Astronomy 101
The Solar System
Tuesday, Thursday
2:30-3:45 pm
Hasbrouck 20

Tom Burbine
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Course

- **Course Website:**
  - http://blogs.umass.edu/astron101-tburbine/
- **Textbook:**
  - **Pathways to Astronomy (2nd Edition)** by Stephen Schneider and Thomas Arny.
  - **You also will need a calculator.**

Office Hours

- Mine
- Tuesday, Thursday - 1:15-2:15pm
- Lederle Graduate Research Tower C 632

- Neil
- Tuesday, Thursday - 11 am-noon
- Lederle Graduate Research Tower B 619-O

Homework

- We will use Spark
- https://spark.oit.umass.edu/webct/logonDisplay.dowebct
- Homework will be due approximately twice a week

Astronomy Information

- Astronomy Help Desk
- Mon-Thurs 7-9pm
- Hasbrouck 205

- The Observatory should be open on clear Thursdays
- Students should check the observatory website at: http://www.astro.umass.edu/~orchardhill for updated information
- There's a map to the observatory on the website.

Final

- Monday - 12/14
- 4:00 pm
- Hasbrouck 20

HW #15

- Due today

HW #16 and #17

- Due Thursday

Exam #3

- Average was 82.2
- Grades ranged from 100s to a 45

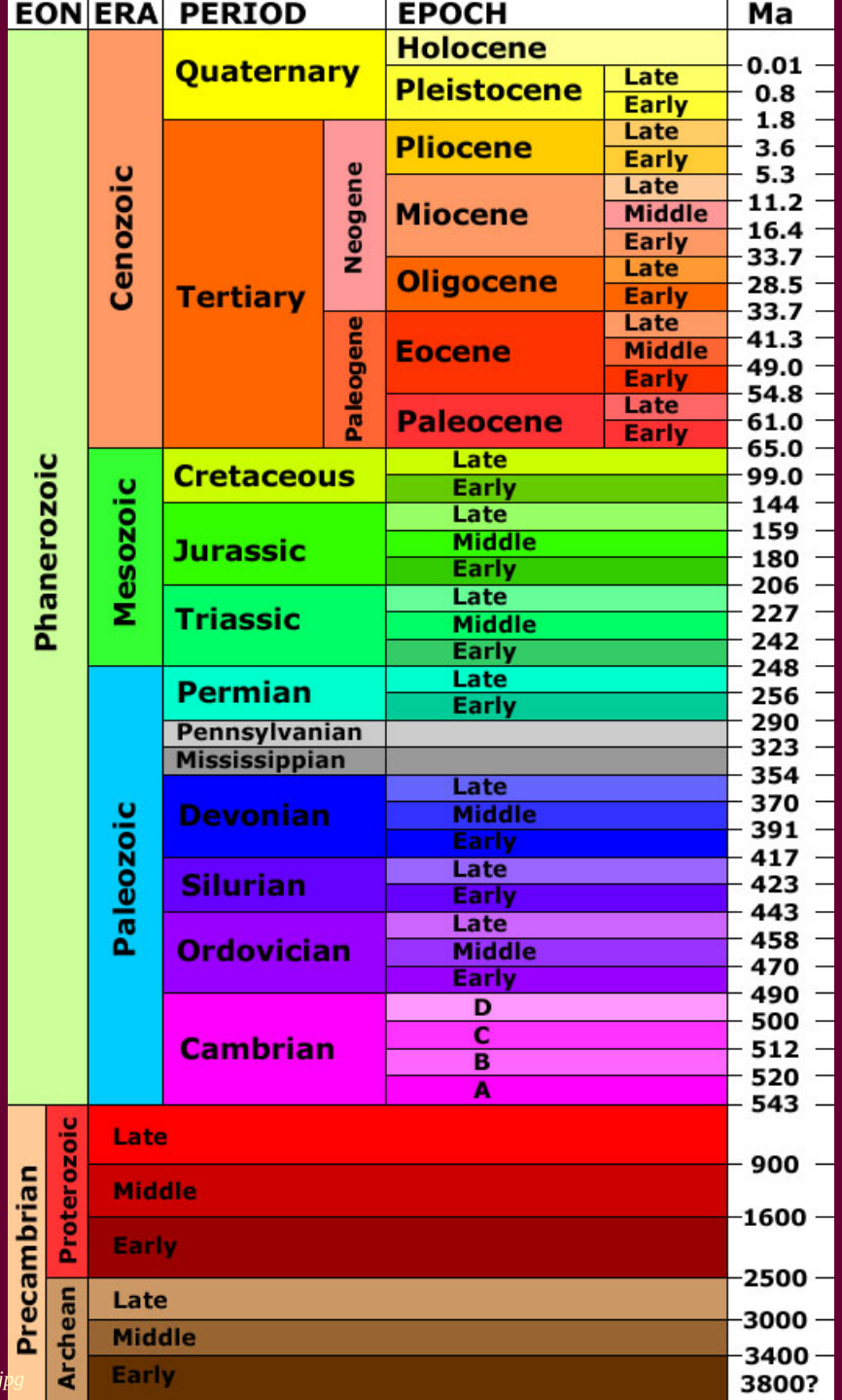
Geologic Time Scale

- A scheme to relate stratigraphy to time
- Divided according to the rock types and type of fossils found in each one.

Eras

- Paleozoic (the era of "ancient life“) is characterized by fossils of invertebrates, primitive tetrapods, etc.
- Mesozoic (era of "middle life“) is characterized by fossils of dinosaurs, etc.
- Cenozoic (era of "recent life“) is characterized by mammals and modern plants and invertebrates.

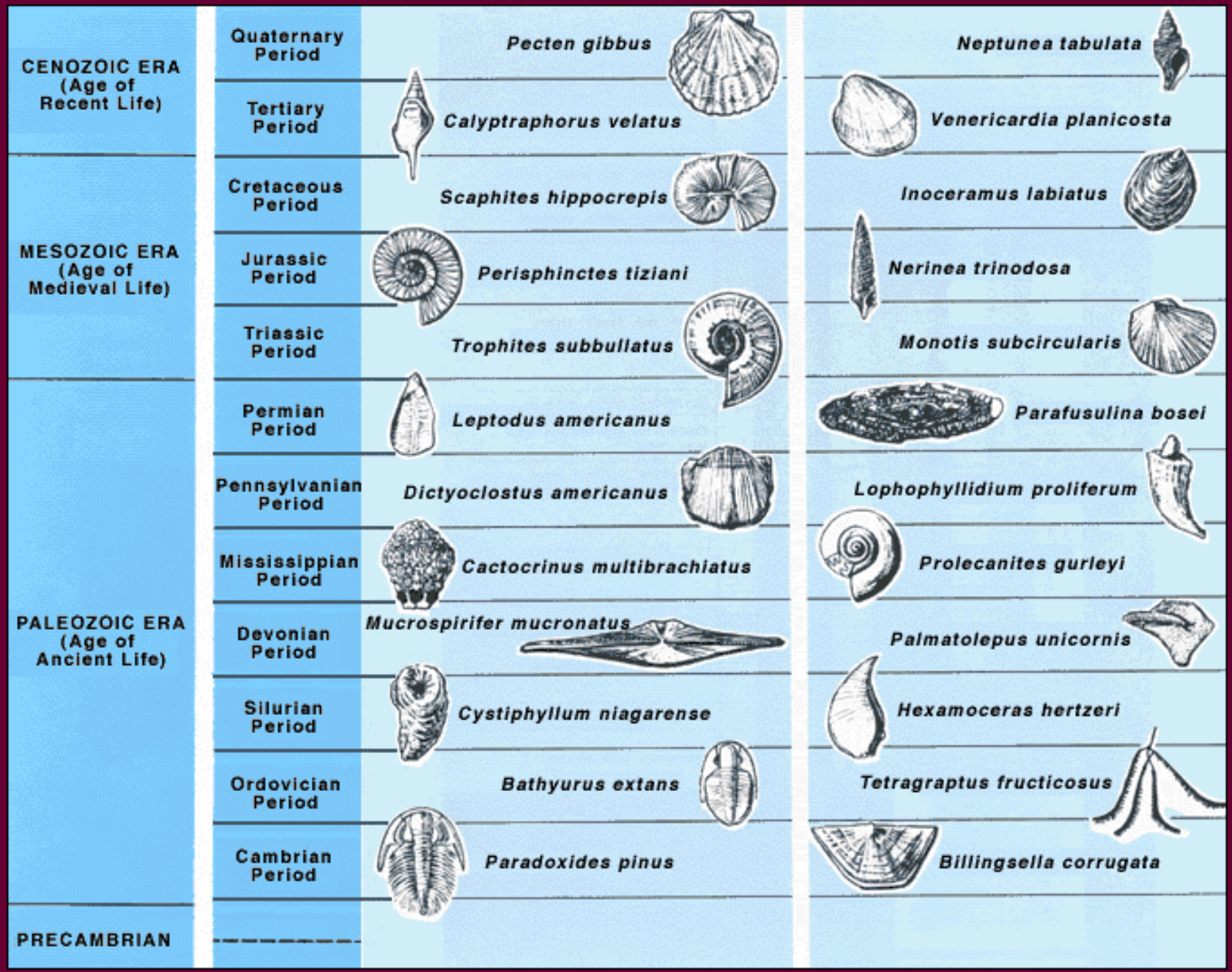
Why is there such a large age difference between the beginning and end of the Cambrian?



