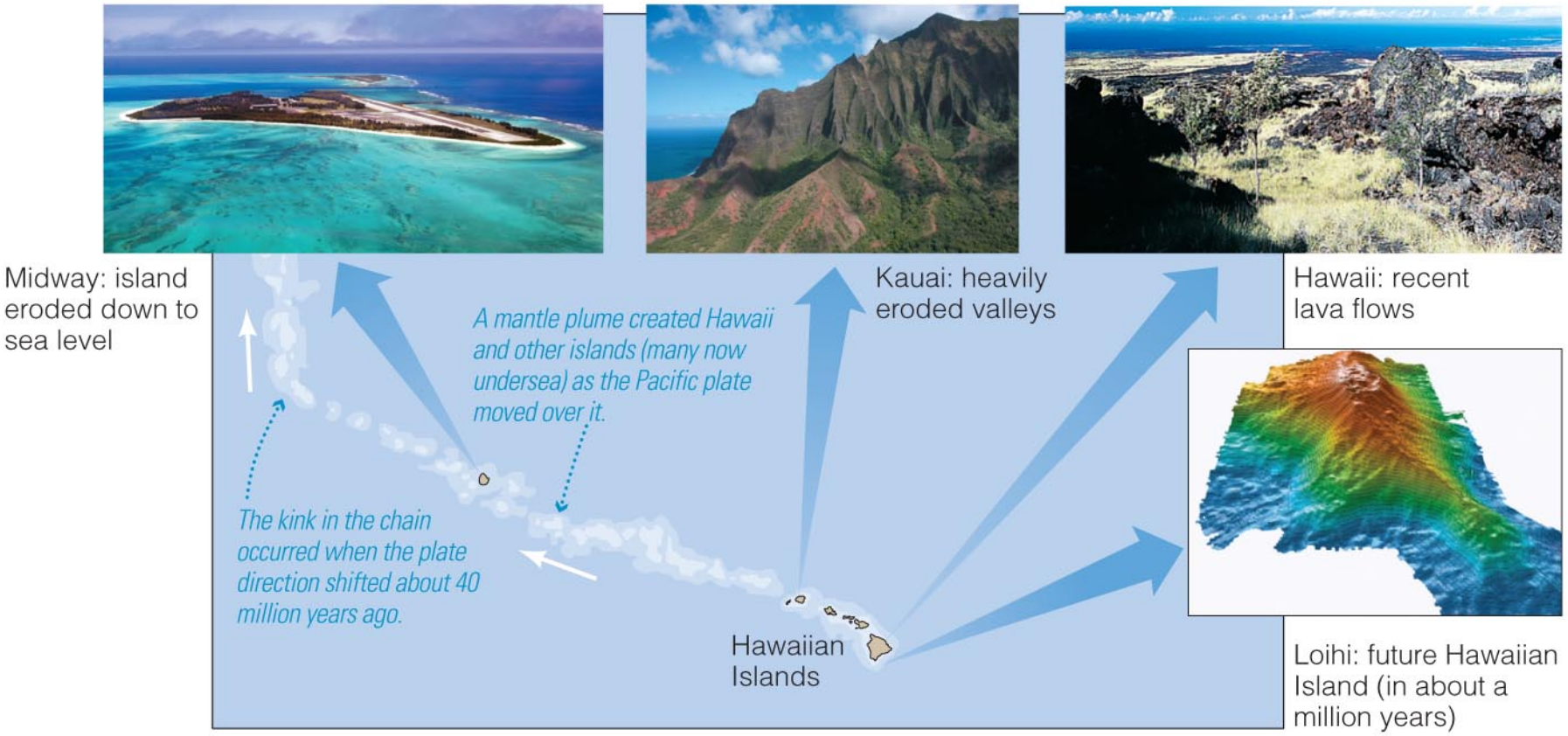

- The San Andreas fault in California is a plate boundary.
- Motion of plates can cause earthquakes.

