Announcements

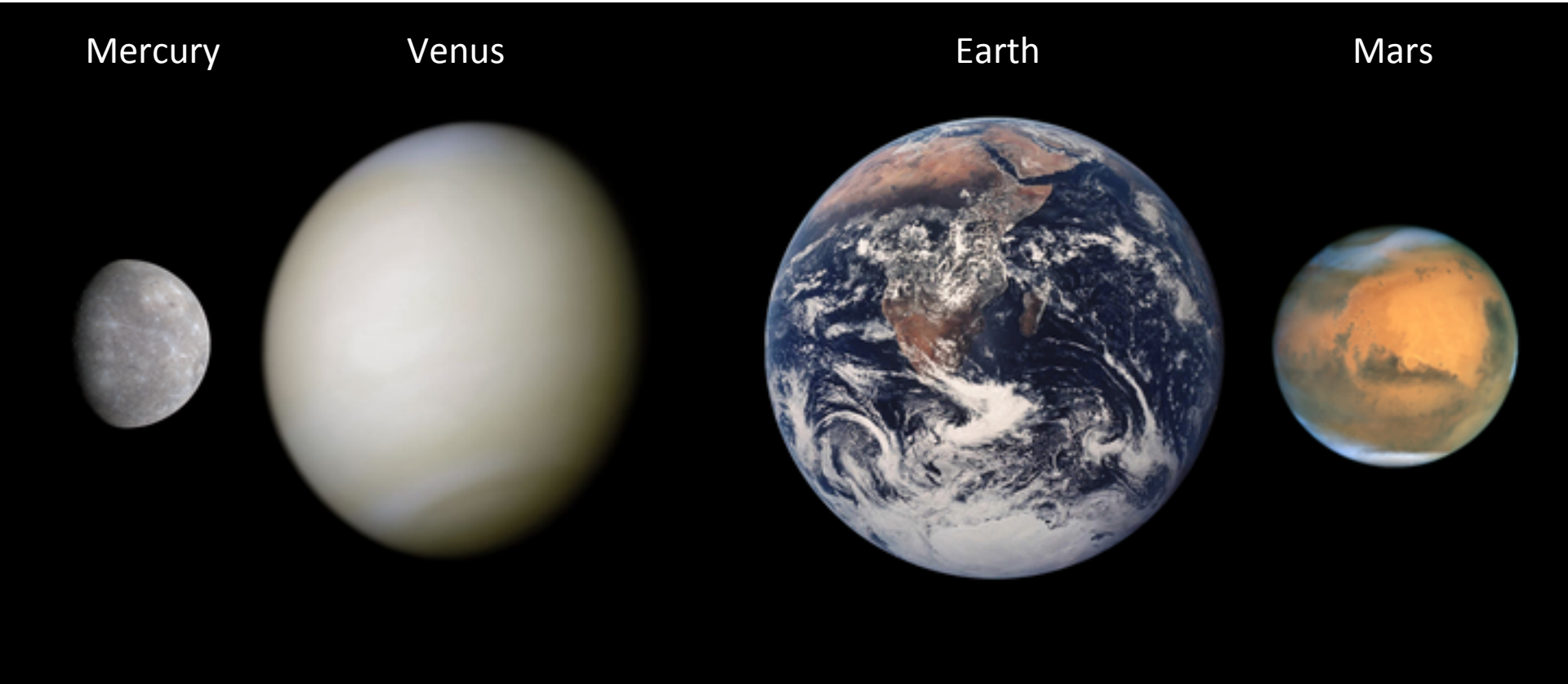
- Midterm 2
  - Grades are posted on D2L
  - Average 72%
  - Scantron forms here if you want them
  - Answers will be posted later today on D2L under Content: Course Handouts
- Upcoming schedule
  - Today: terrestrial planets (Ch 6, some Ch 5)
  - Friday: Jovian planets (Ch 7, some Ch 8)
  - Monday: Extrasolar planets (Section 4.4)
- Later next week: start Chapter 14, the Milky Way Galaxy

Astronomy 103

The terrestrial planets

Please read chapter 6

- **Terrestrial planets**: Mercury, Venus, Earth, and Mars
- We'll start by looking at the most well-known terrestrial planet, Earth, and see how each of the others differ
- The Earth is discussed in more detail in Chapter 5 of the text, which we mostly won't cover. Just the basics here.



Earth

Radius ~ 6400 km

Density ~ 5000 kg/m^3 – five times density of water

Has a thick **atmosphere** of mostly nitrogen and oxygen

Has active **volcanoes**

Has a **magnetic field**

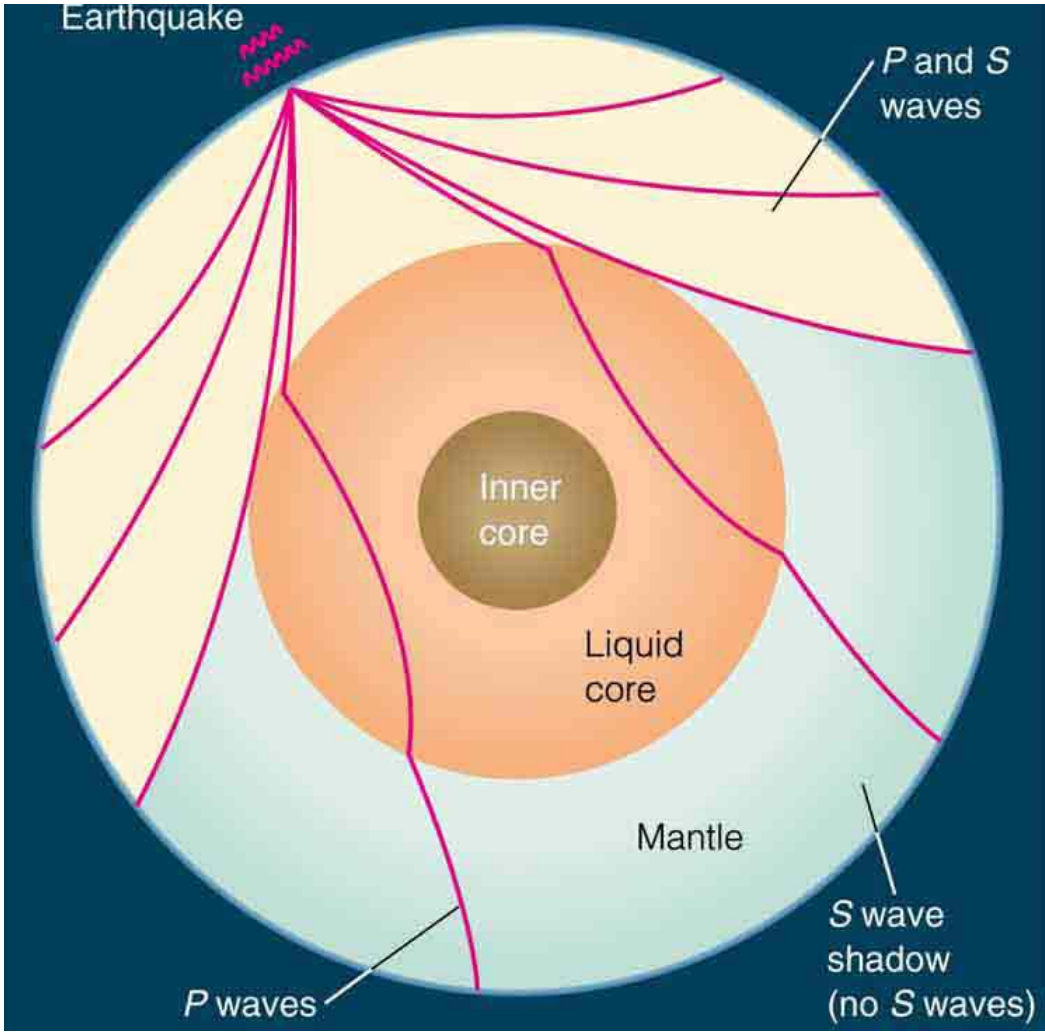
Structure of the Earth

Inner core is solid iron

Outer core is liquid iron and nickel.

Mantle is mostly molten rock (silicon and oxygen)

Crust (30 km thick) is solid rock.



Know this structure from looking at **earthquake waves**.

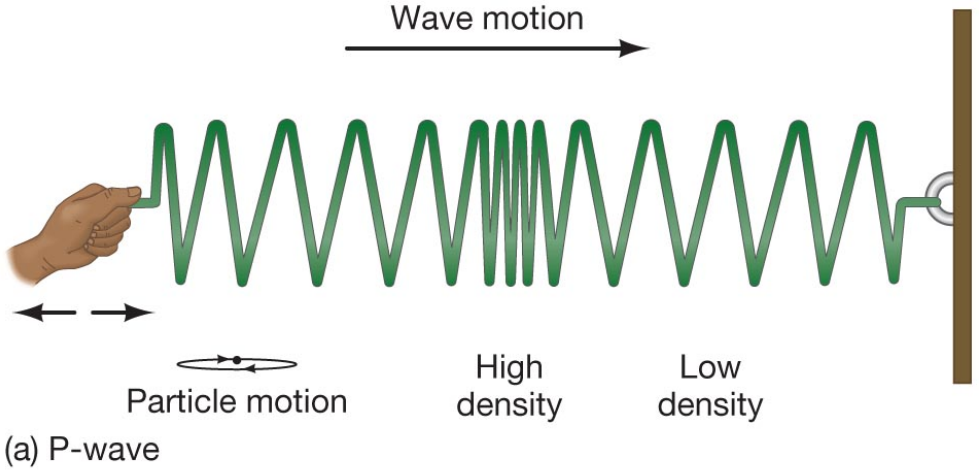
Structure of the Earth

Seismic waves:

- **Earthquakes produce both pressure and shear waves.**
- **Pressure waves will travel through both liquids and solids.**
- **Shear waves will not travel through liquids, as liquids do not resist shear forces.**
- **Wave speed depends on density of material.**

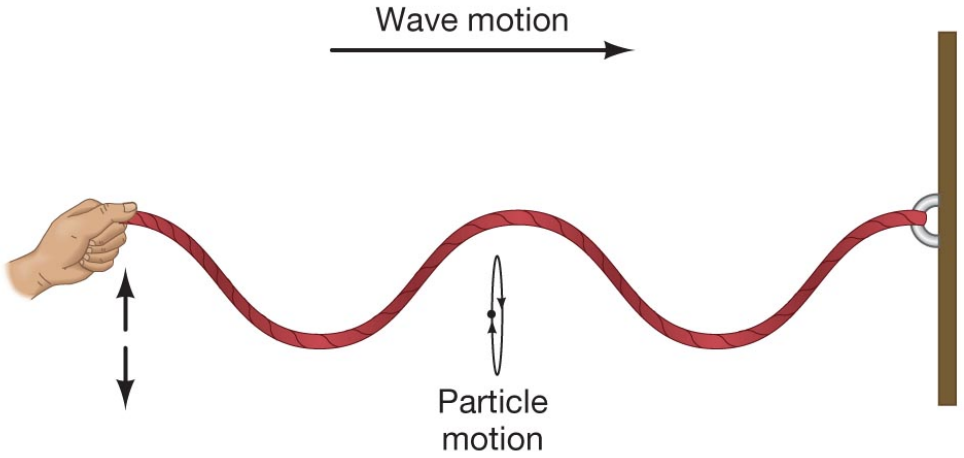
Structure of the Earth

The pressure wave is a longitudinal wave: material is compressed in the direction of the wave motion.



(a) P-wave

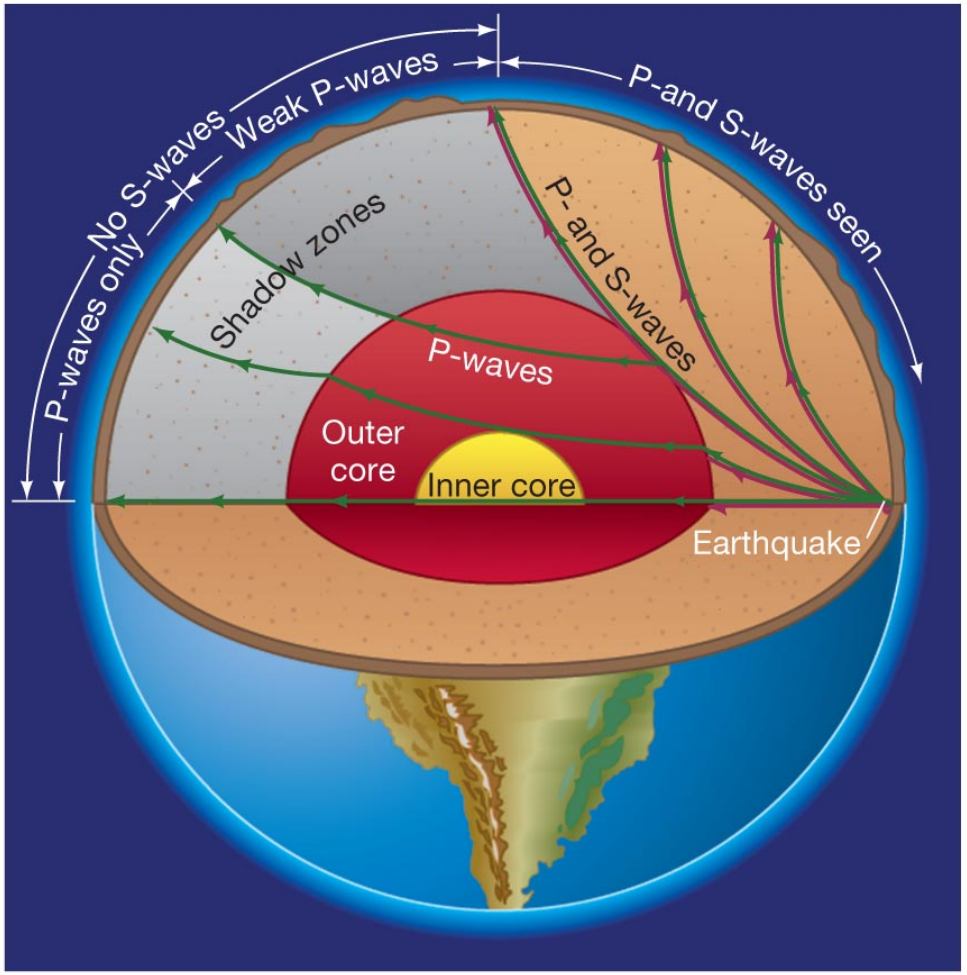
The shear wave is a transverse wave: material is compressed perpendicular to wave motion. A shear wave cannot propagate within a liquid.



(b) S-wave

Structure of the Earth

Can use pattern of reflections during earthquakes to deduce interior structure of Earth.



Structure of the Earth

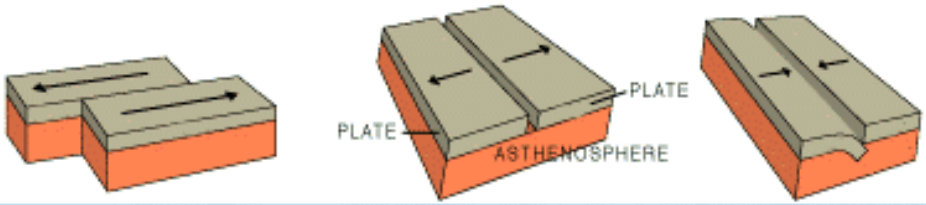
Combination of solid inner iron core and liquid outer iron core makes Earth's magnetic field. Without a liquid core (that is in motion), we would have no magnetic field.

The mantle has large magma flows. Sometime these magma flows get close to the surface, giving volcanoes.

These flows in the mantle drag the stuff on the crust along with them. This makes continents move over time.

This is known as the theory of continental drift, one of the great discoveries in Earth science.