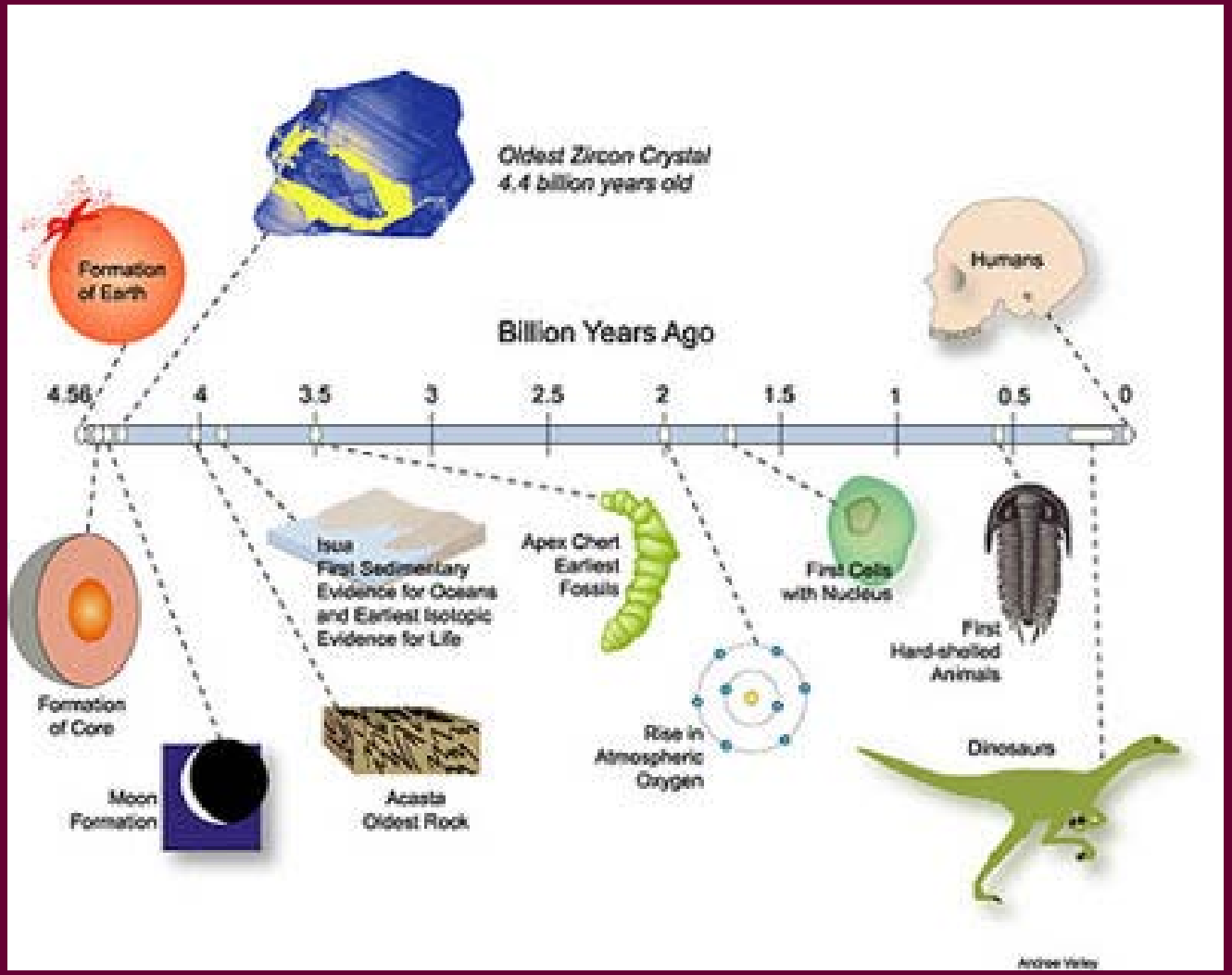
Ma – million years

http://geomaps.wr.usgs.gov/socal/geology/geologic_history/images/geologic_time_scale.jpg

- Cambrian is the earliest period where rocks are found with numerous large multicellular organisms that could be found as fossils

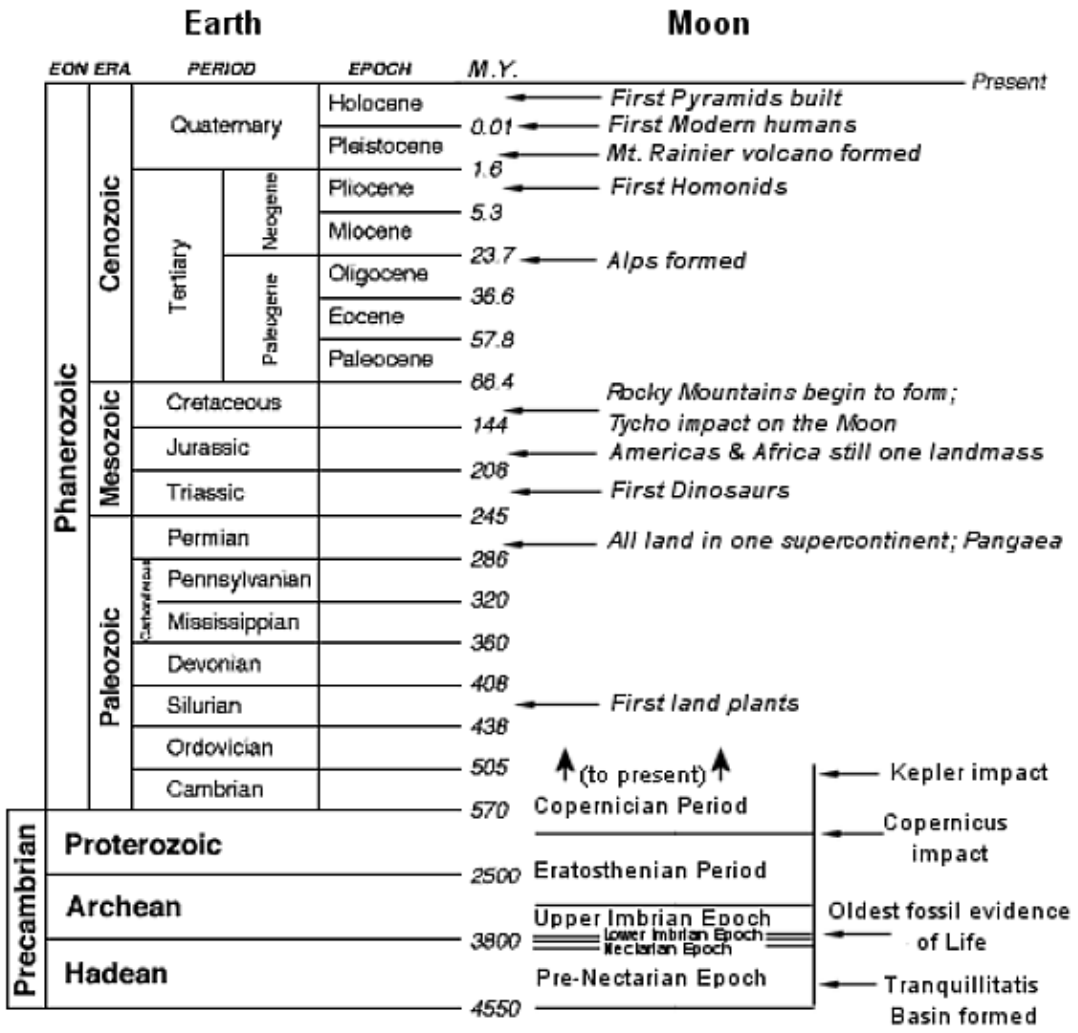


http://pubs.usgs.gov/gip/geotime/fossils.html



http://creationwiki.org/pool/images/thumb/c/c5/Evolution_timeline.jpg/400px-Evolution_timeline.jpg