# Hot Spots



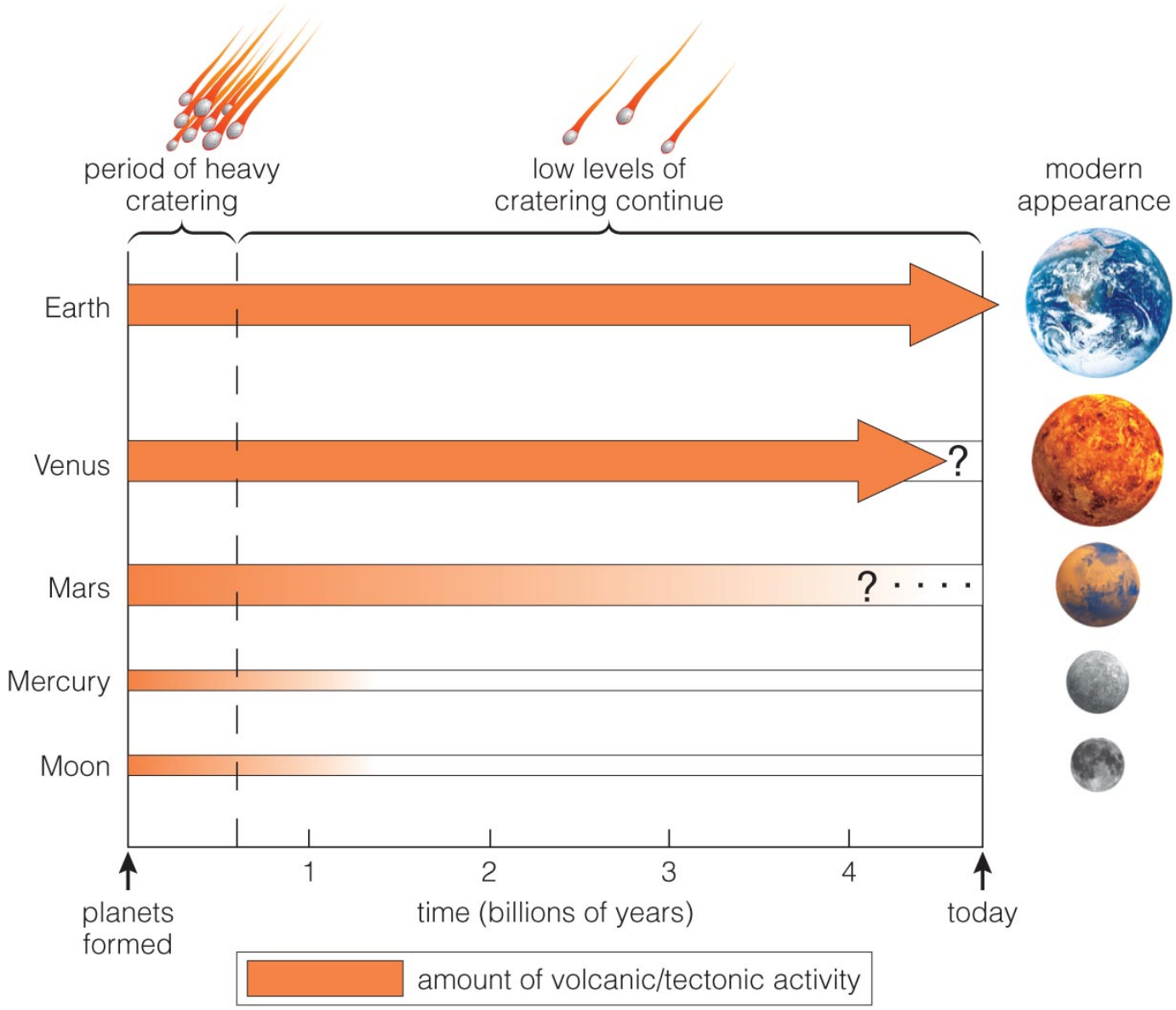

The Hawaiian islands have formed where a plate is moving over a volcanic hot spot.