Plate Tectonics



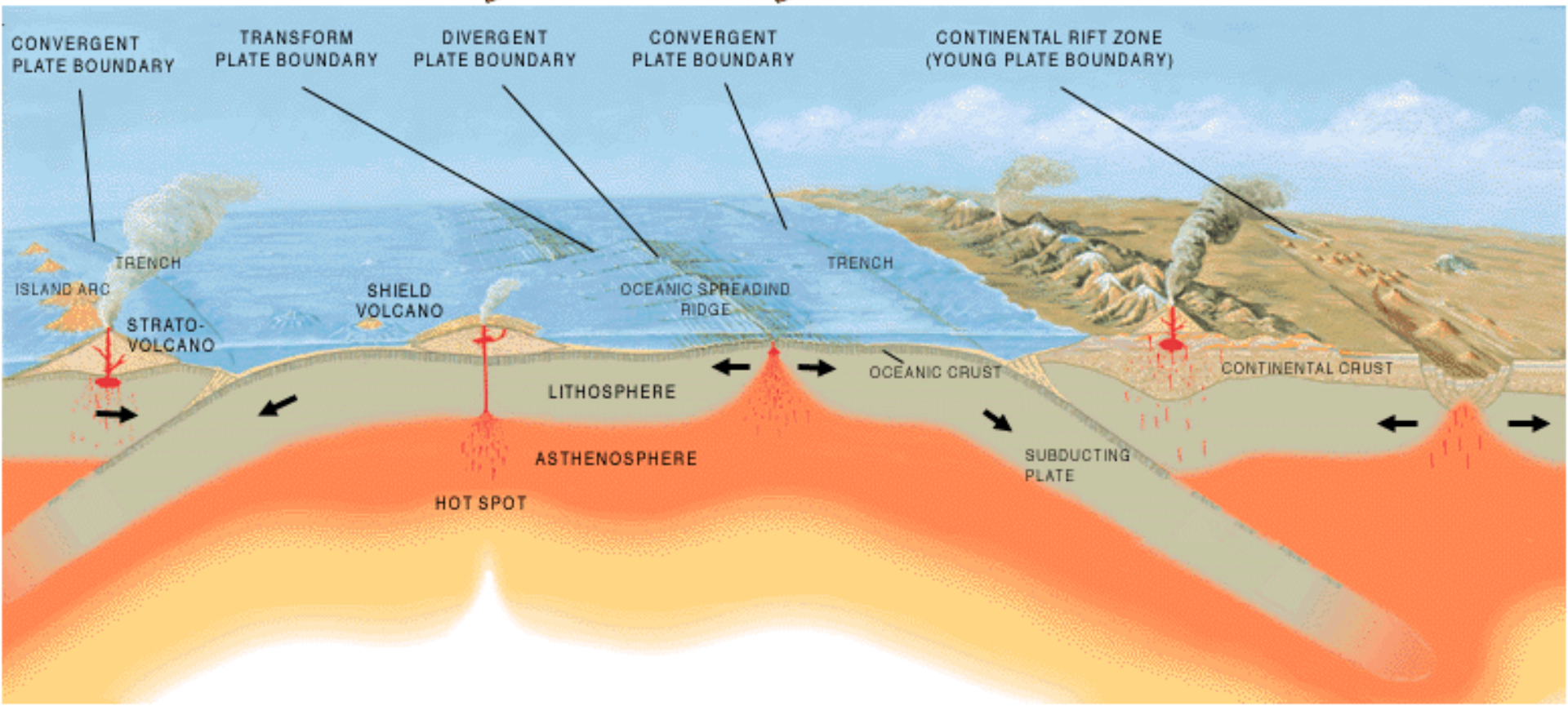
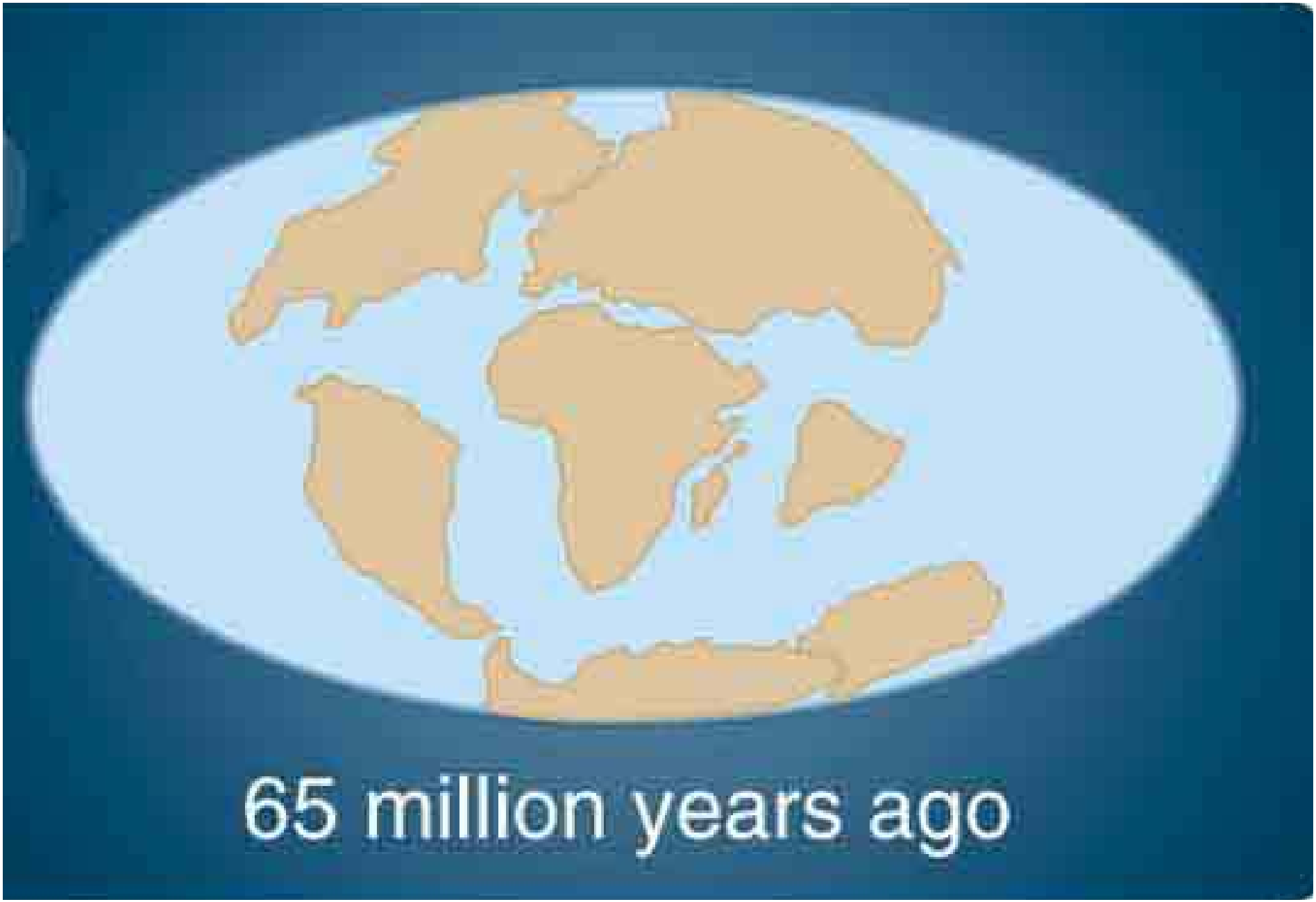


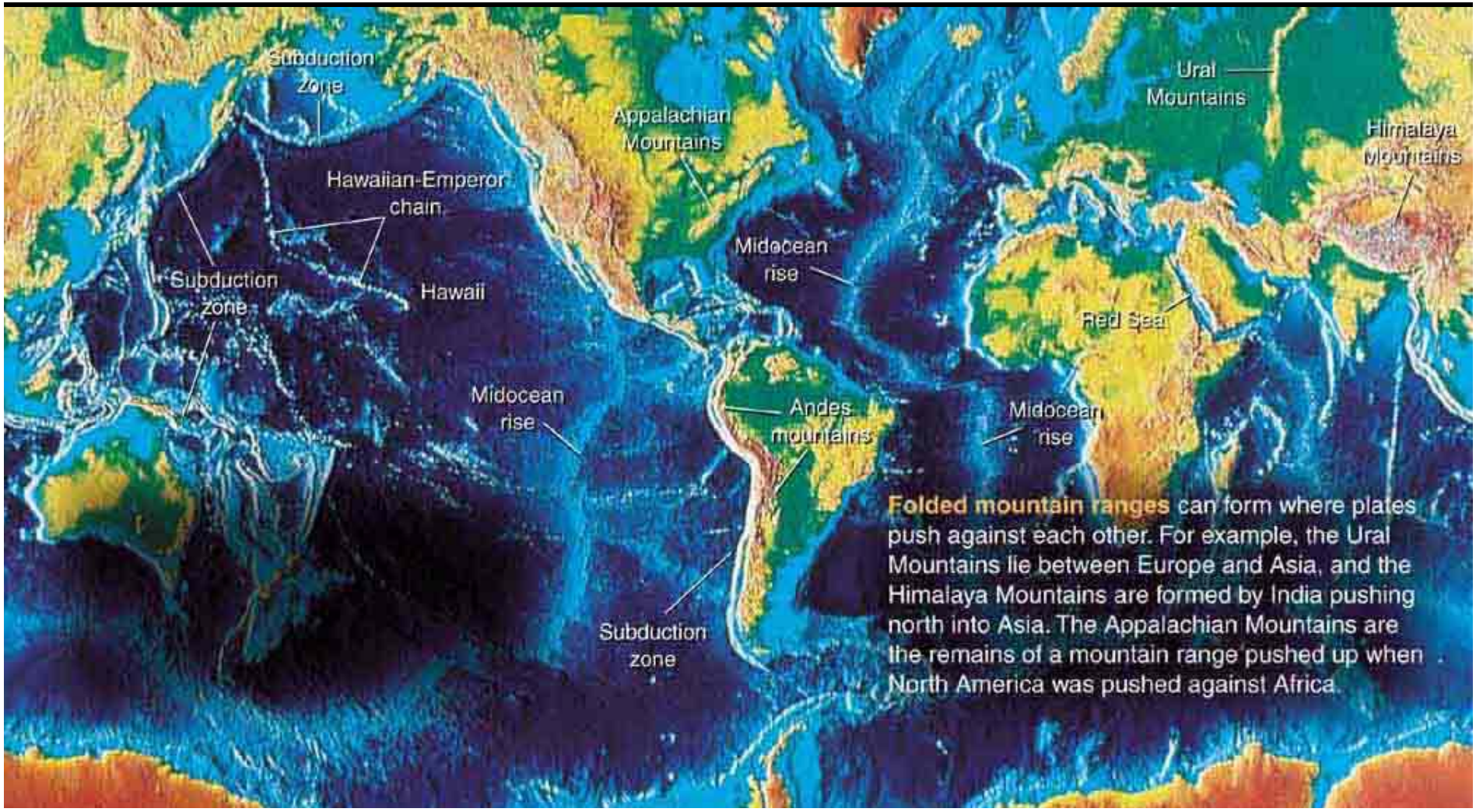
Plate tectonics is driven by the motion of magma in the Earth's mantle. Leads to motion of continents over time.


Pangaea
200 million years ago


Laurasia
Gondwanaland
135 million years ago


65 million years ago


Today


Subduction zone
Hawaiian-Emperor chain
Subduction zone
Hawaii
Midocean rise
Appalachian Mountains
Midocean rise
Andes mountains
Subduction zone
Ural Mountains
Himalaya Mountains
Red Sea
Midocean rise
Folded mountain ranges can form where plates push against each other. For example, the Ural Mountains lie between Europe and Asia, and the Himalaya Mountains are formed by India pushing north into Asia. The Appalachian Mountains are the remains of a mountain range pushed up when North America was pushed against Africa.