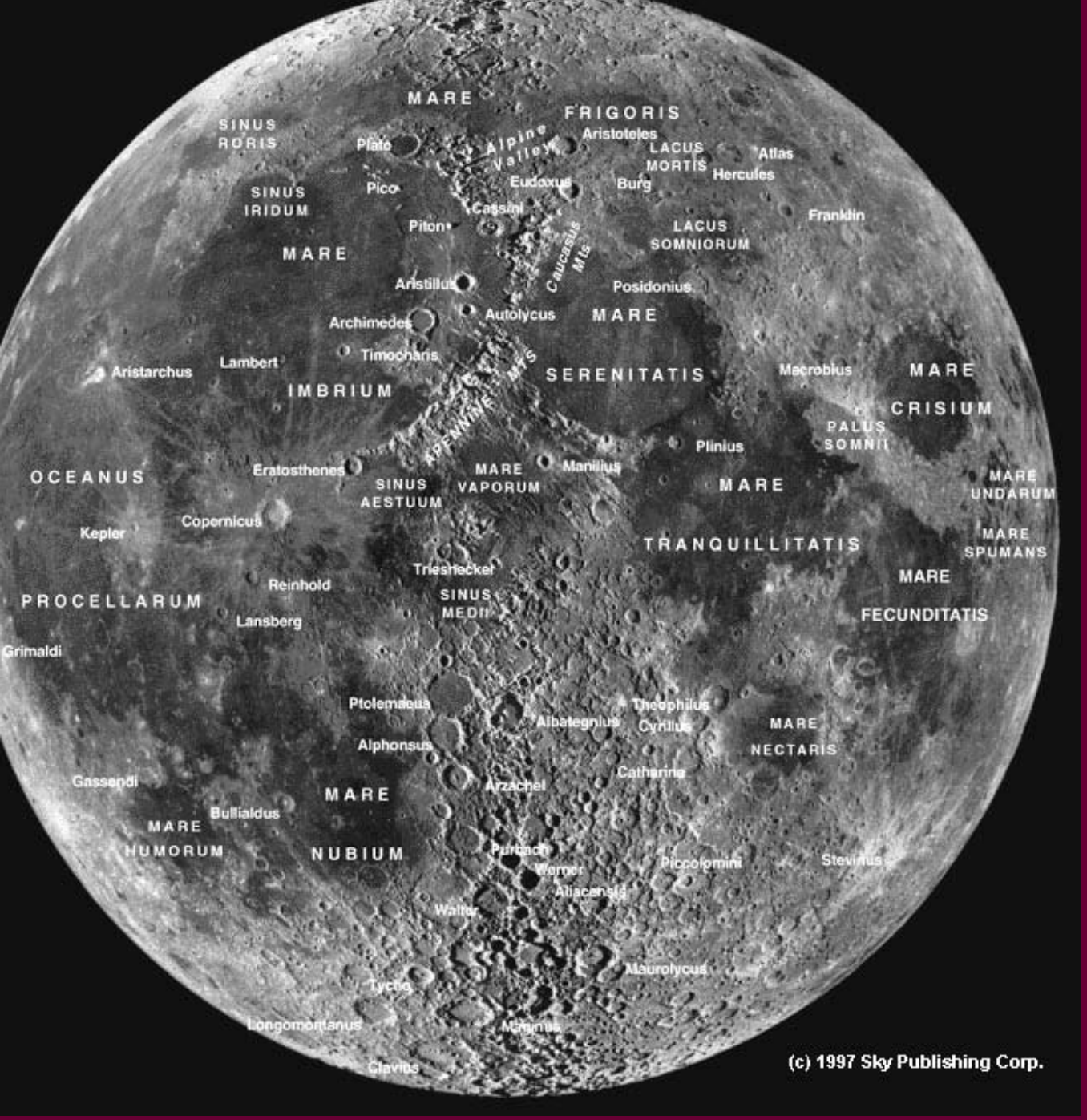
Geologic time



Copernician Period : 1100 MY to present
Eratosthenian Period : 3200 MY to 1100 MY
Upper Imbrian Epoch : 3800 MY to 3200 MY
Lower Imbrian Epoch : 3850 MY to 3800 MY
Nectarian Epoch : 3920 MY to 3850 MY
Pre-Nectarian Epoch: 4550 MY to 3920 MY

Whitepeak Obs. Graphic

http://www.cityastronomy.com/geologic-earth-moon-graphic.bmp



http://www.etsu.edu/physics/etsuobs/starprty/21200mwc/moonmap.jpg

LUNAR TIME SCALE

oldest . . . . . youngest

NAME OF SYSTEM	BILLION YEARS AGO
Copernican	1.1 to present
Eratosthenian	3.2 to 1.1
Imbrian	3.85 to 3.2
Nectarian	3.9 to 3.85
pre-Nectarian	4.5 to 3.9

PSRD

http://www.psrd.hawaii.edu/WebImg/LunarTimeScale.gif

Mars

http://www.daviddarling.info/images/Mars_large.jpg

Mars

- Names after Mars, Roman God of War
- Mars has two tiny natural moons, Phobos and Deimos, which orbit very close to the planet and are thought to be captured asteroids.
- Both satellites were discovered in 1877 by Asaph Hall, and are named after the characters Phobos (panic/fear) and Deimos (terror/dread) who, in Greek mythology, accompanied their father Ares, God of War

Percival Lowell (1855-1916)

- Lowell produced intricate drawings of the Red Planet
- Finding hundreds of straight lines (termed "canals")


National Air and Space Museum
Smithsonian Institution

He thought

- Lowell concluded that the bright areas were deserts and the dark were patches of vegetation
- Lowell thought the canals were constructed by intelligent beings who once flourished on Mars.

For years

- People thought life could exist on Mars and Venus, the closest planets to Earth

However,

- Venus is extremely hot (~700-800 K)
- Atmospheric pressure is 90 times that of Earth

What happened on October 30, 1938?

What happened on October 30, 1938?