# Hot Spots

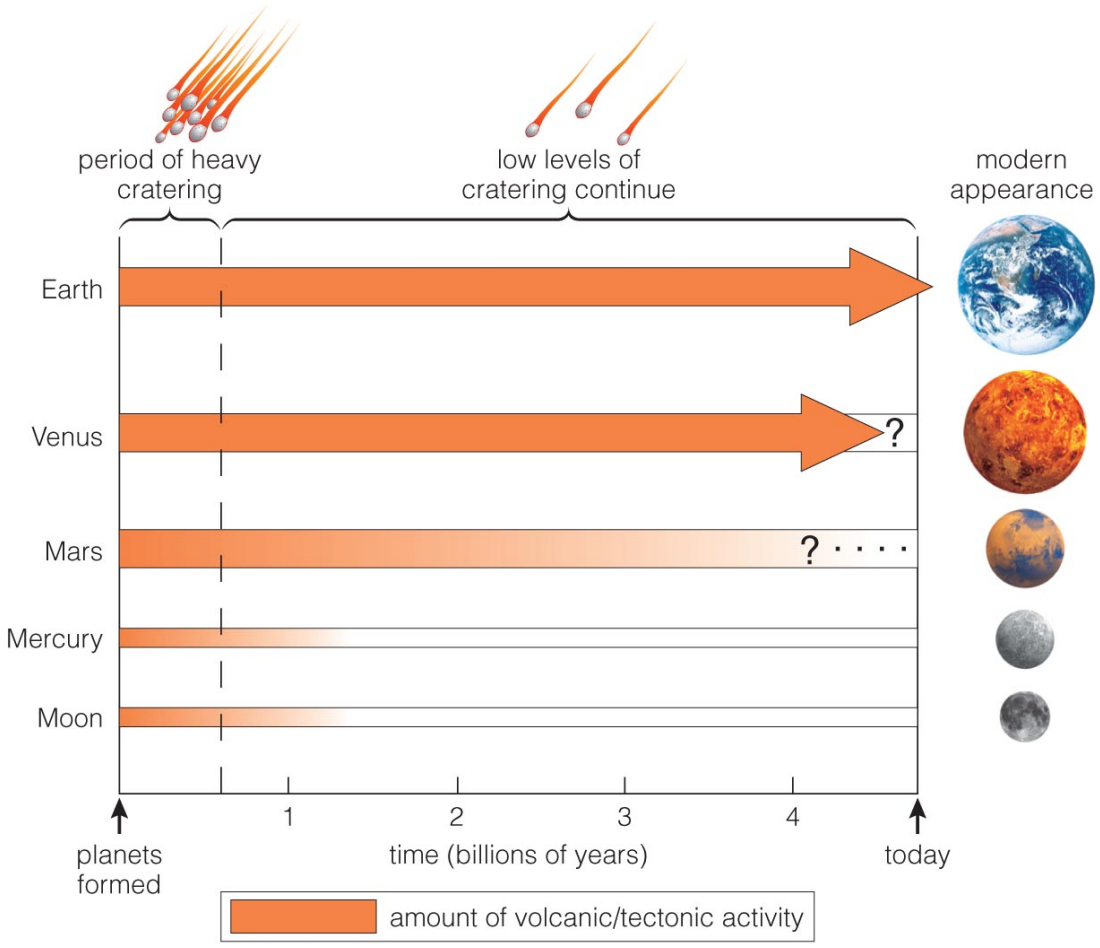



- The Hawaiian islands have formed where a plate is moving over a volcanic hot spot.

# Was Earth's geology destined from birth?



# Earth's Destiny




- Many of Earth's features are determined by its size, rotation, and distance from Sun.
- The reason for plate tectonics is not yet clear.

# What have we learned?

- **How is Earth's surface shaped by plate tectonics?**
  - Measurements of plate motions confirm the idea of continental drift.
  - Plate tectonics is responsible for subduction, seafloor spreading, mountains, rifts, and earthquakes.

# What have we learned?

- **Was Earth's geology destined from birth?**
  - Many of Earth's features are determined by its size, distance from Sun, and rotation rate.
  - The reason for plate tectonics is still a mystery.