Mercury

Radius ~ 2400 km

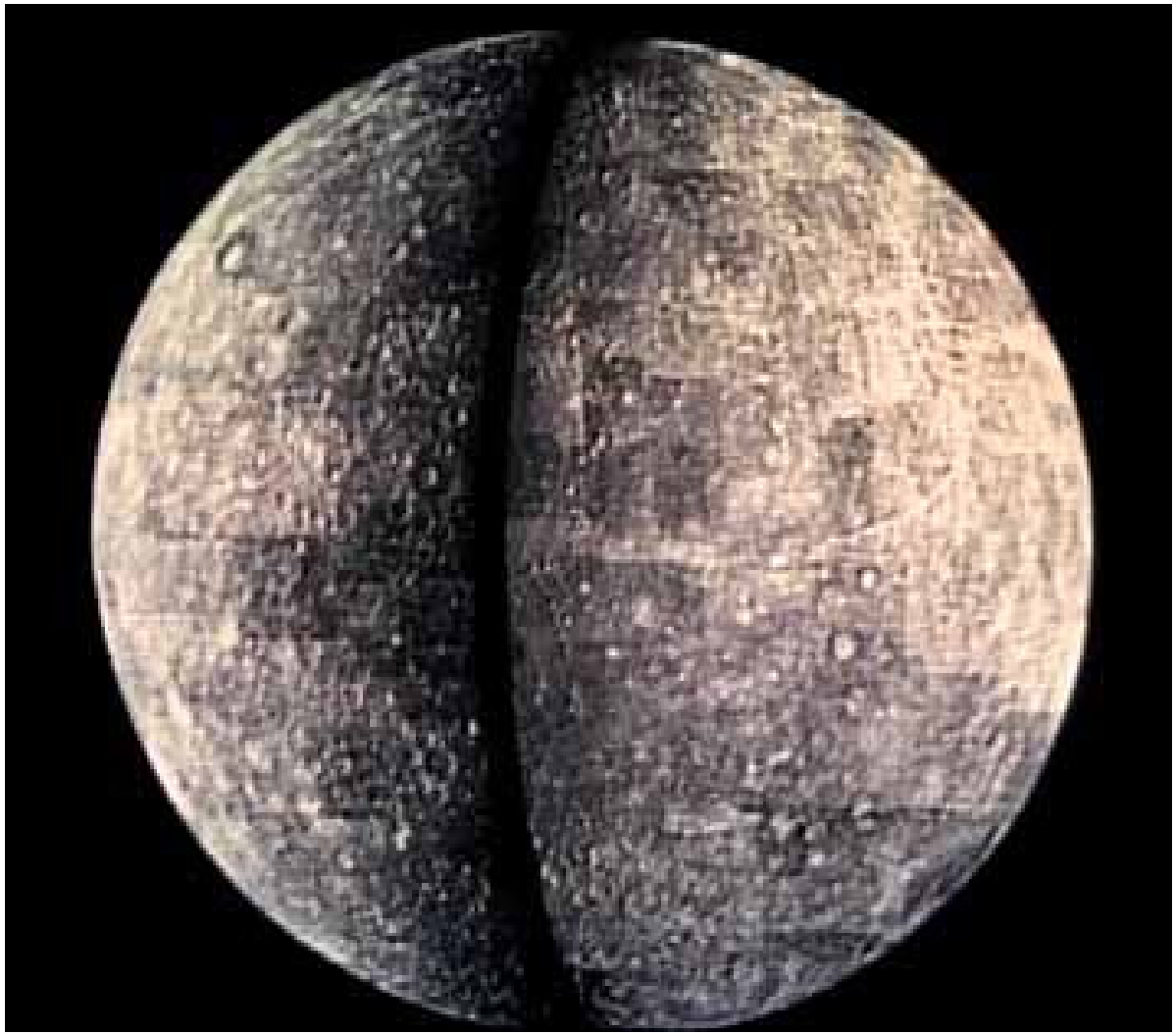
Mass ~ 5% of Earth

Density 5400 kg/m^3 – about the same as Earth

No atmosphere

No volcanoes

Has a magnetic field



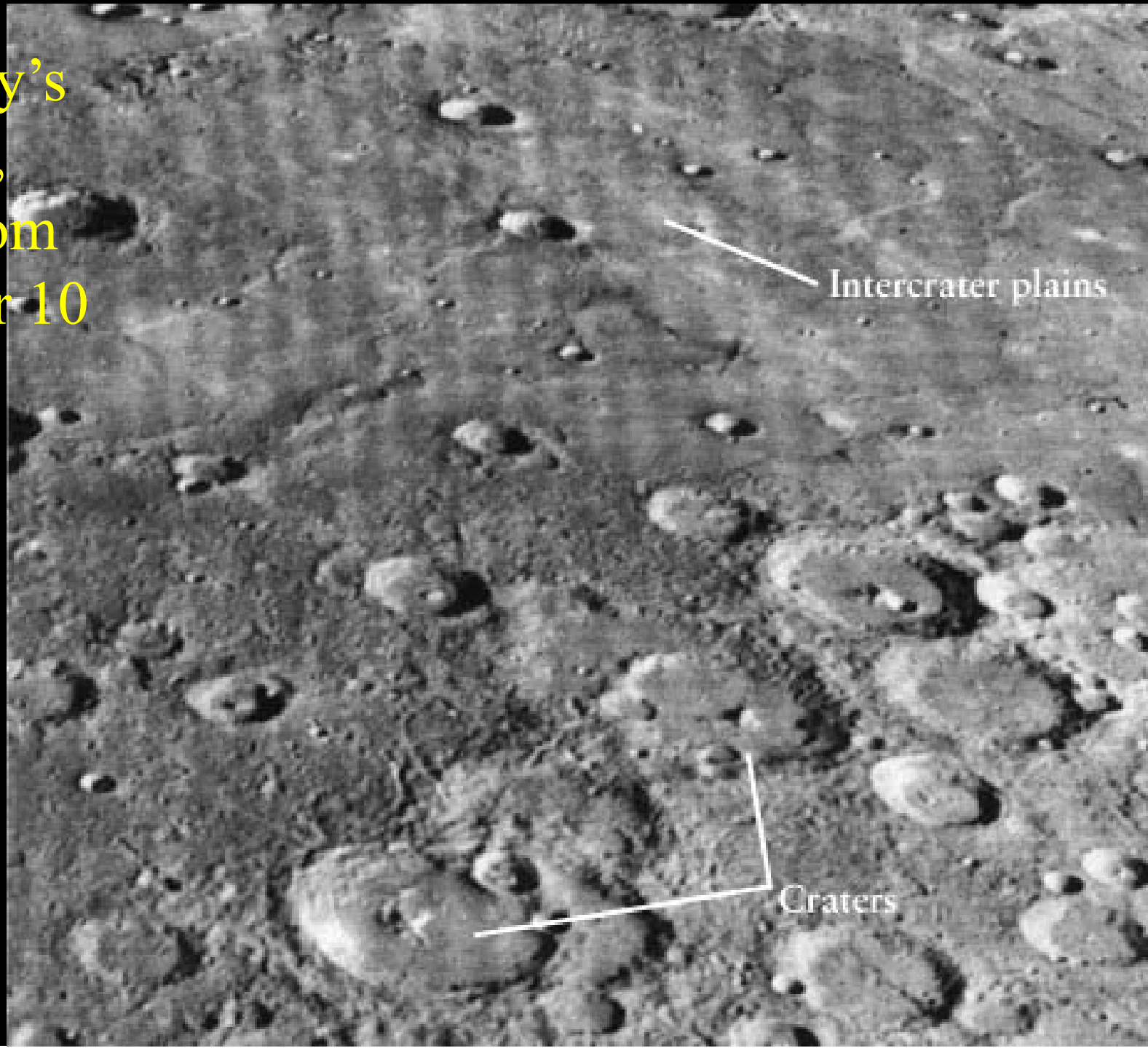
Mercury

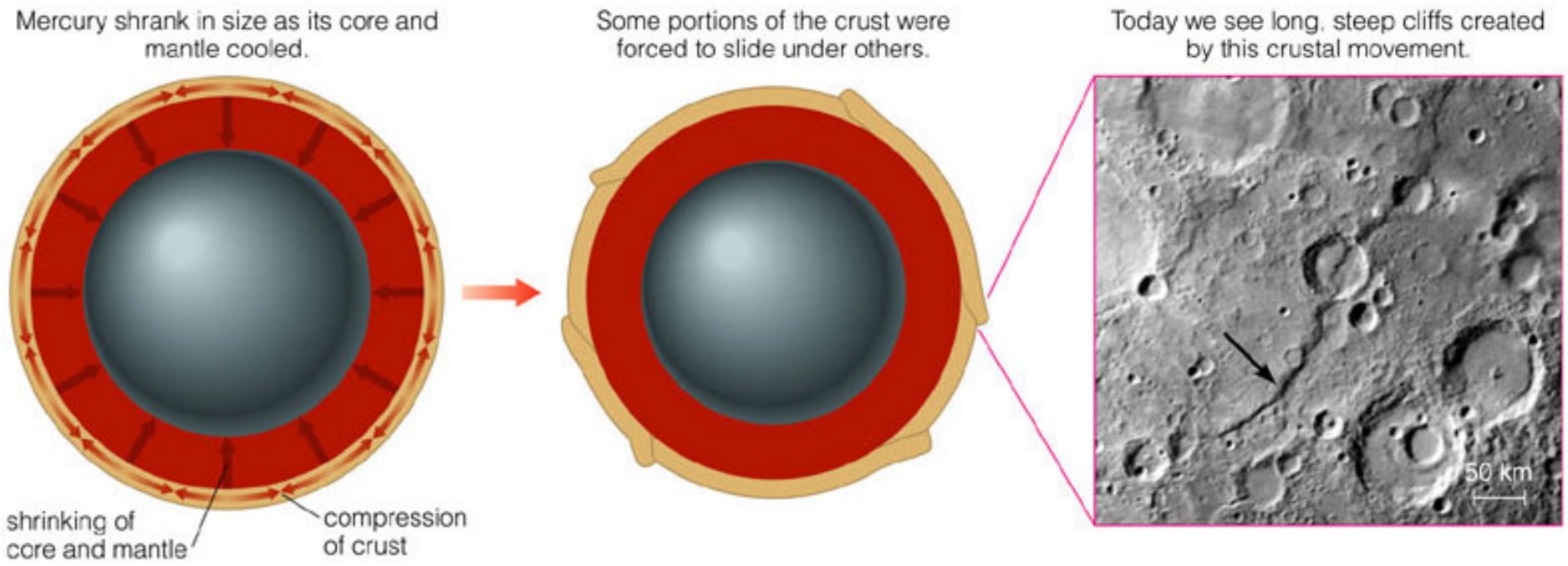
- Temperature on Mercury varies drastically! On the day side it is hot, 700K, but on the night side it is cold, 100 K (-200 F)

- Wide variation in temperature because there is no atmosphere to trap heat and moderate temperatures

- Because Mercury has no atmosphere and no water, there is no erosion, so the surface is heavily cratered like the Moon

Mercury's surface, seen from Mariner 10



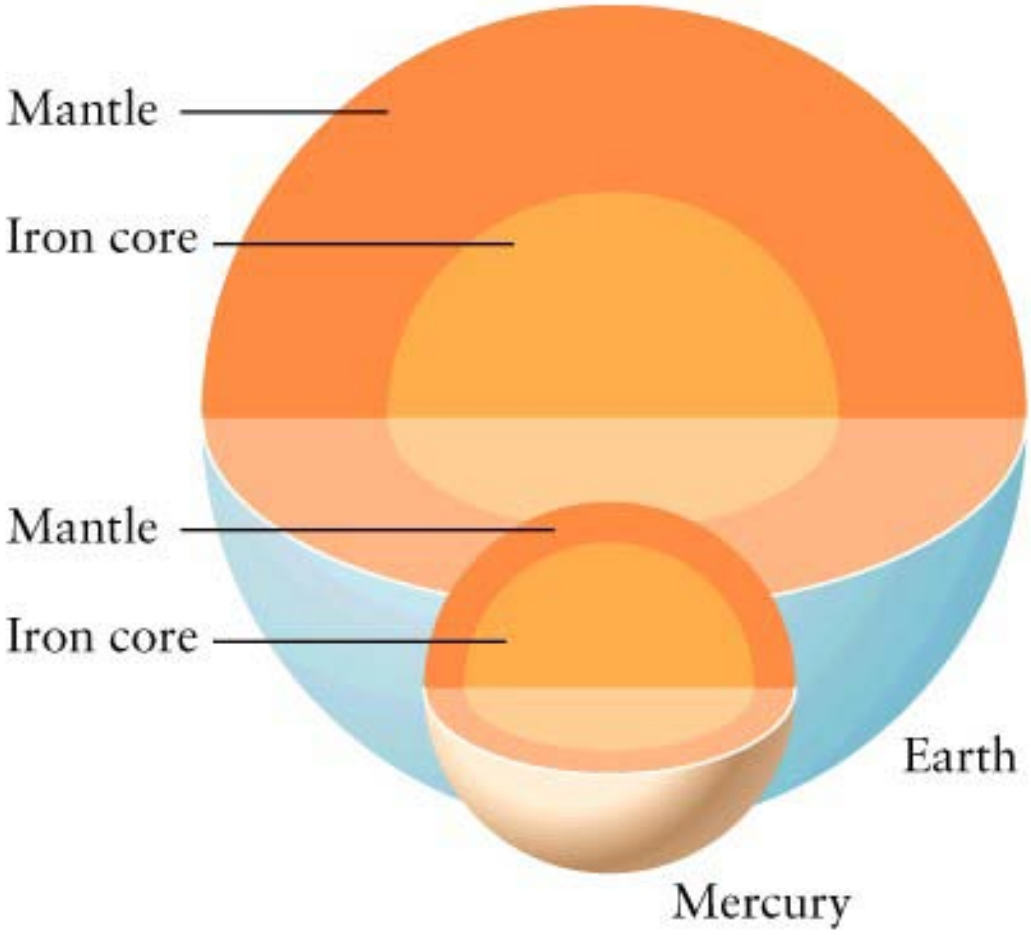


- Mercury has one feature unique to it and not found on the Moon. It has scarps or cliffs.
- These scarps result from the cooling (and shrinking) of Mercury, which resulted in compression and cracking of the surface.

Mercury

Mercury has a magnetic field that is 1/100 of the strength of Earth's field.