- http://sounds.mercurytheatre.info/mercury/381030.mp3

Mars

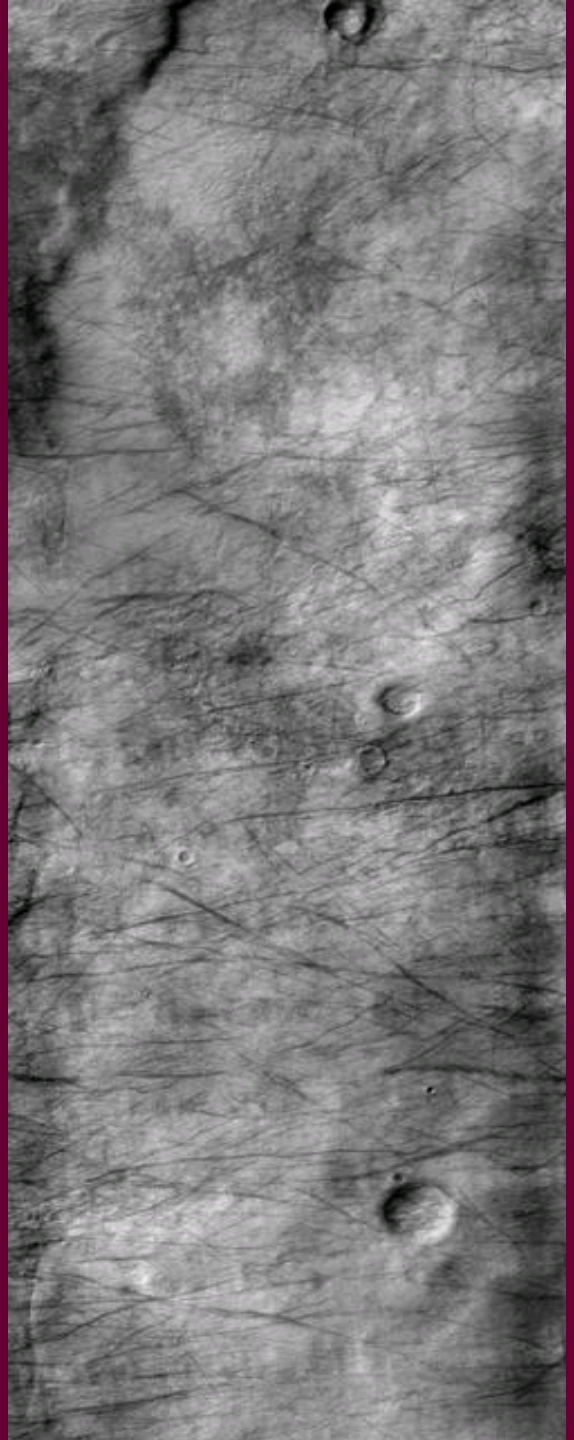
- The average recorded temperature on Mars is -63 °C with a maximum temperature of 20 °C and a minimum of -140 °C
- Atmospheric pressure is 1/100 of Earth's
- Mars is often enveloped by planet-wide dust storms

Dust Devils

- http://en.wikipedia.org/wiki/Image:Marsdustdevil2.gif

Dust Devils

- Dust devils are smaller and weaker than tornadoes
- They are caused by convection on hot, calm summer days.
- Air near the surface becomes much warmer than the air above, creating an updraft.

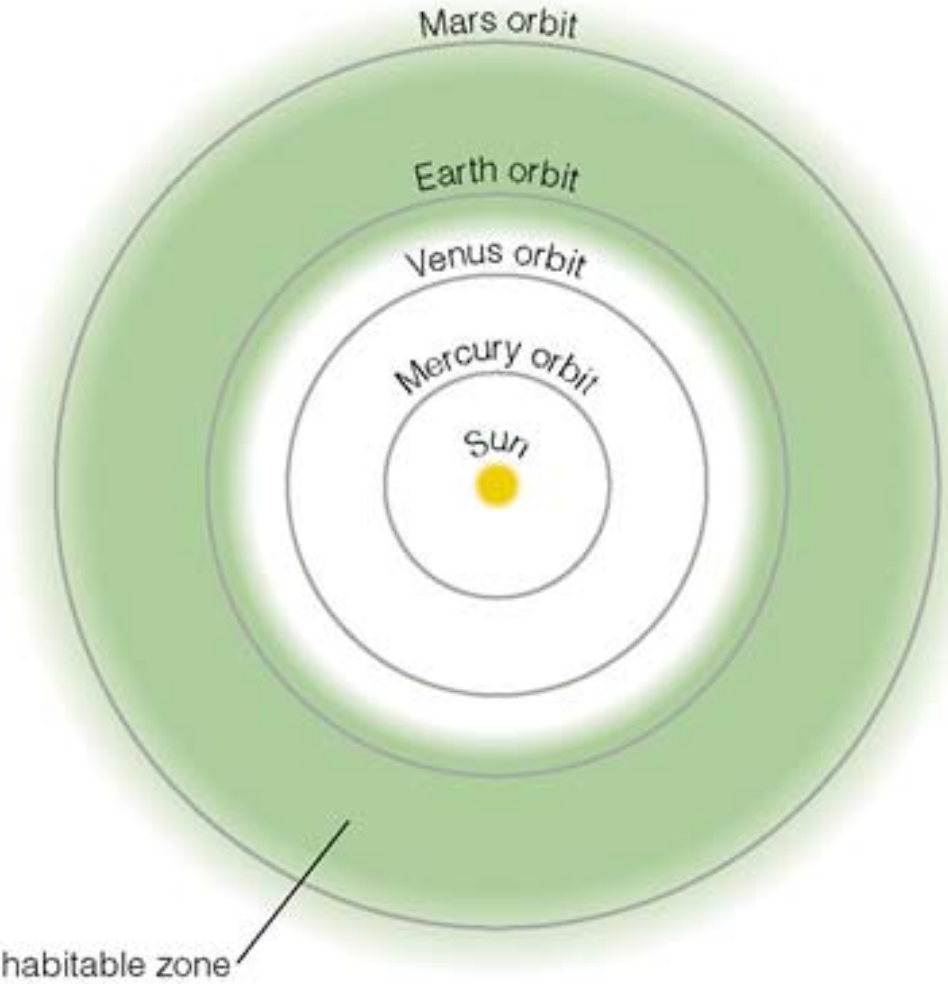


Key to Life

- All life on Earth depends on water
- So if you find water, you may find life

Habitable Zone

- The region around a star in which planets could potentially have surface temperatures which liquid water could exist



Solar System

Star with Mass $\frac{1}{2}M_{Sun}$

Star with Mass $\frac{1}{10}M_{Sun}$

In the past

- Mars appeared to be warmer and wetter

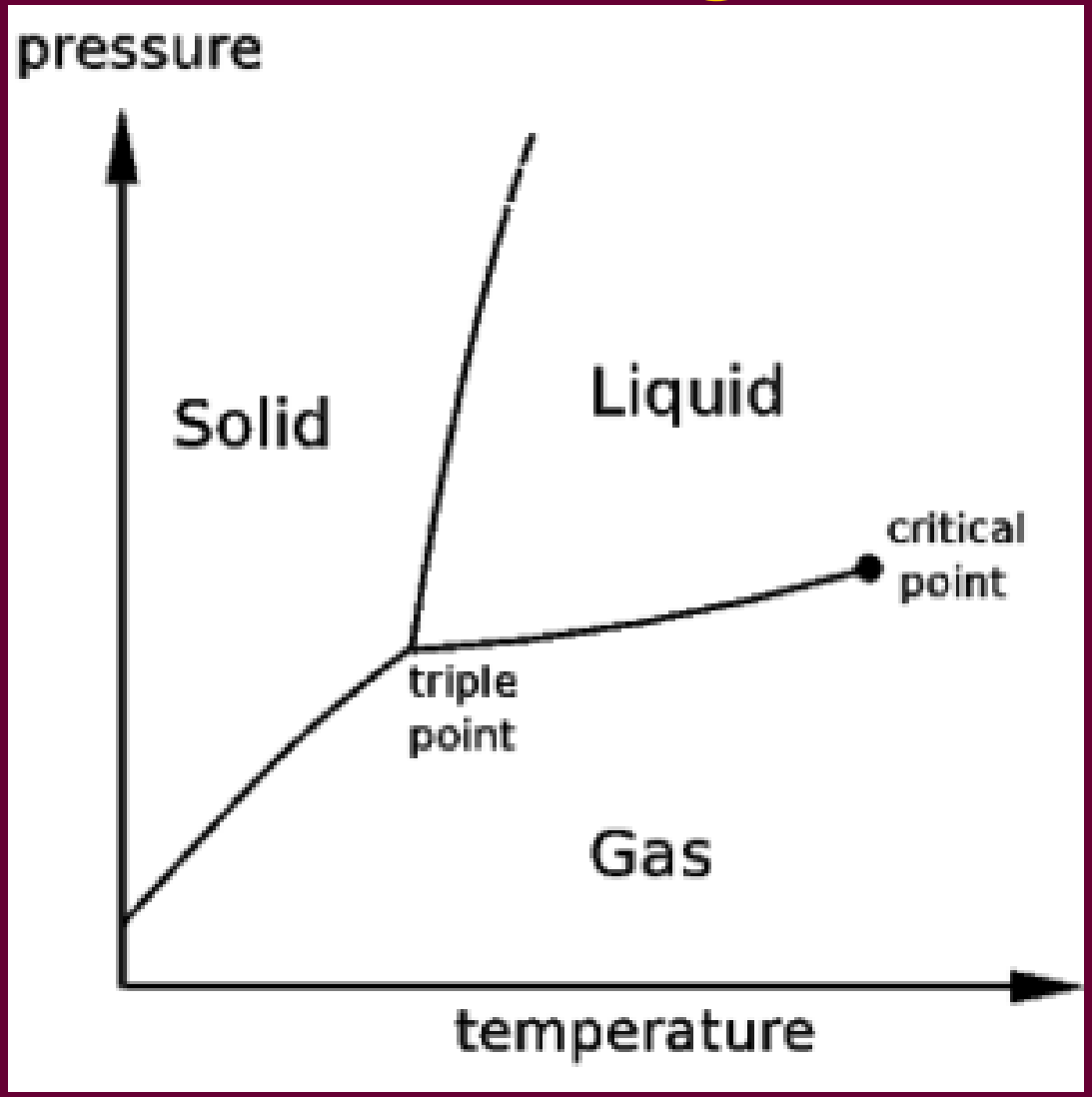
Atmospheres

- Layer of gases that surround a body with sufficient mass
- Gravity keeps the gases around the body