So it has a liquid iron core like the Earth



Venus

Radius ~ 6100 km

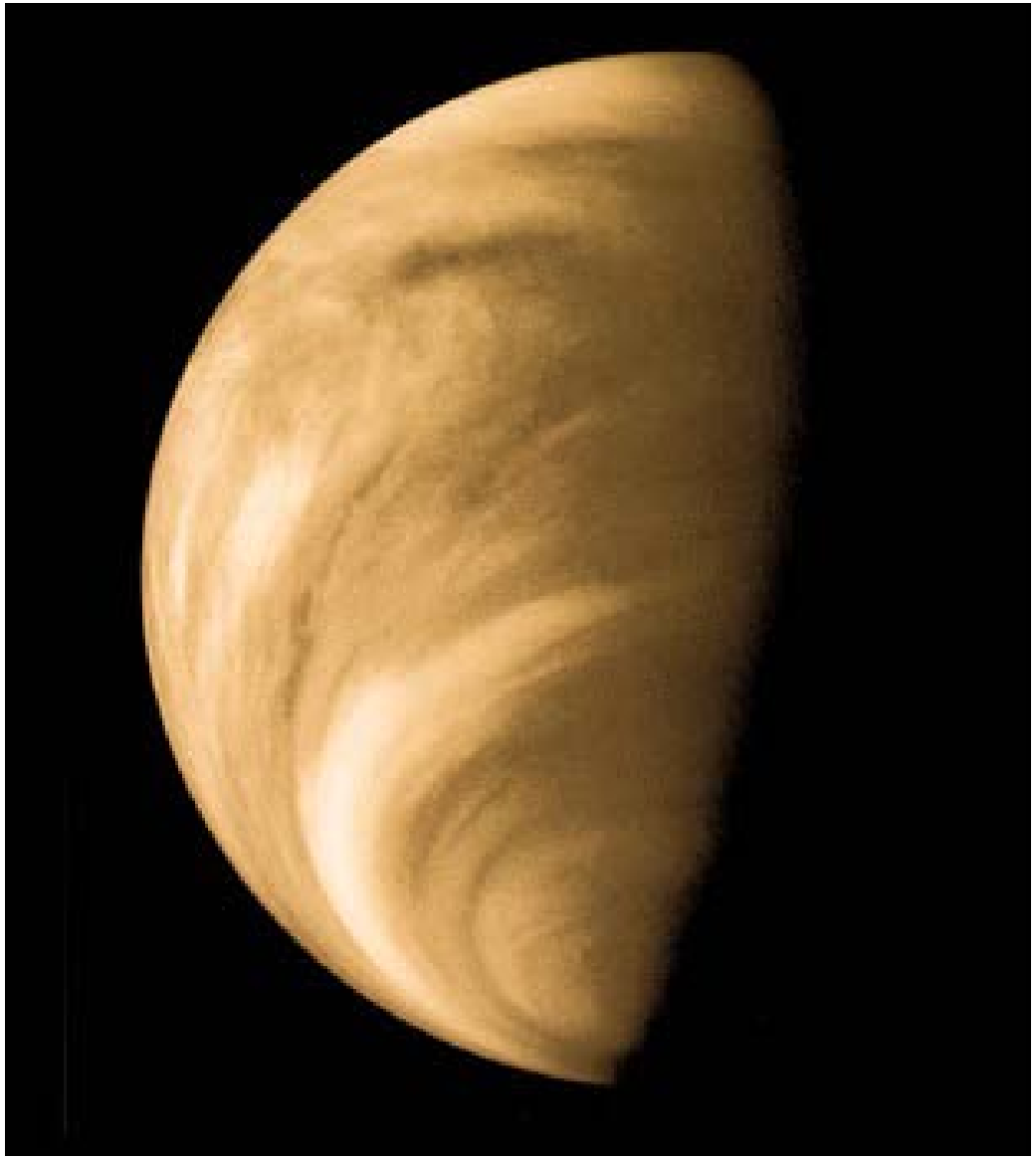
Mass ~ 82% of Earth

Density ~ 5300 kg/m^3 – about the same as Earth

Very thick atmosphere

Many volcanic features, indirect evidence of current volcanic activity

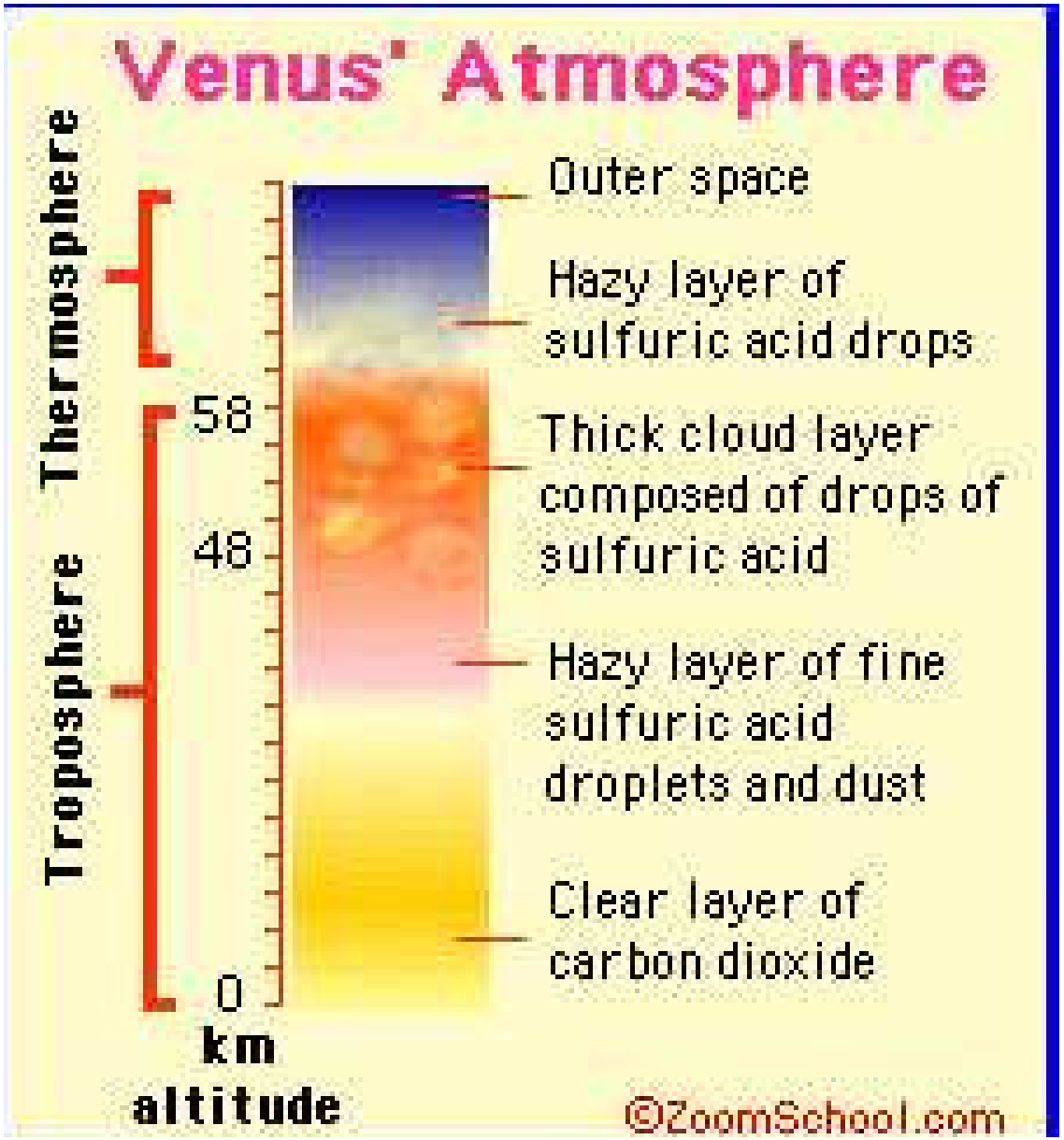
No magnetic field



Venus

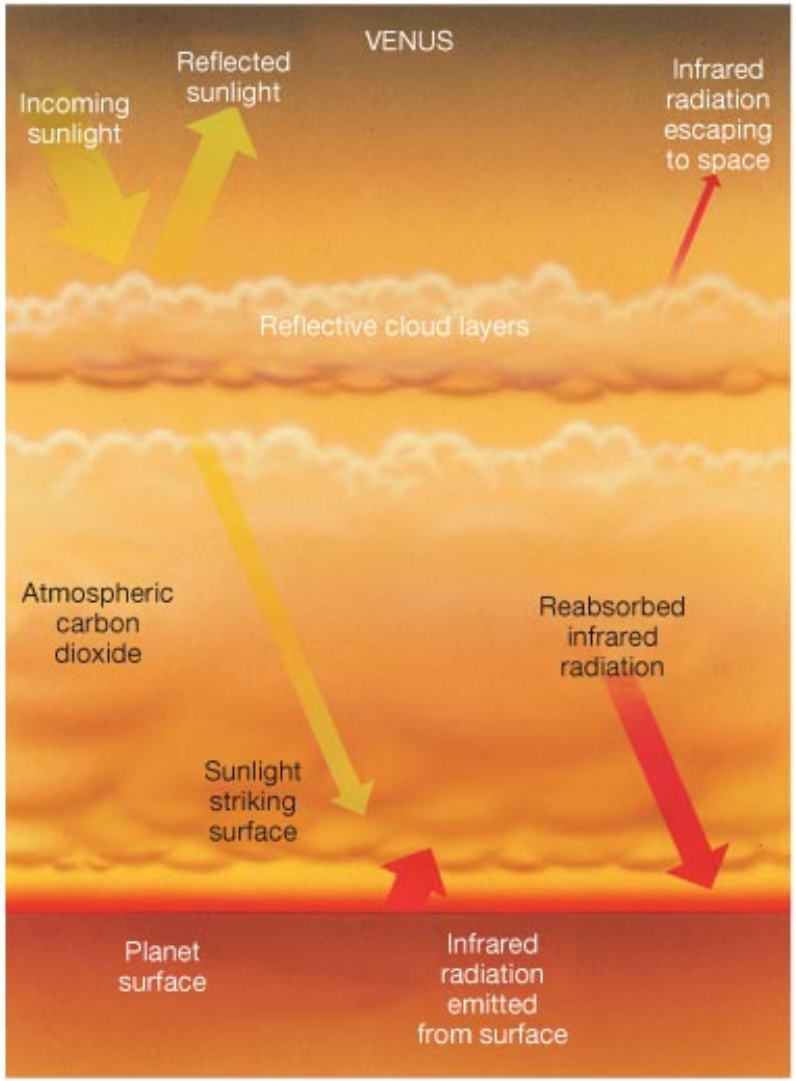
Venus has a large, thick atmosphere which covers the entire surface with clouds of sulfuric acid.

Its atmosphere is 90x thicker than the Earth's: pressure on the surface is 90 times higher than on Earth



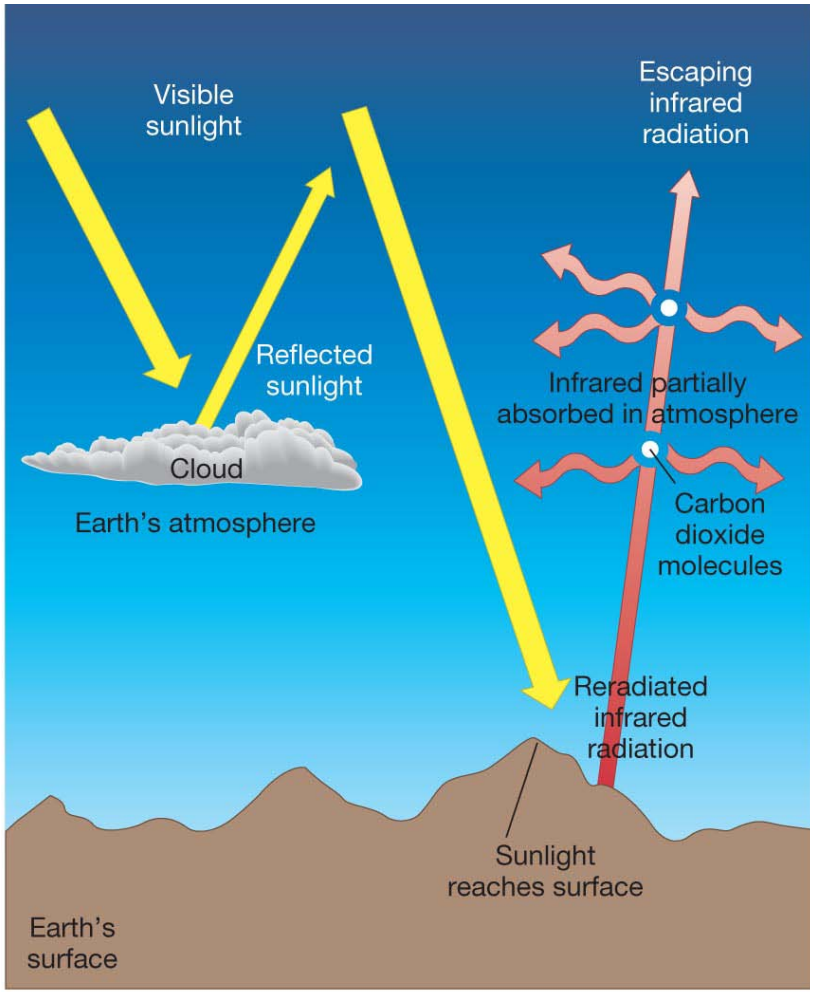
Venus

- Venus is HOT! Its average temperature is 730 K – hotter than Mercury and hot enough to melt lead
- This is because the atmosphere traps heat via the greenhouse effect
- Sunlight strikes surface and is converted to heat, which is absorbed and re-radiated by carbon dioxide in the atmosphere instead of radiating out into space
- Also operates on Earth

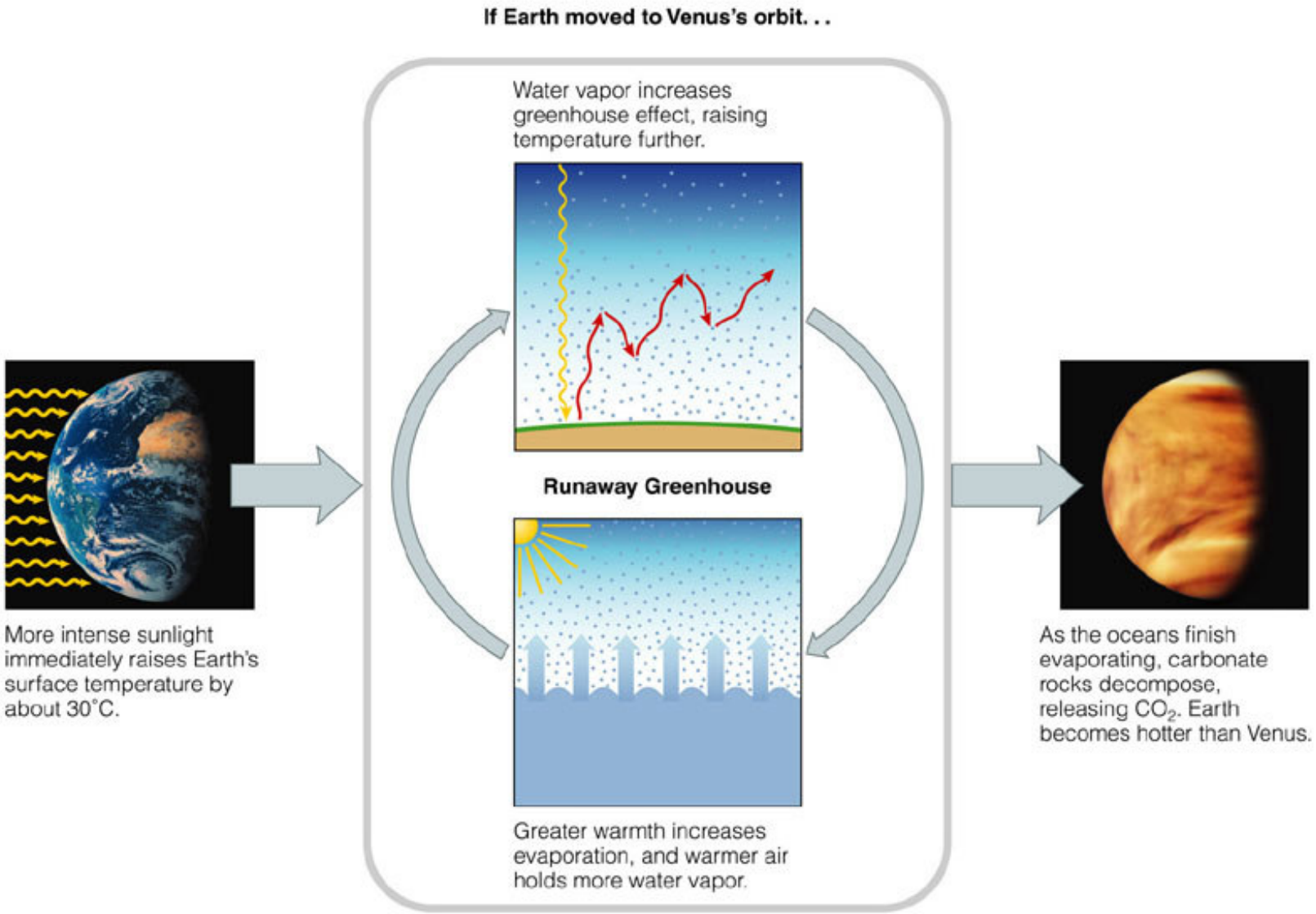


The greenhouse effect on Earth

- Greenhouses gases (carbon dioxide, water vapor, methane) in the atmosphere trap heat
- Sunlight strikes surface and is converted to heat, which is absorbed and re-radiated in the atmosphere instead of radiating out into space
- An increase in the amount of greenhouse gases in the atmosphere increases the heat trapped

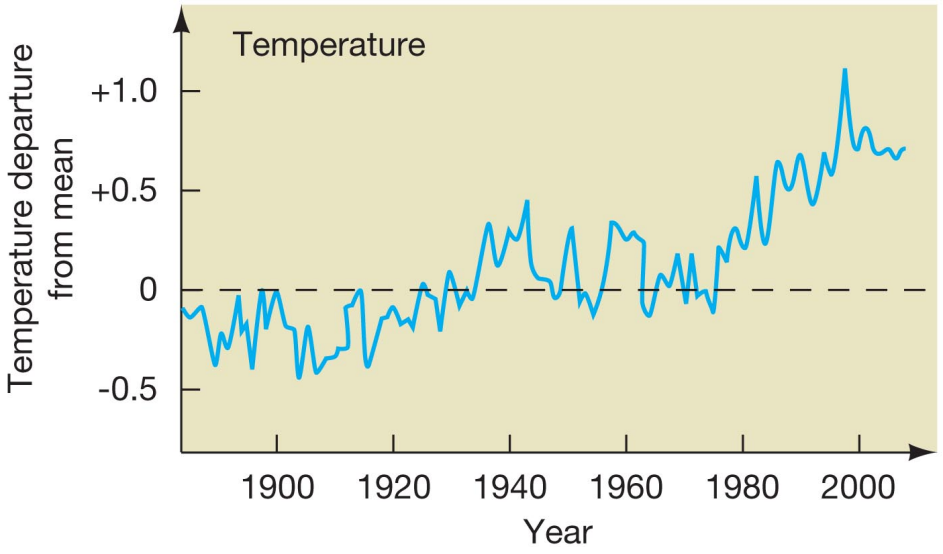


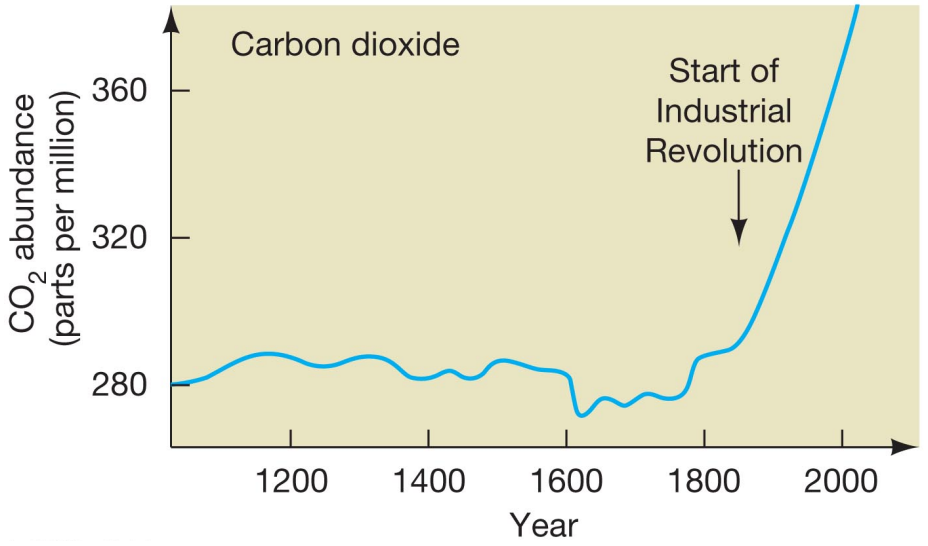
Runaway Greenhouse Effect



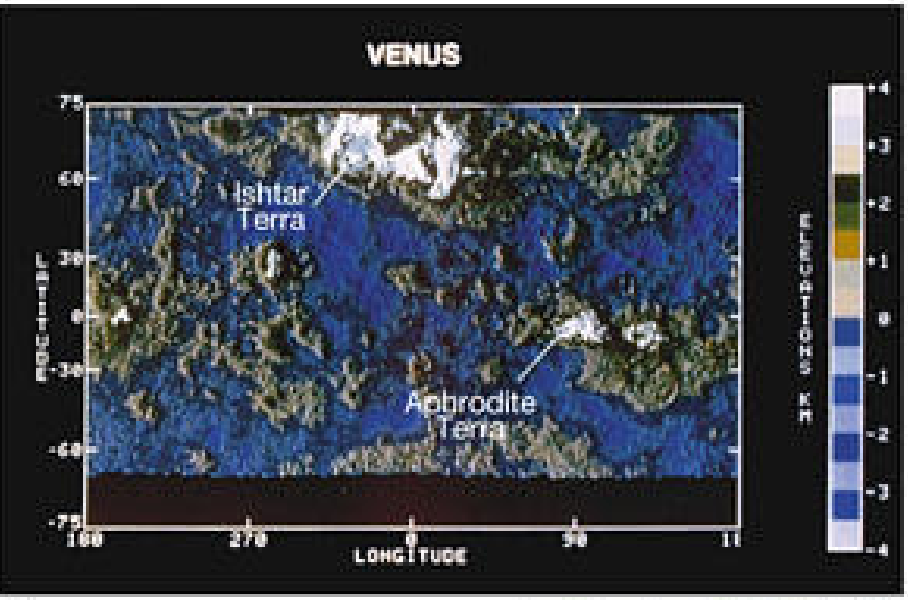
The Greenhouse Effect and Global Warming

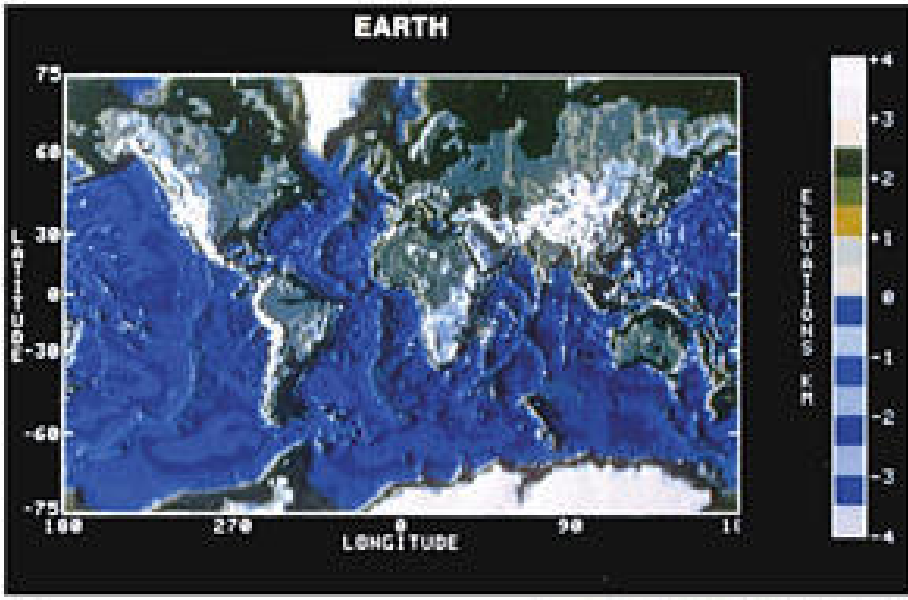
There is extremely strong evidence that Earth is getting warmer, and that this warming is related to the increase in atmospheric carbon dioxide.





Venus



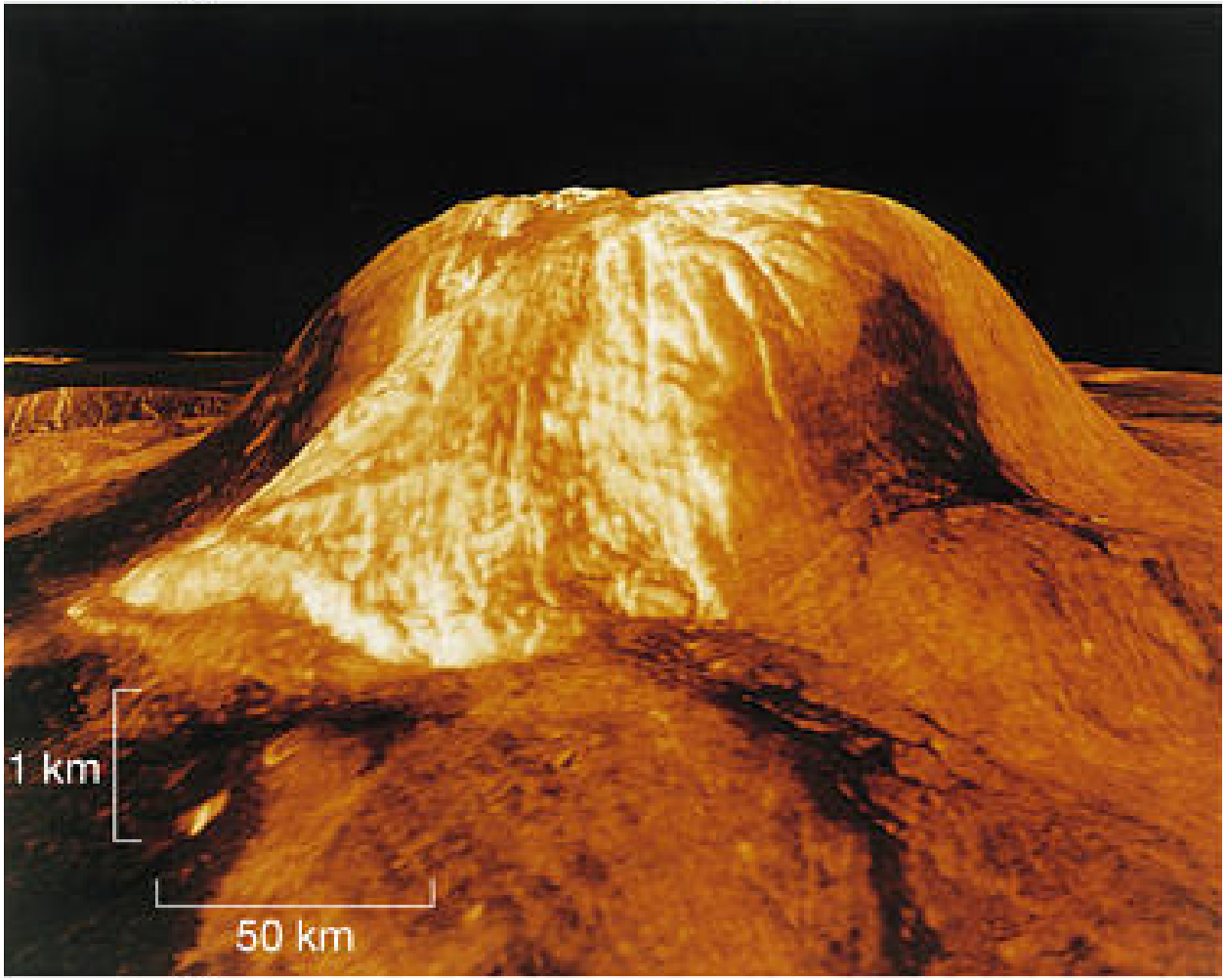


No plate tectonics on Venus – possible causes:

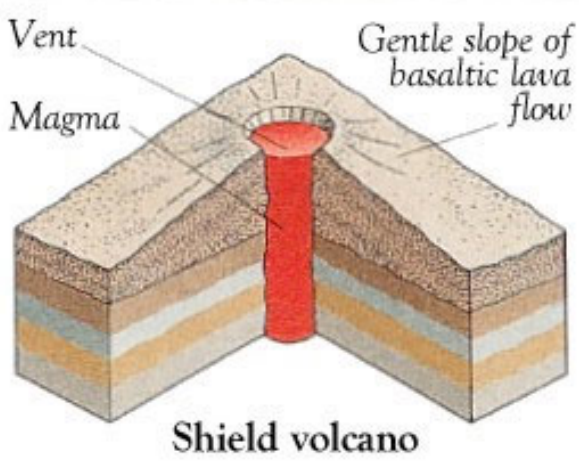
- Slow cooling – weak convection
- Soft crust – very plastic, so it doesn't crack
- No water – lack of lubricant

However, Venus has many volcanoes, and shows indirect evidence of current volcanic activity – young surface, changes in the sulfur content of the atmosphere, etc.

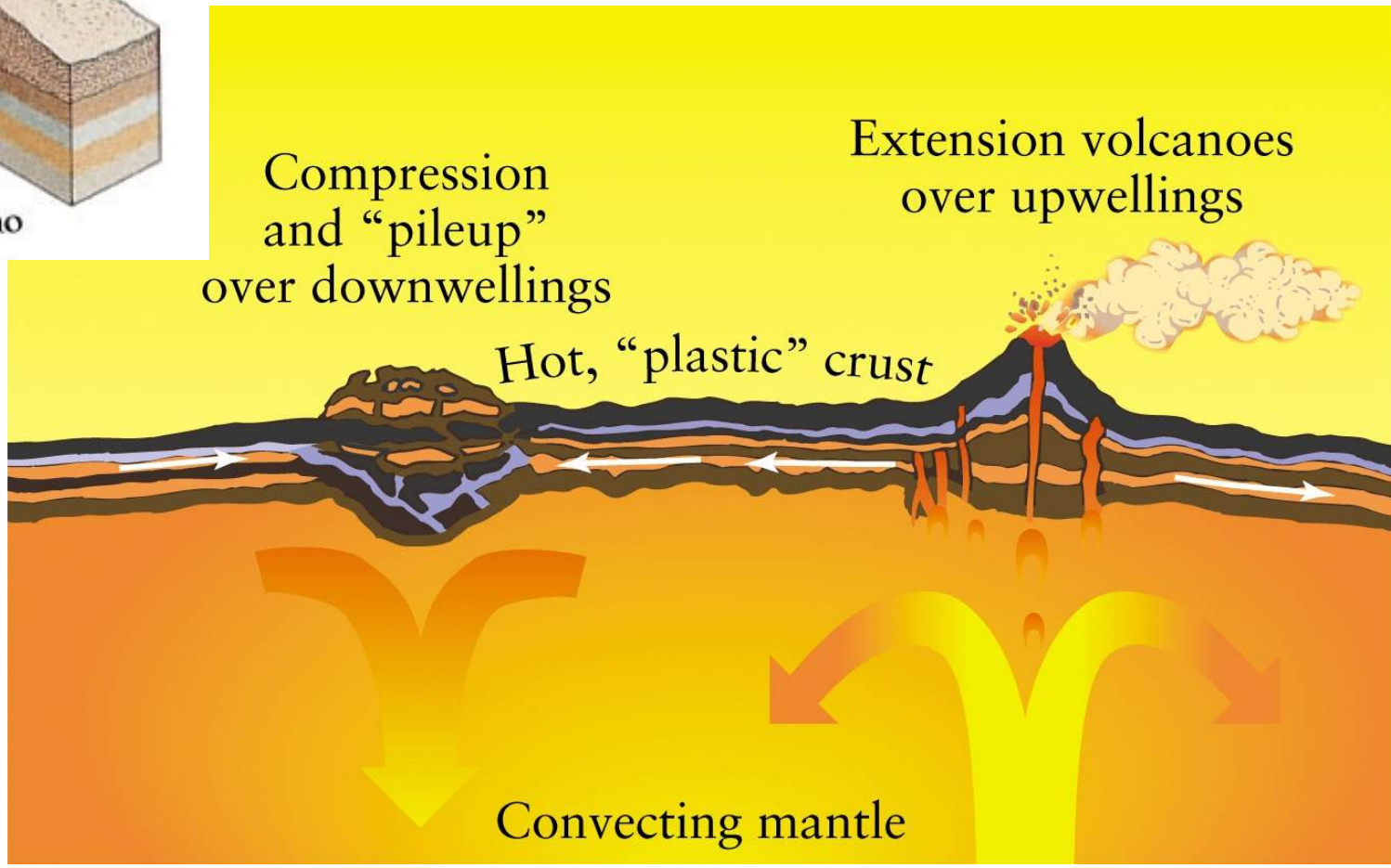
Venus



- Gula Mons – a large shield volcano on Venus. It is 4 km in height and over 100 km across at the summit



Venus



The volcanoes on Venus form from hot spots in the crust – these are called shield volcanoes. On earth the Hawaiian islands are shield volcanoes

Which gas is responsible for the greenhouse effect on Venus?

A nitrogen

B hydrogen

C carbon dioxide

D sulfuric acid

Which gas is responsible for the greenhouse effect on Venus?

A nitrogen

B hydrogen

C carbon dioxide

D sulfuric acid

Mars

Radius ~ 3400 km – ½ radius of earth

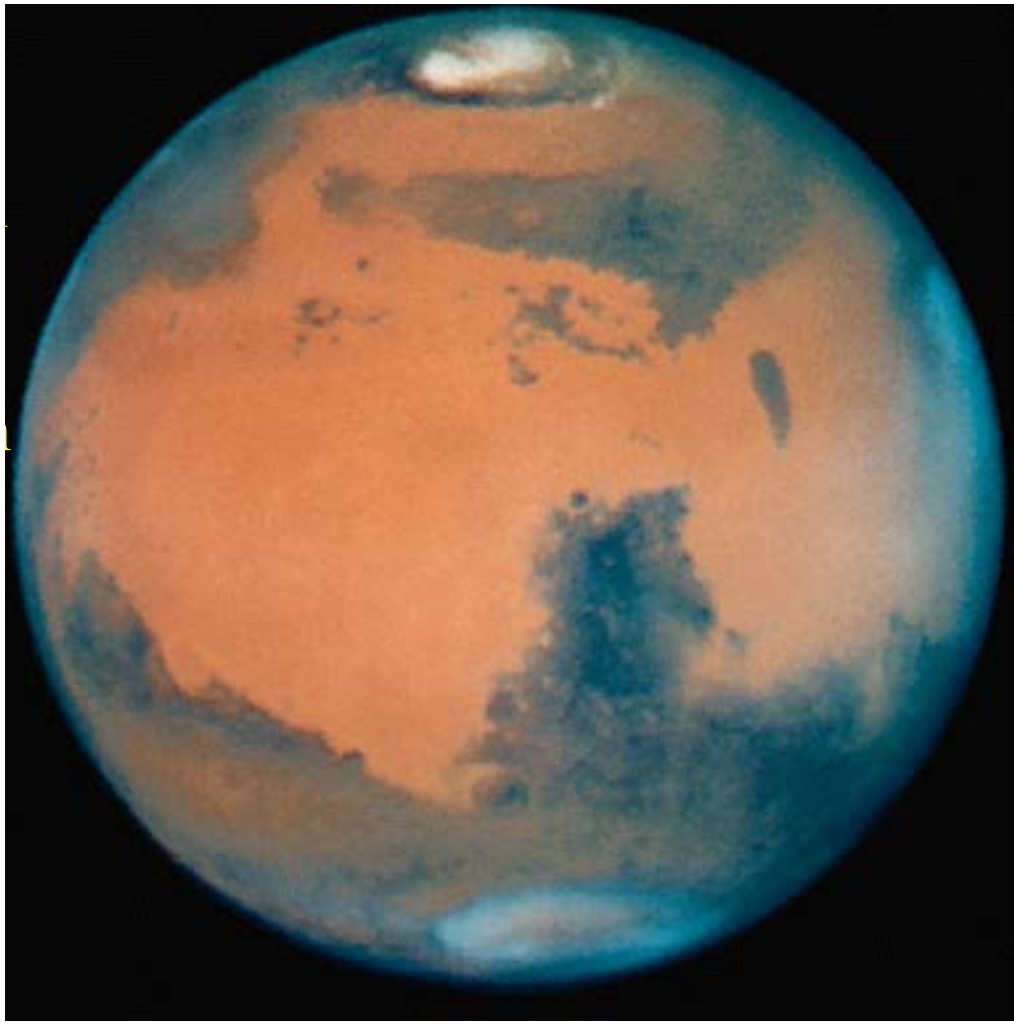
Mass ~ 10% of Earth

Density ~ 3900 kg/m^3 – smaller than Earth – density of rock.