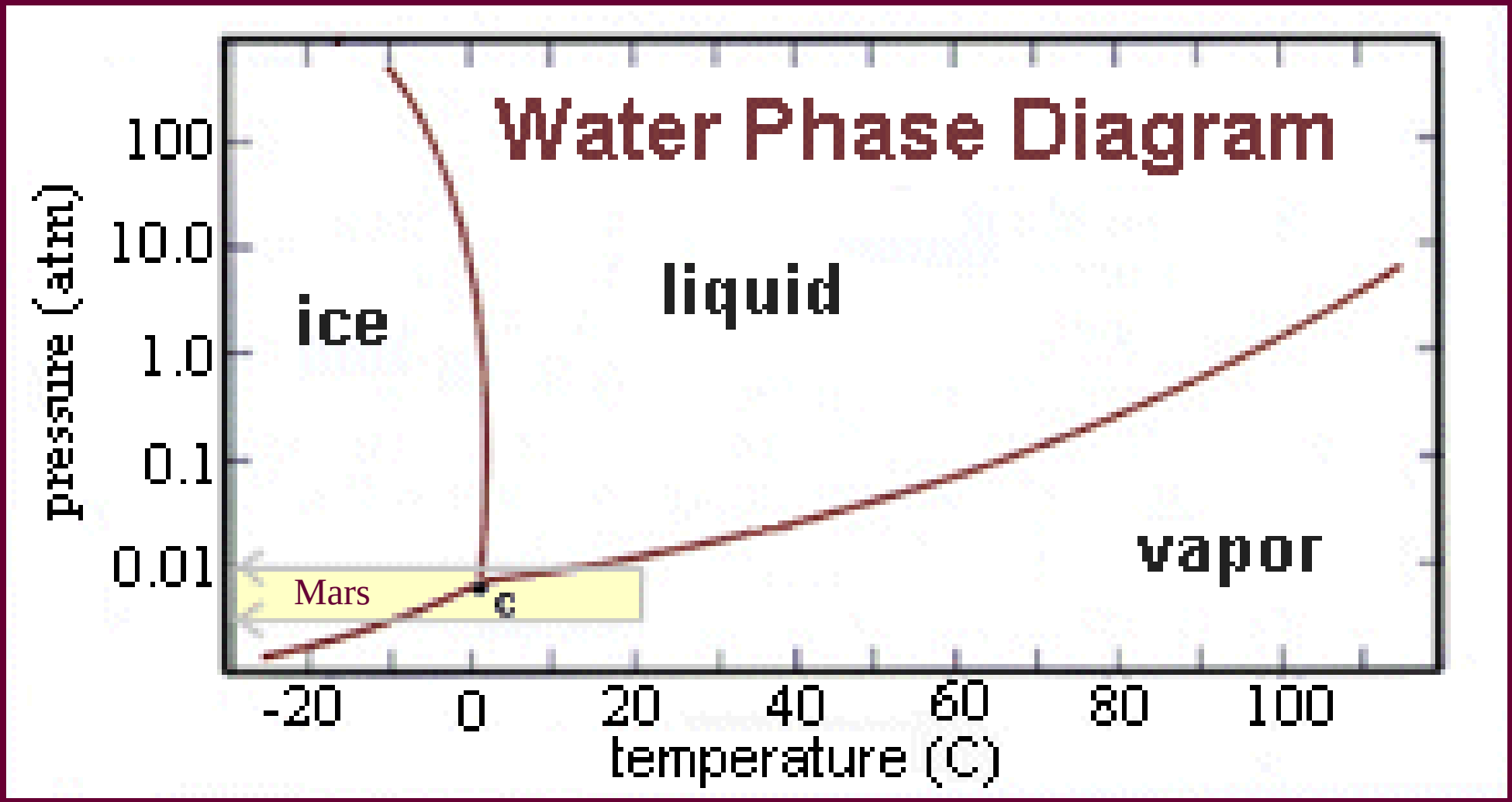
Atmospheric Pressure

- Pressure due to the weight of air above the measurement point
- Pressure is force per unit area
- **Standard atmosphere** is defined as being precisely equal to 101,325 Pascals where a Pascal is 1 N/m^2
- 1 bar = 100,000 pascals
- Pressure in the solar nebula was ~10^{-4}-10^{-8} bars