Thin atmosphere

Extinct volcanoes

No magnetic field



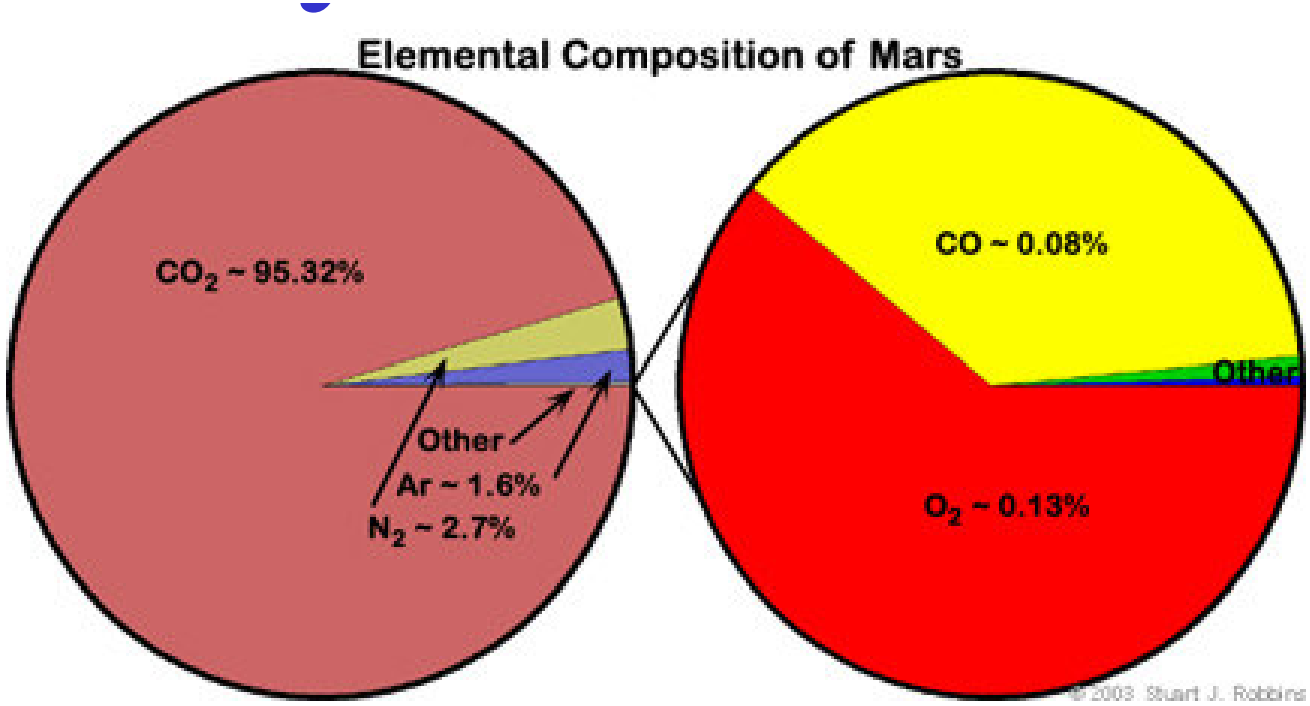
Mars

- Called the red planet because of its red color – due to rust, iron oxide
- Has nearly a 24 hour day – very similar to earth
- Atmosphere is made mainly of carbon dioxide, but it is very thin – 1/150 that of earth. Remember Venus is 90x that of earth
- Has seasons – tilt of Mars is close to that of earth.

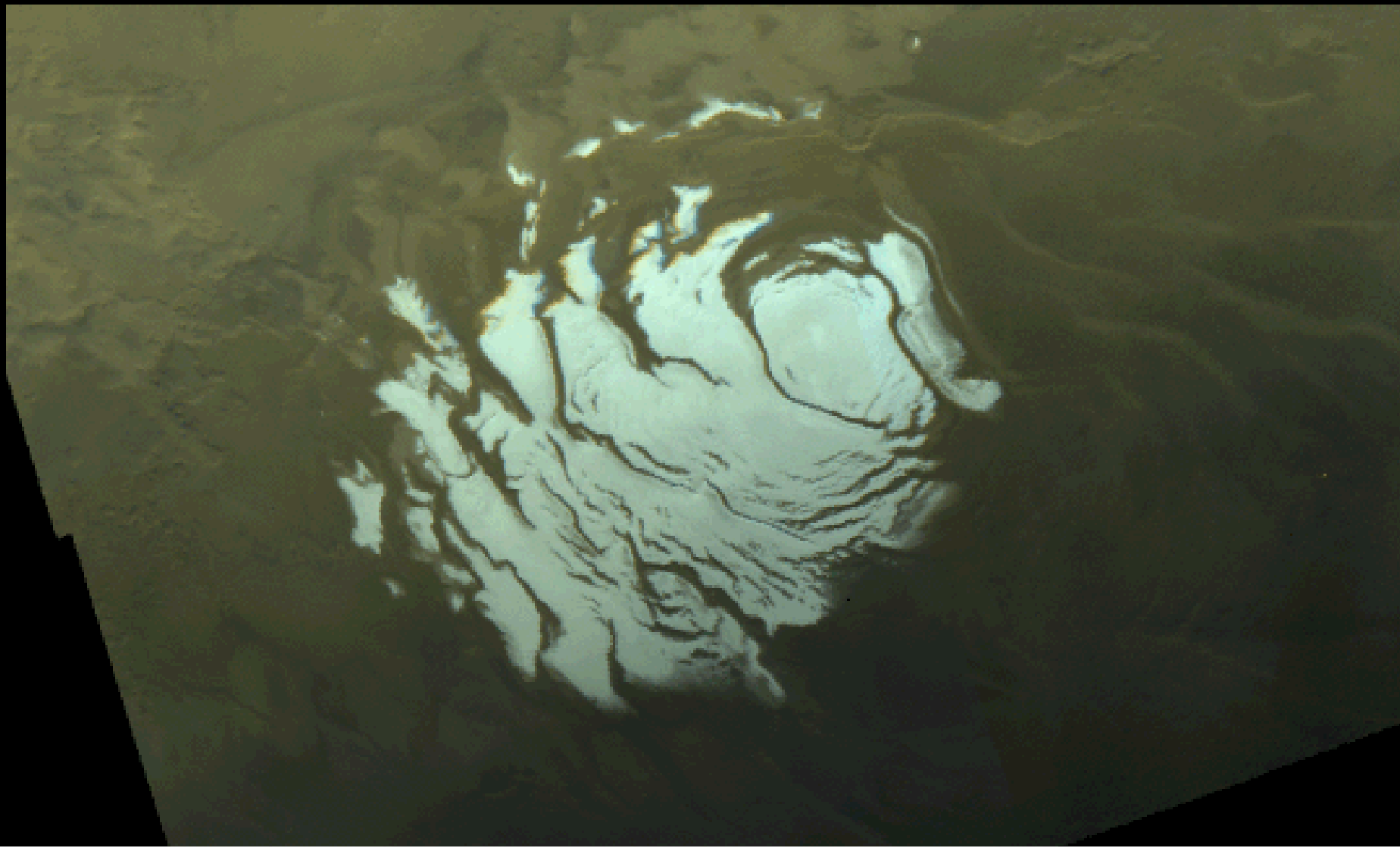
Mars

- Atmosphere is mainly CO_2 (carbon dioxide) with some nitrogen and argon.

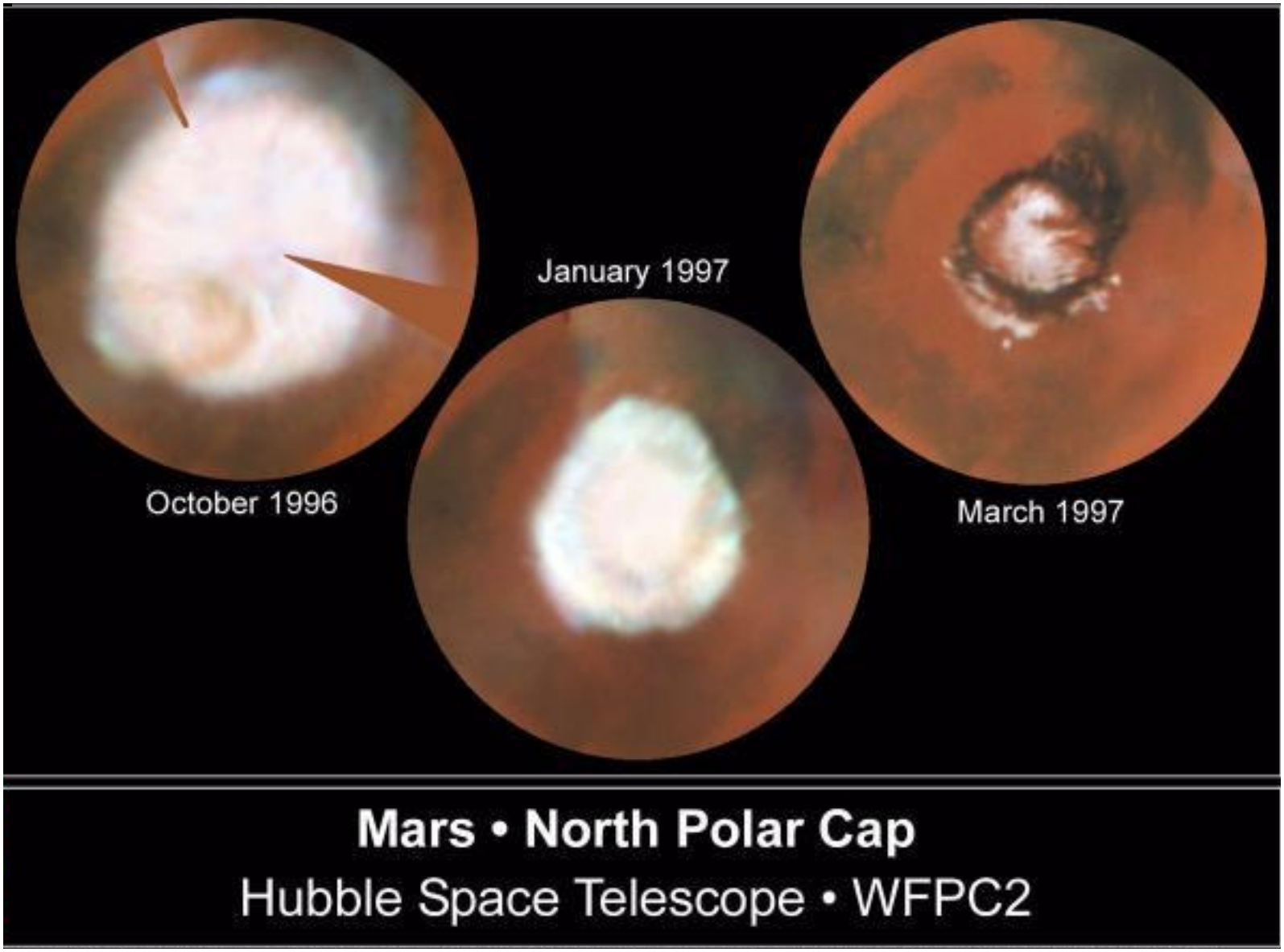
- It is so cold that the atmosphere freezes onto the poles as frozen CO_2 depending on the season



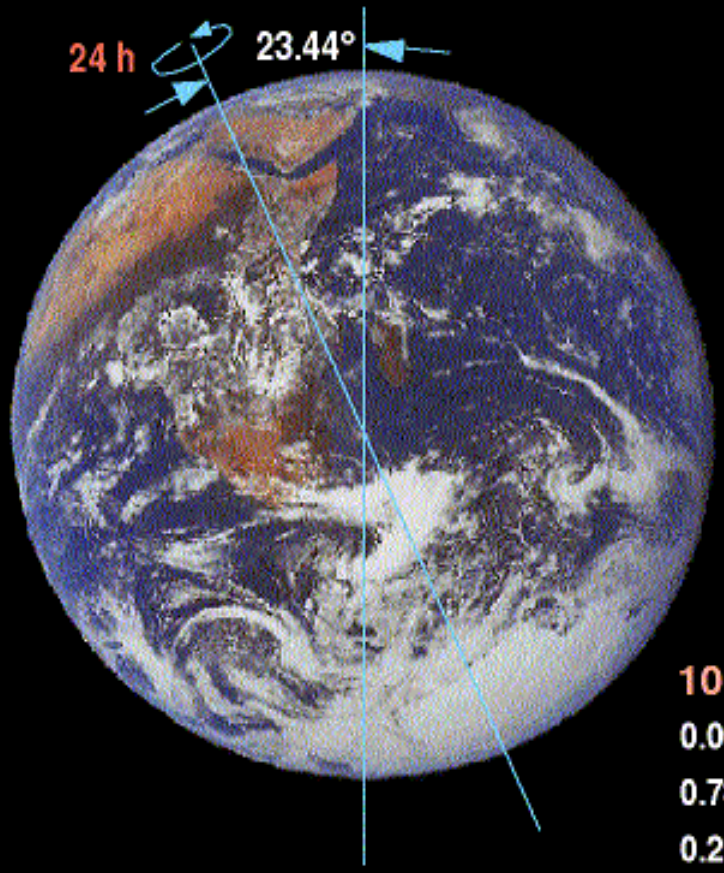
In winter for each pole, carbon dioxide freezes and the polar cap is much larger. Mars' dry-ice south pole in winter for the southern hemisphere:



Seasons on Mars



EARTH COMPARISON MARS



YEAR

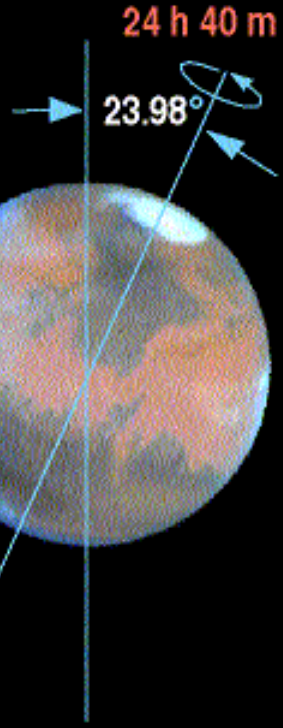
365 Days 686 Days (667 Sols)

GRAVITY

38% of earth

SUNLIGHT

44% of earth



ATMOSPHERE

1013mb	Total	7.6 mb
0.00035	CO_2	0.95
0.781	N_2	0.027
0.210	O_2	0.0013
0 to 0.04	H_2O	0 to 0.00021
0.0093	Ar	0.016

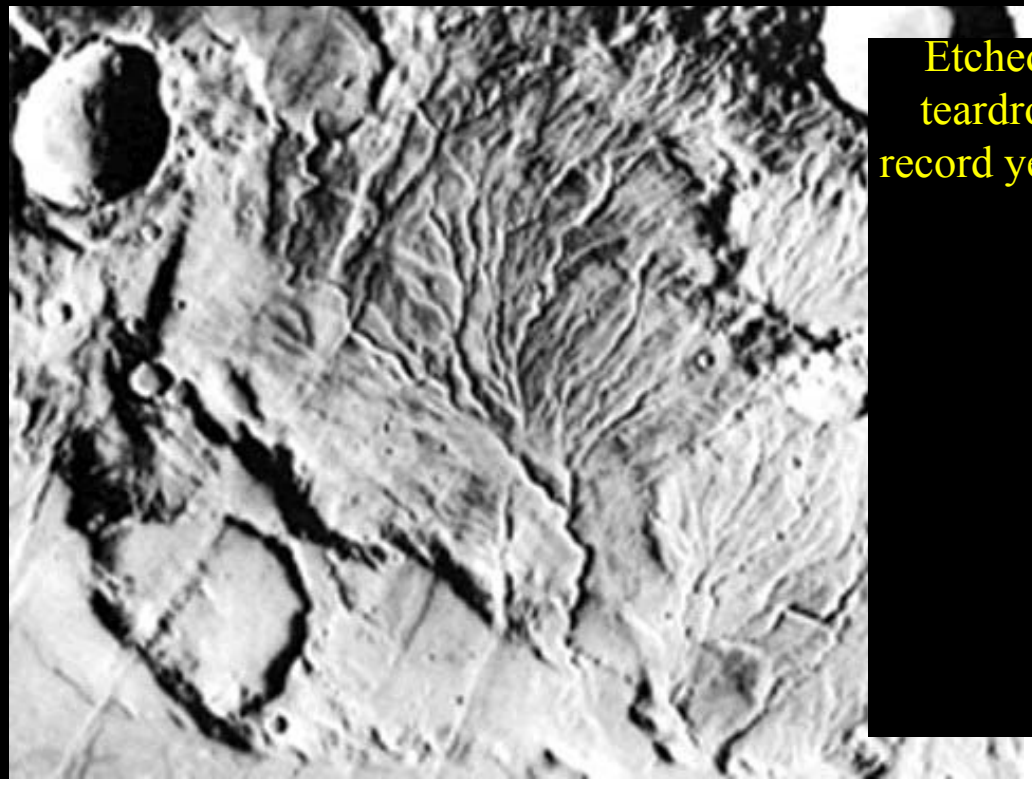
© U.Washington,Live from Earth and Mars (K.Dewar, J. Tillman)

Mars, courtesy P. James and NASA

Mars

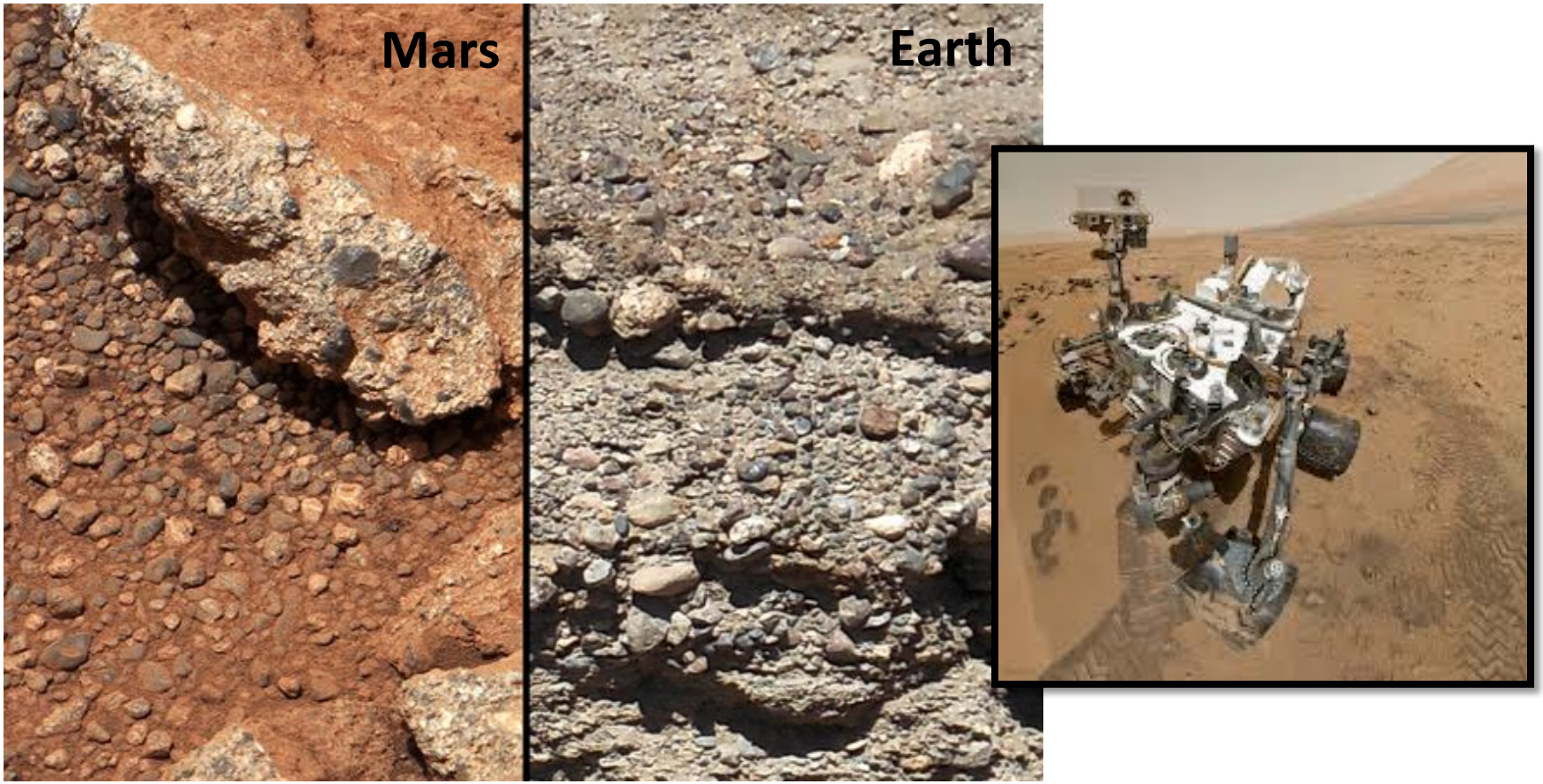
The atmosphere of Mars might have been thicker in the past, so thick as to support liquid water on the surface. There is evidence of liquid water on the past Martian surface.

Probably dried streambeds of ancient rivers



Etched in rock, teardrop shapes record years of flow

Evidence for water on Mars

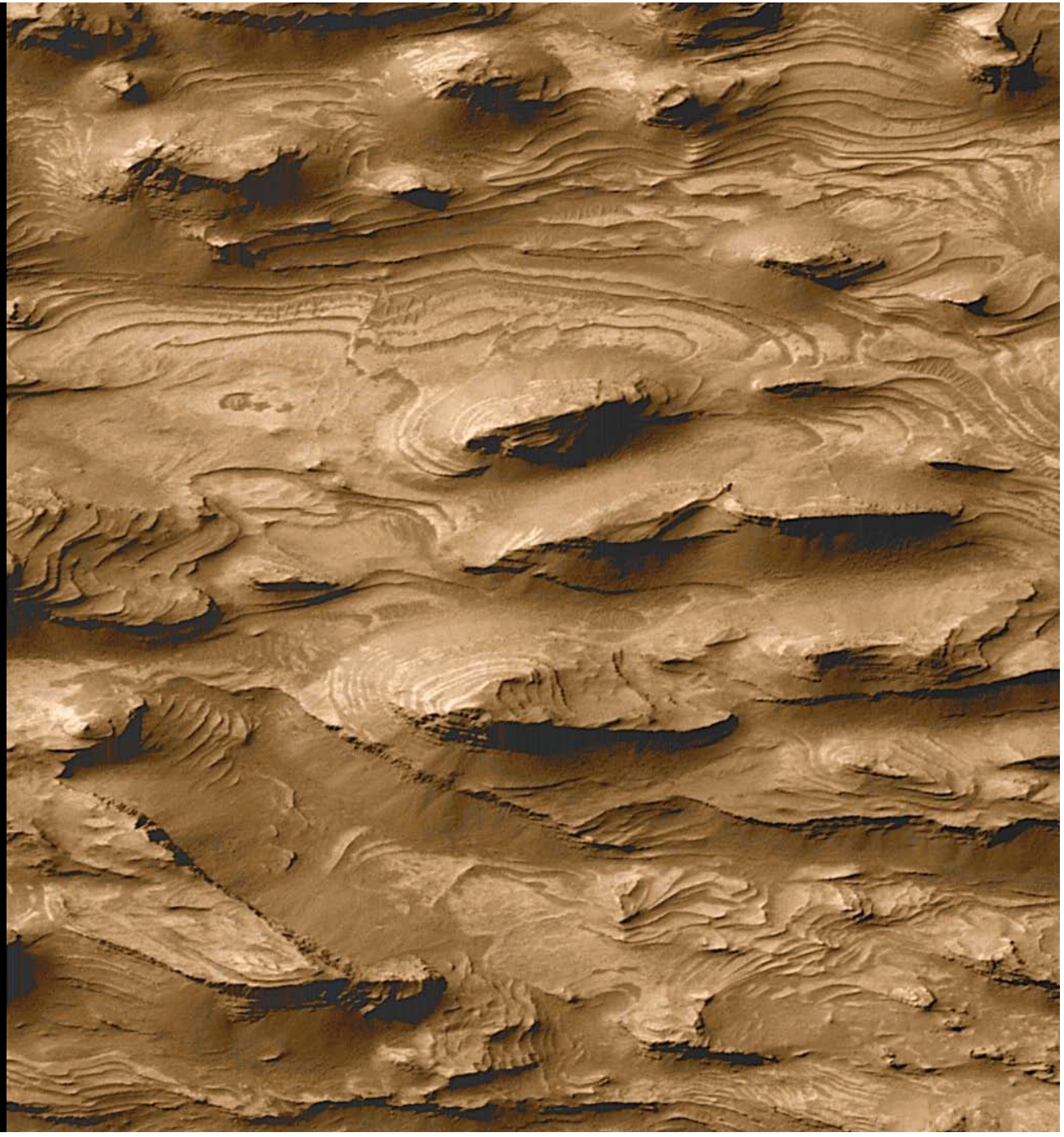


September 2012: Curiosity rover finds ancient streambed, pebbles moved and smoothed by water, present for thousands to millions of years

2003 photo of rock thought to be sedimentary

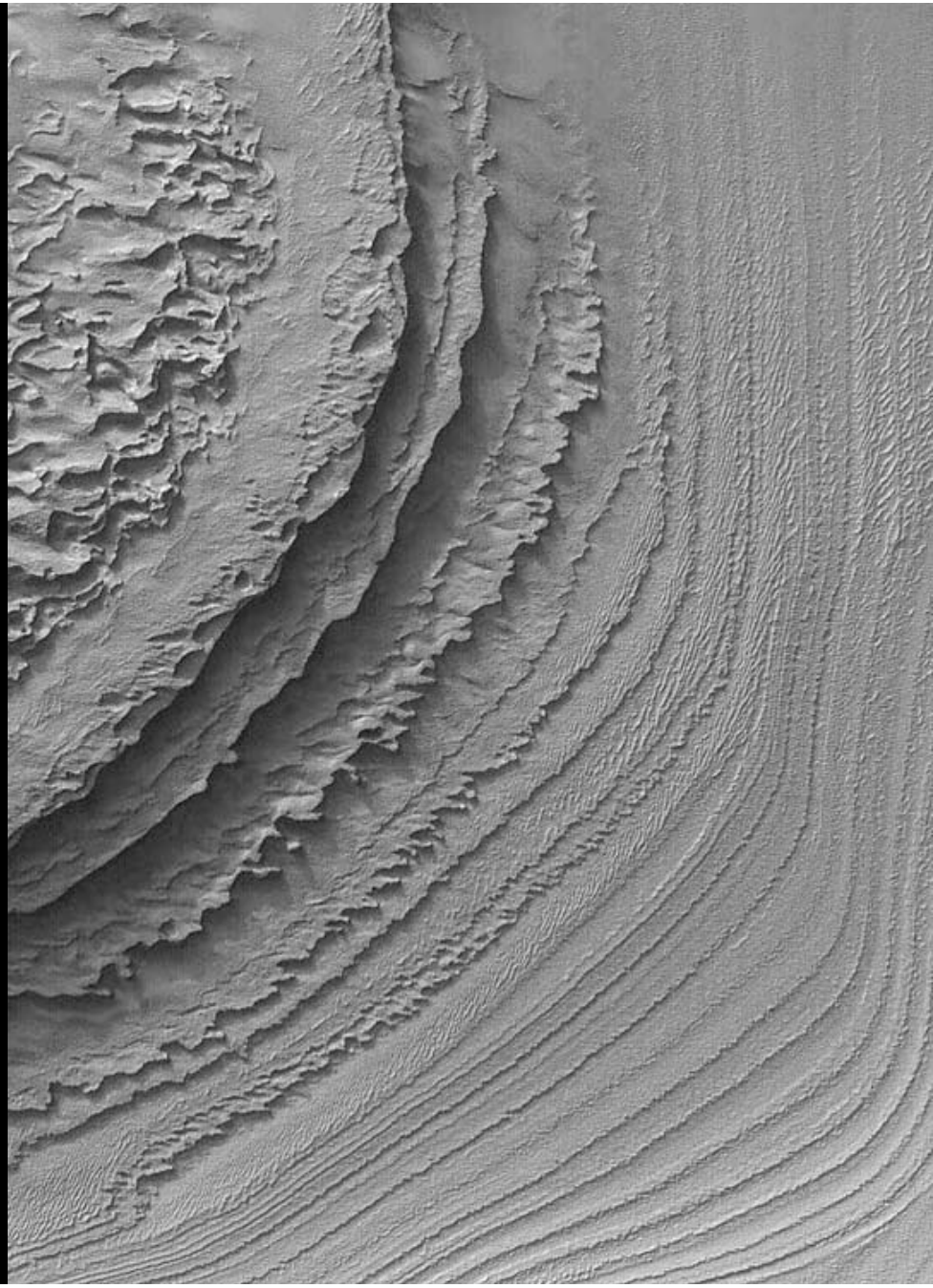
Sedimentary rock builds up in layers, probably deposited by water

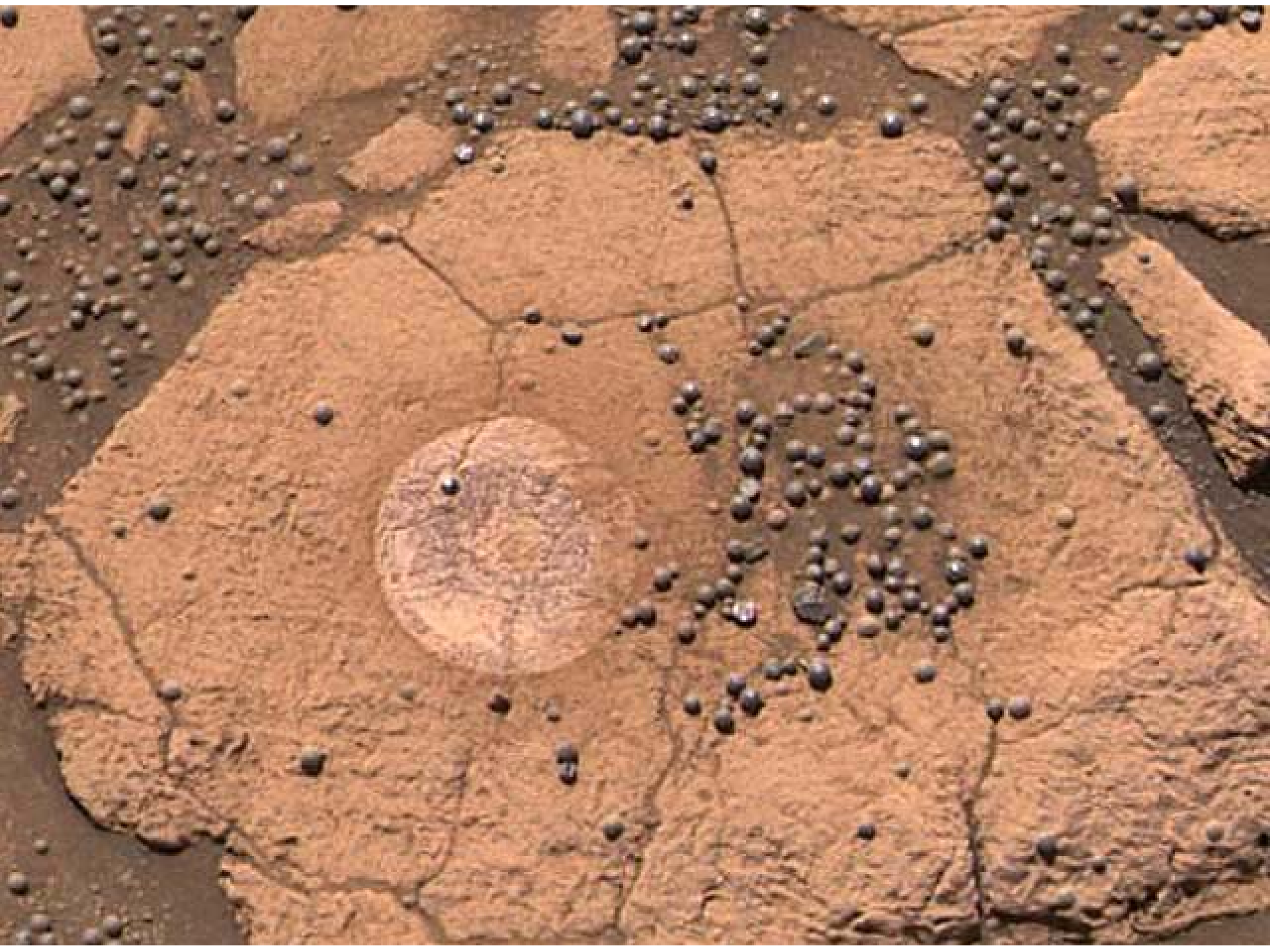
Very common on Earth



2003 image of Galle crater from Mars Orbital Camera "a glimpse of the layered sedimentary rock in the Galle crater"

Sedimentary rock on Mars found in craters and other depressions





“Berrybowl,” another Opportunity photo:
NASA’s claim:

The underlying rock has a much different composition than the hematite-rich blueberries. This information contributes to the growing consensus is that these small, strange, gray orbs were slowly deposited from a bath of dirty water.