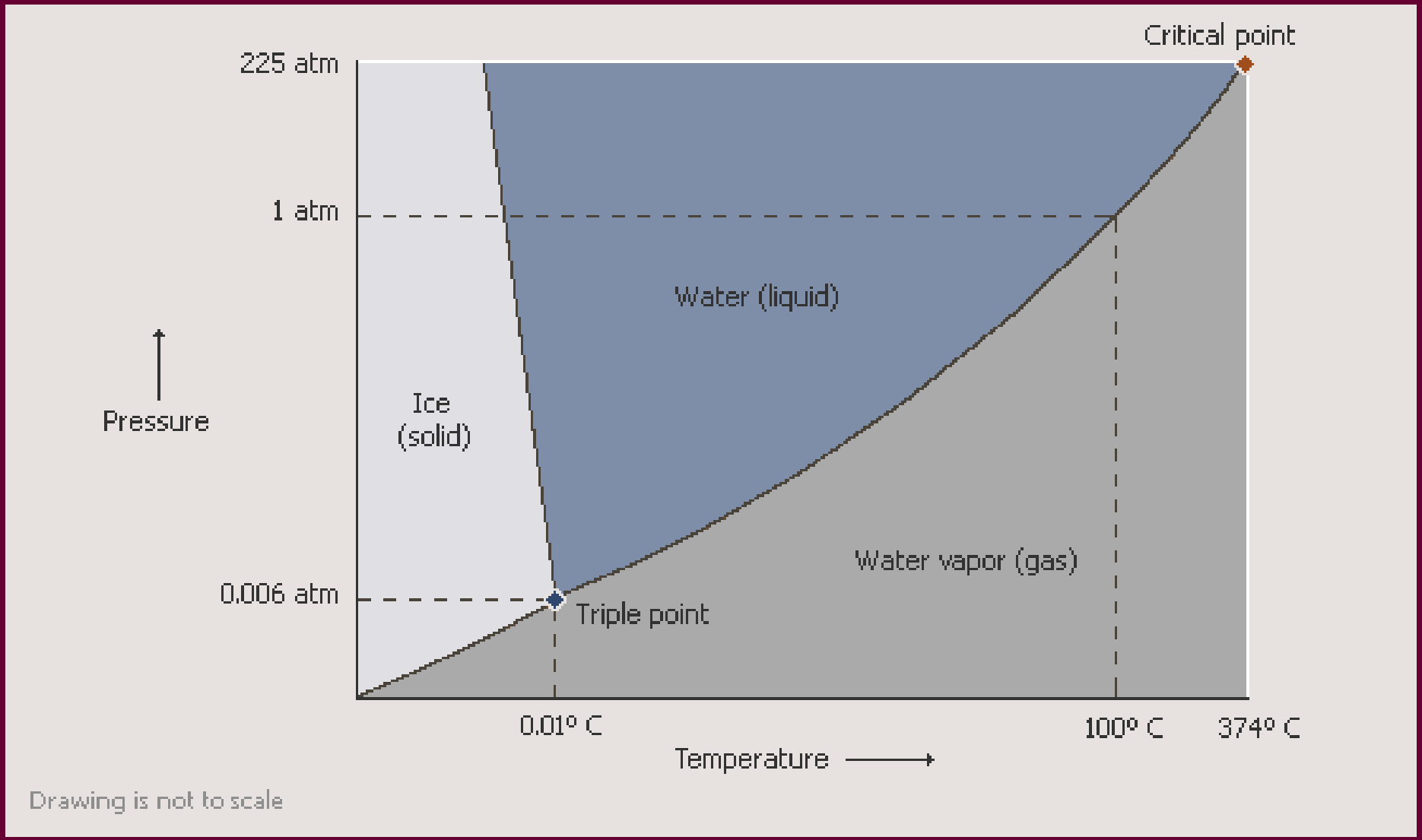
Phase Diagram



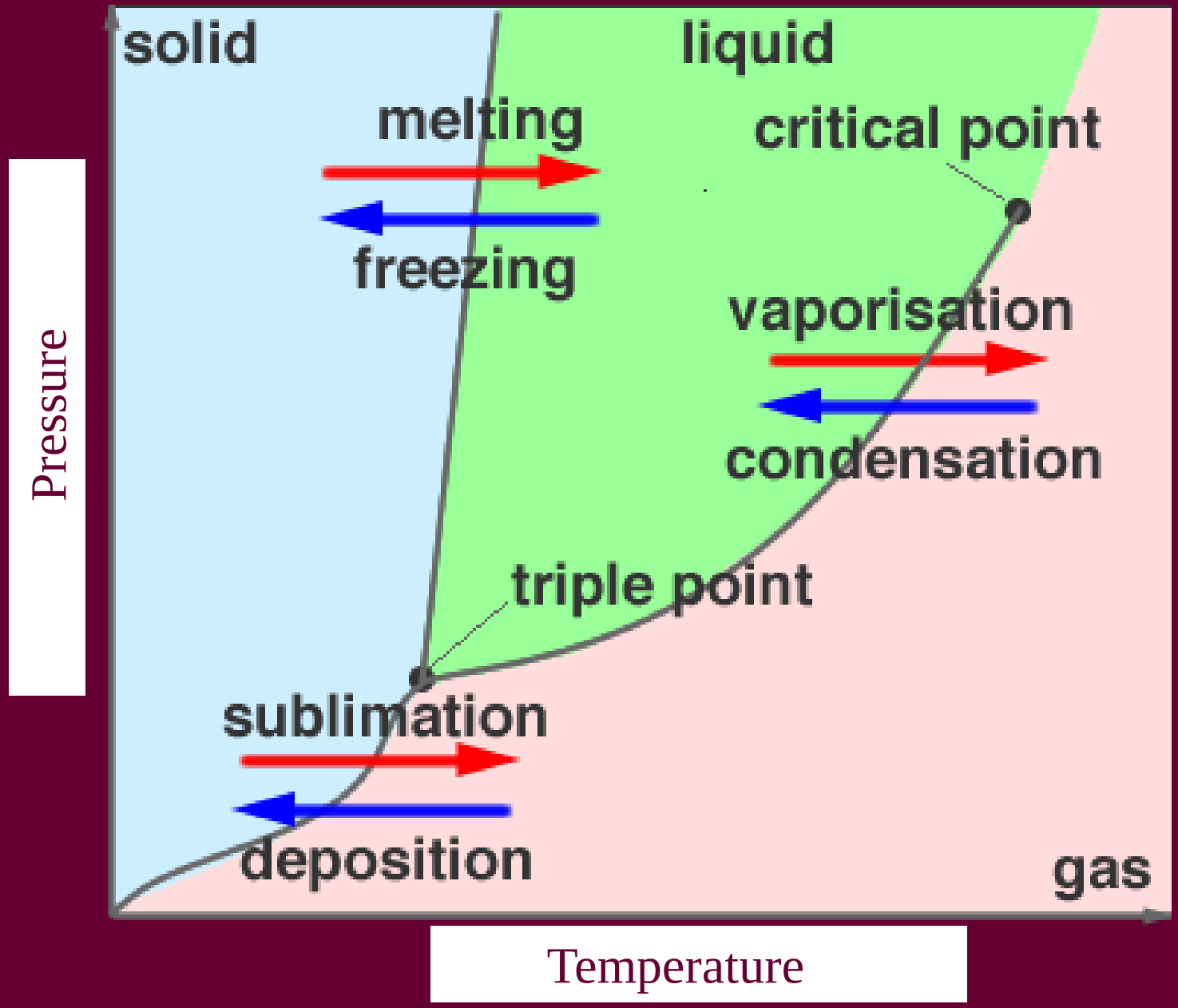
http://img.search.com/thumb/d/dc/Phase-diag.png/300px-Phase-diag.png

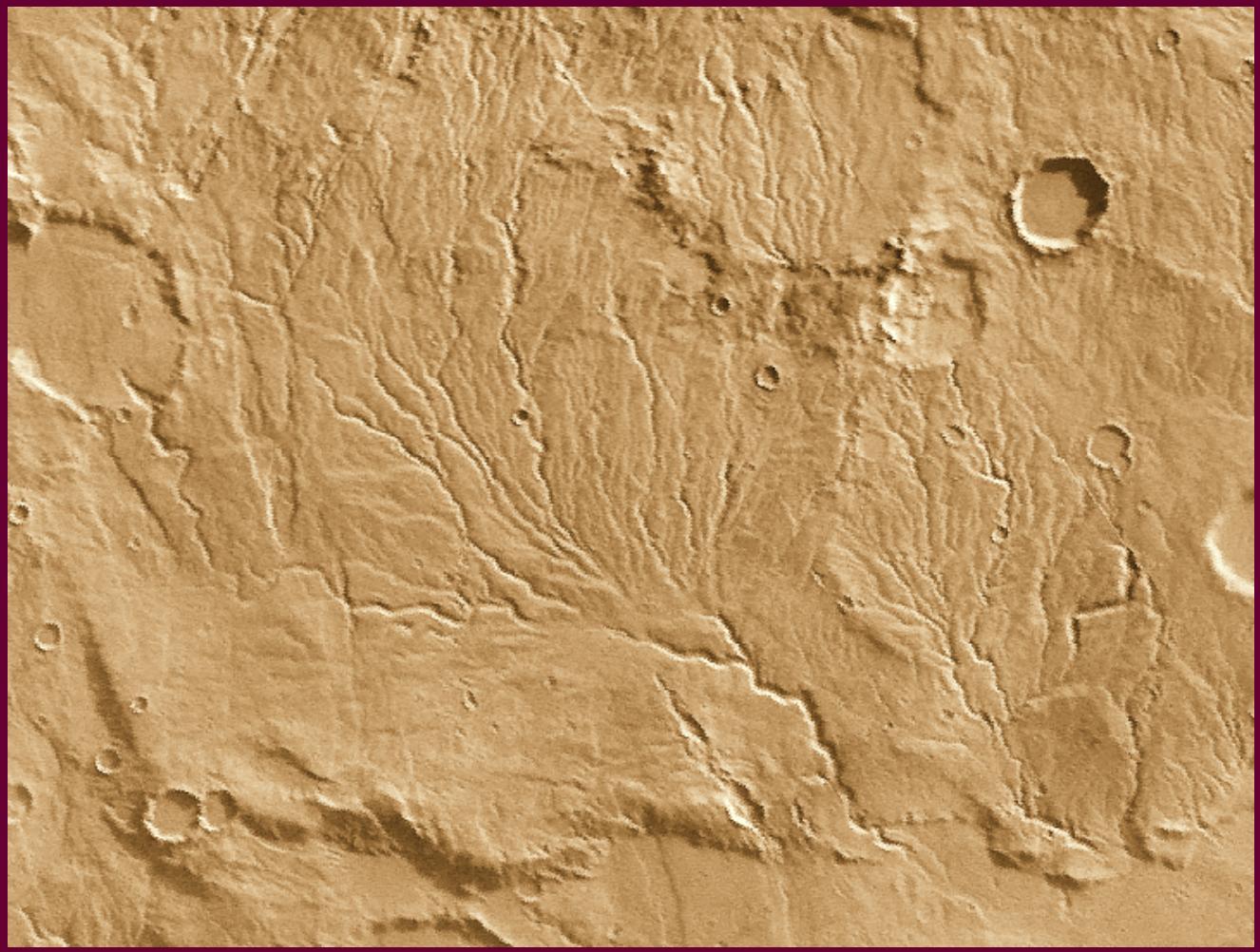


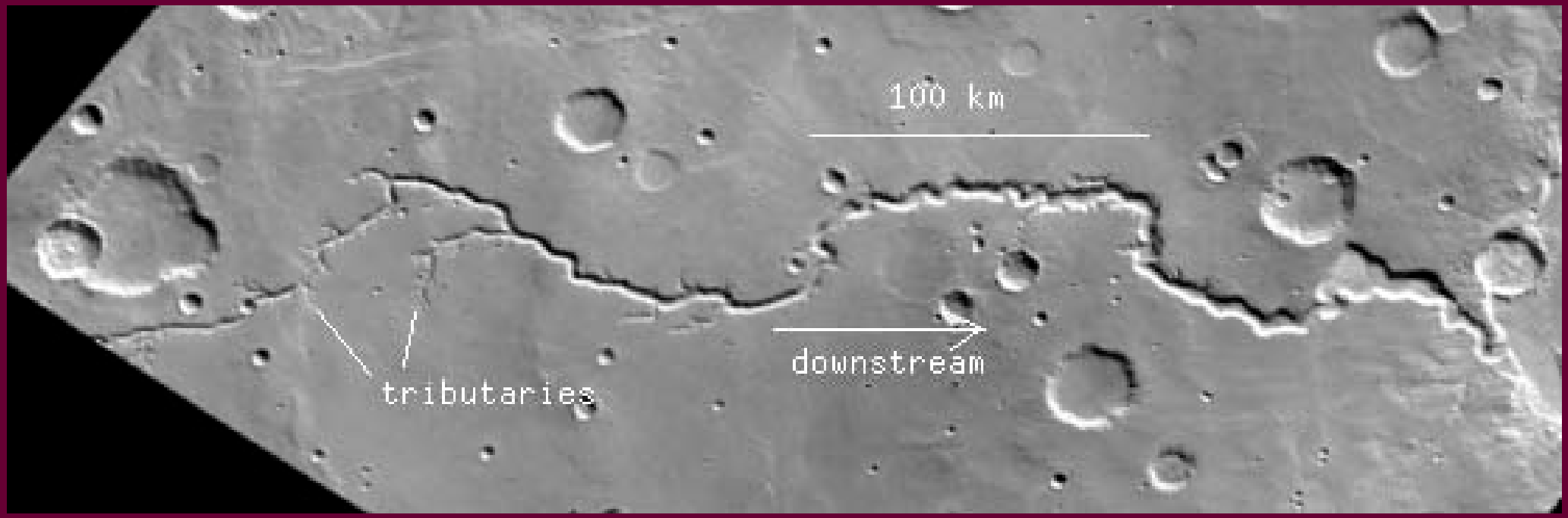
http://science.nasa.gov/headlines/y2000/ast29jun_1m.htm



http://images.encarta.msn.com/xrefmedia/aencmed/targets/illus/cha/T073590A.gif

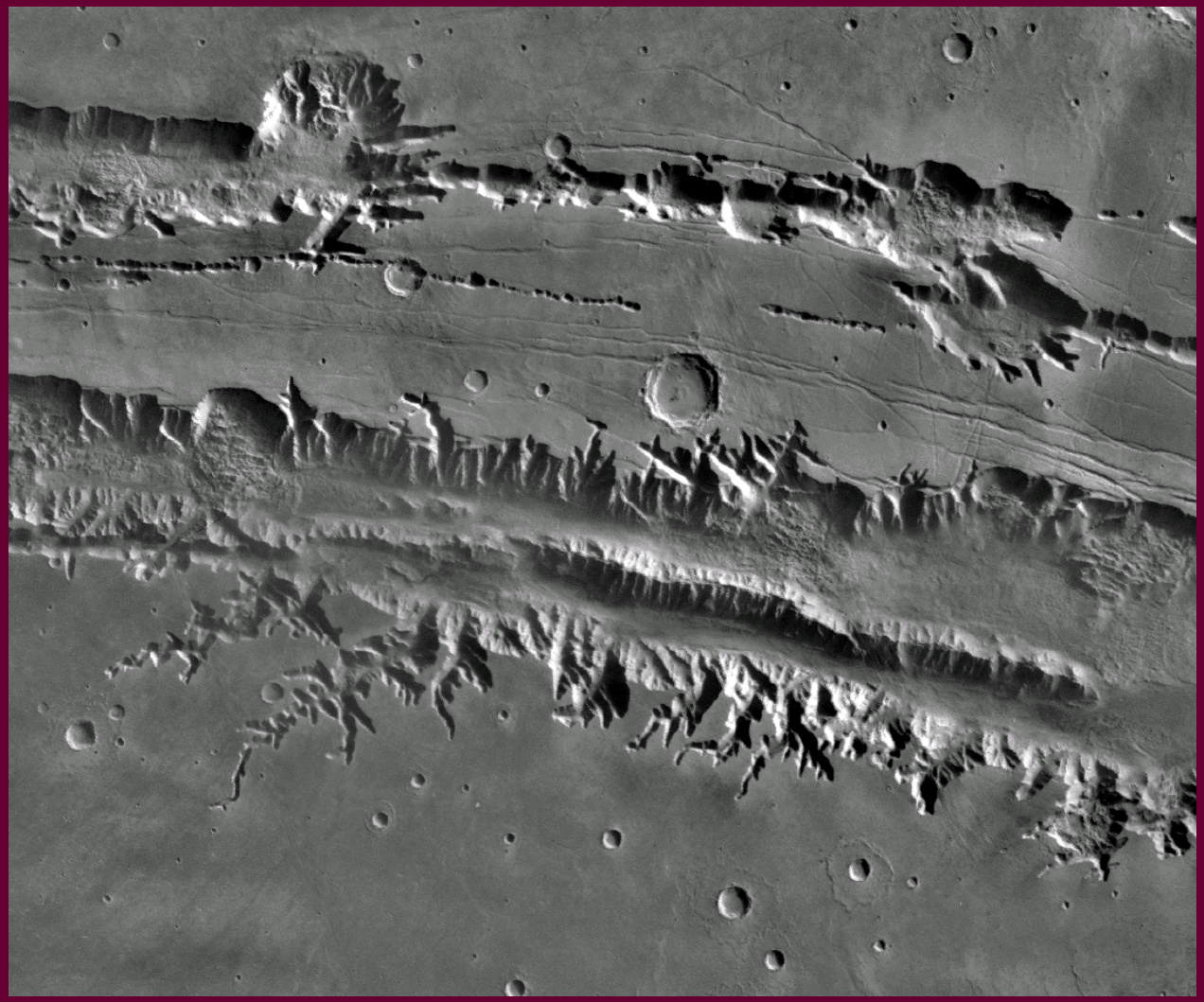

solid
liquid
melting
freezing
critical point
vaporisation
condensation
triple point
sublimation
deposition
gas
Pressure
Temperature




100 km
tributaries
downstream

- Valles Marineris is a system of canyons located just south of the Martian equator. The system is about 4000 km long,