Mars

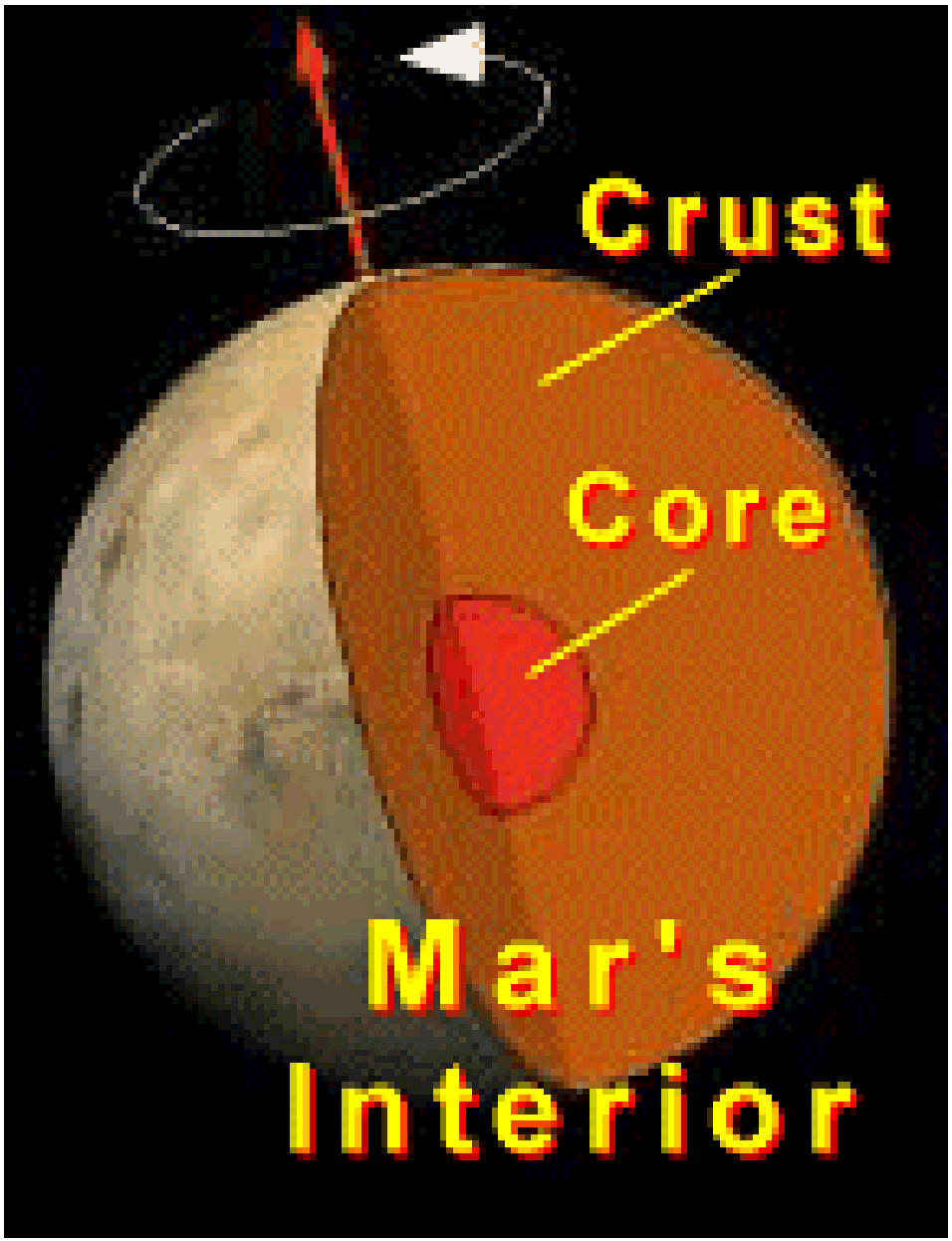
The water is likely to have been lost to space or permanently frozen into permafrost.
Some evidence in impact craters and possibly flowing mud.

Mars

Like the other terrestrial planets, Mars has a core.

It has a weak magnetic field – 1/800 that of the Earth.

The core is probably still molten, but large scale activity is largely dormant.

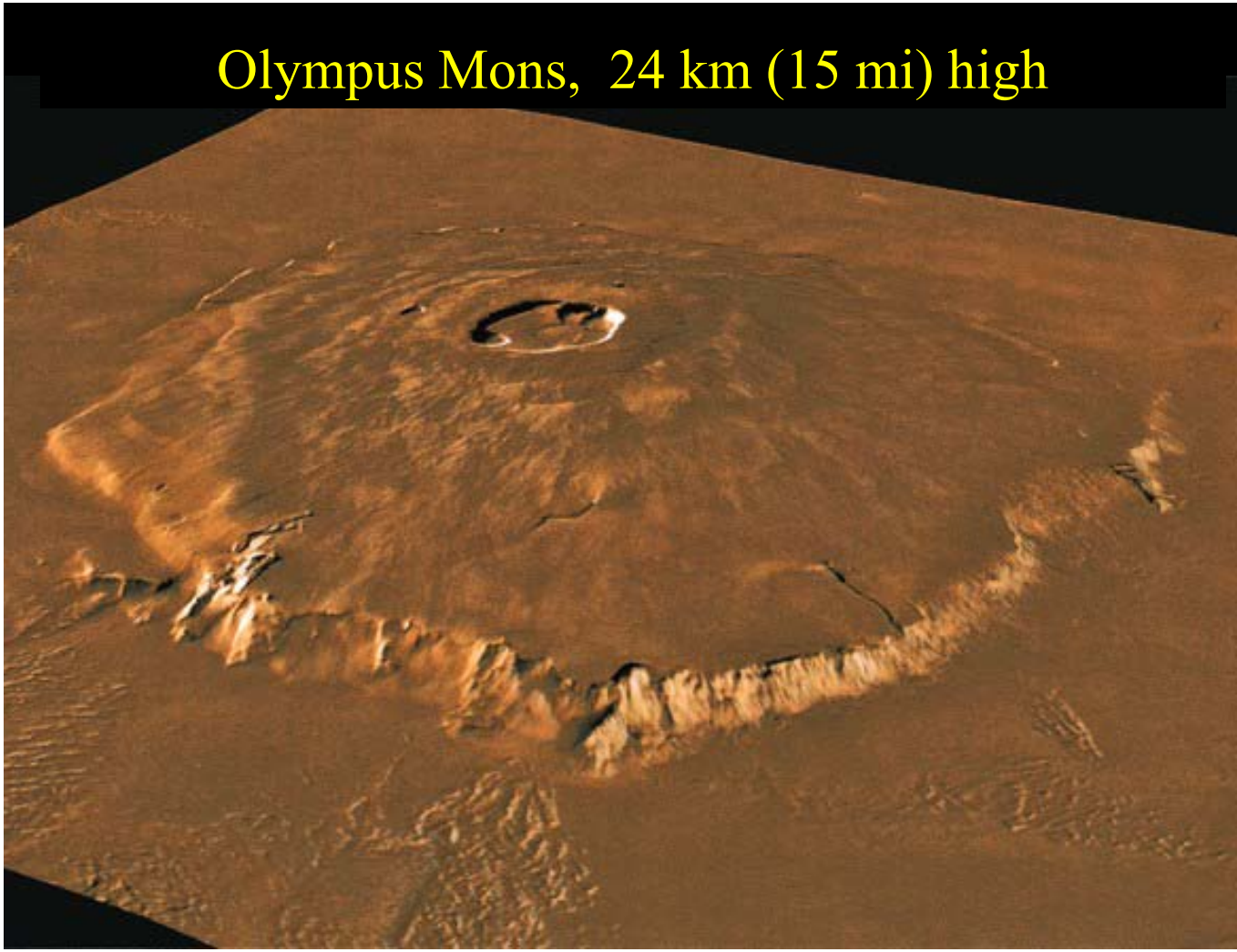


Mars

- Has huge volcanoes – now extinct. Olympus Mons is the largest volcano in the solar system.

3 x the size of Mount Everest!

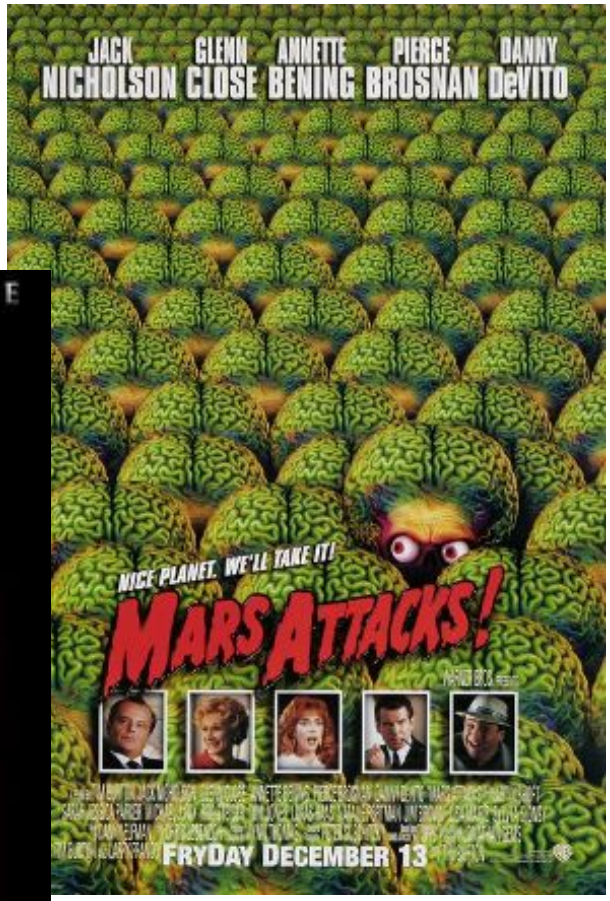
These are also shield volcanoes. They are much larger than ones on Earth and Venus because of lower gravity.



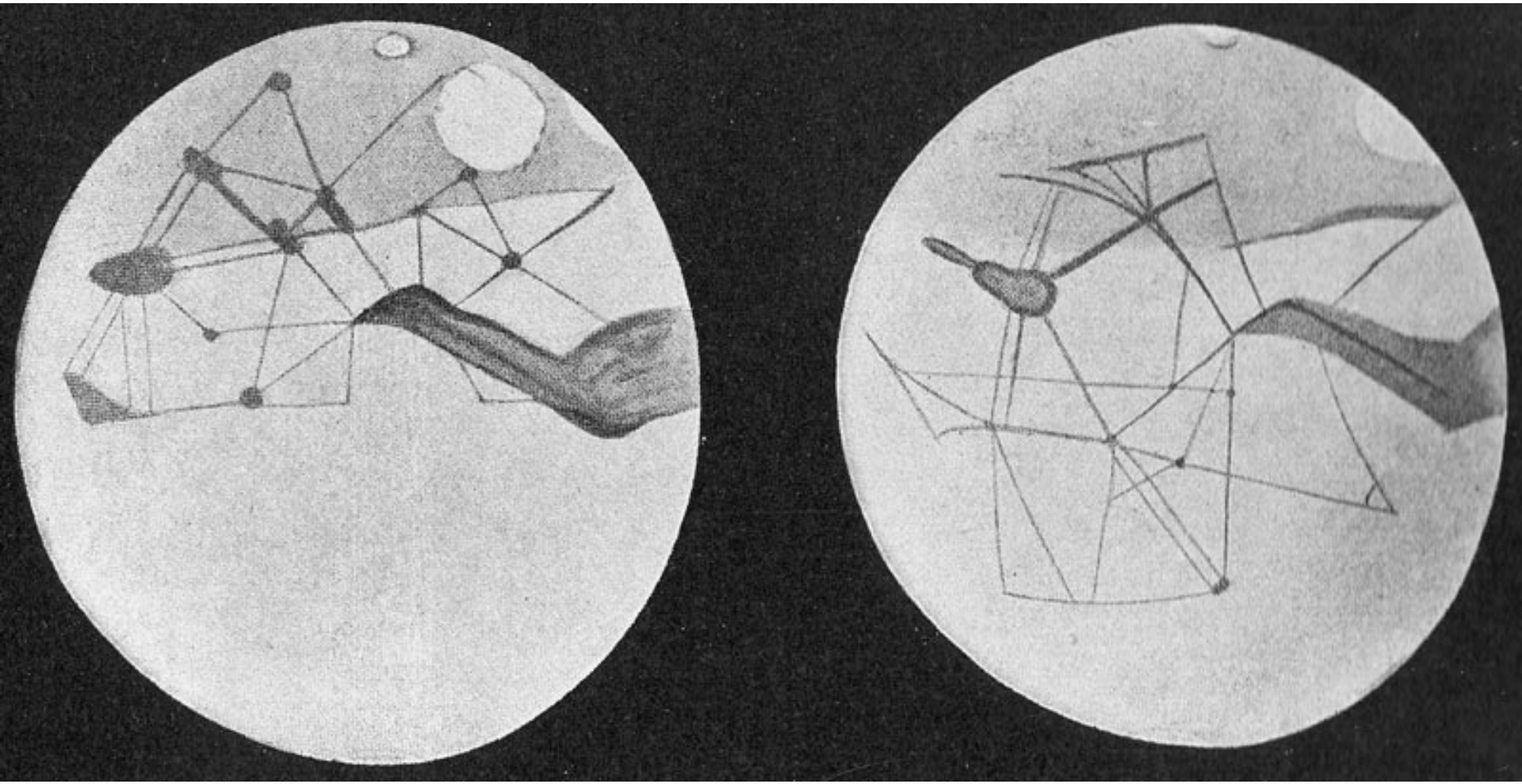
Life on Mars

The idea of life on Mars is a very old one.

The fact that Mars was so similar to Earth drove a lot of the early speculation.



Life on Mars



In the 19th century astronomers believed that they saw canals on Mars – evidence of intelligent life

Life on Mars

Meteor ALH840001 is a Martian meteorite with possible indications of early Martian life.
Very controversial – shows both mineral deposits of magnetite and possible fossils of nanobacteria

Life on Mars