Valles Marineris



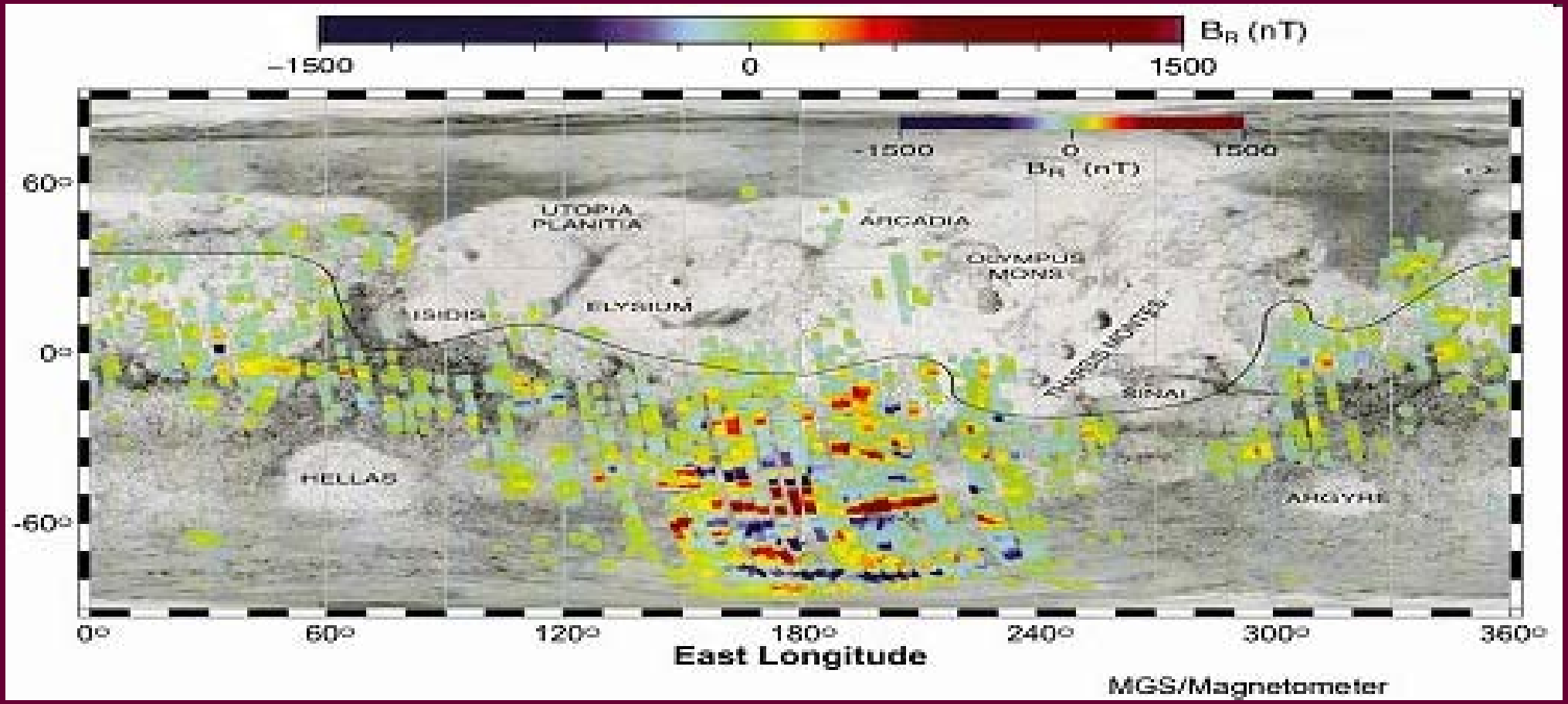
Water on Mars

- Most of the water is frozen (permafrost and polar caps)
- No bodies of liquid water, which could create a hydrosphere
- Only a small amount of water vapor is in the atmosphere

How did Mars lose its water?

How did Mars lose its water?

- One possibility:
- On Earth, we're protected from the solar wind by a global magnetic field
- Mars appears to have had a global magnetic field, which turned off
- When it turned off, Mars’ atmosphere may have been eroded by the solar wind



Hellas and Argyre basins, both thought to be about four billion years old, are demagnetized. Magnetic field must have turned off more than four billion years ago.

http://science.nasa.gov/headlines/y2001/ast31jan_1.htm

Topography

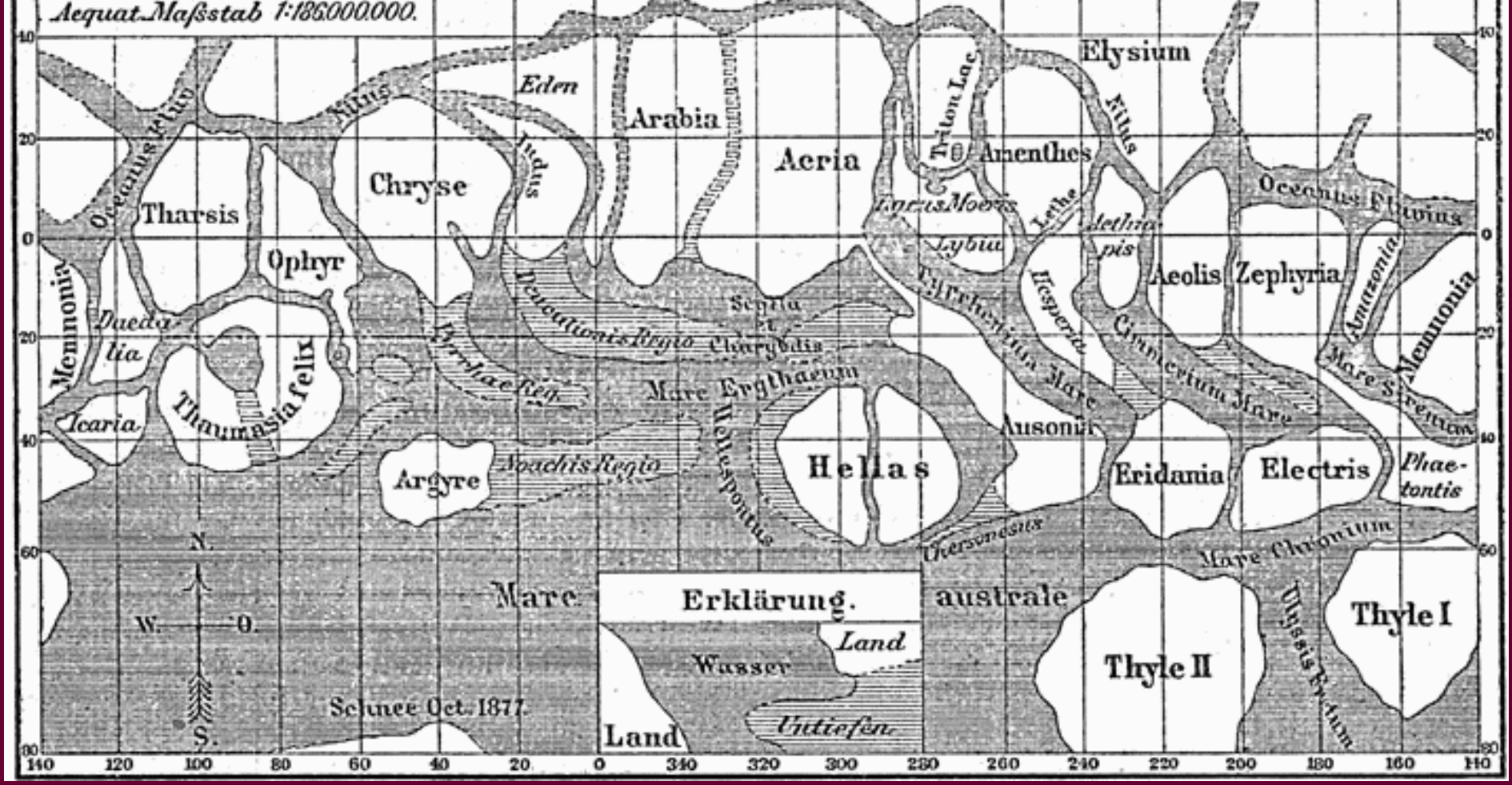
- The dichotomy of Martian topography is striking: northern plains flattened by lava flows contrast with the southern highlands, pitted and cratered by ancient impacts.
- The surface of Mars as seen from Earth is consequently divided into two kinds of areas, with differing albedo.

MOLA

- MOLA is the Mars Orbiter Laser Altimeter on Mars Global Surveyor (MGS) spacecraft
- This altitude determination process works by measuring the time that a pulse of light takes to leave the spacecraft, reflect off of the ground, and return to MOLA's collecting mirror.
- By multiplying the reflection time by the speed of light, scientists are able to calculate Surveyor's altitude above the local terrain to within 30 meters (98 feet) or better.

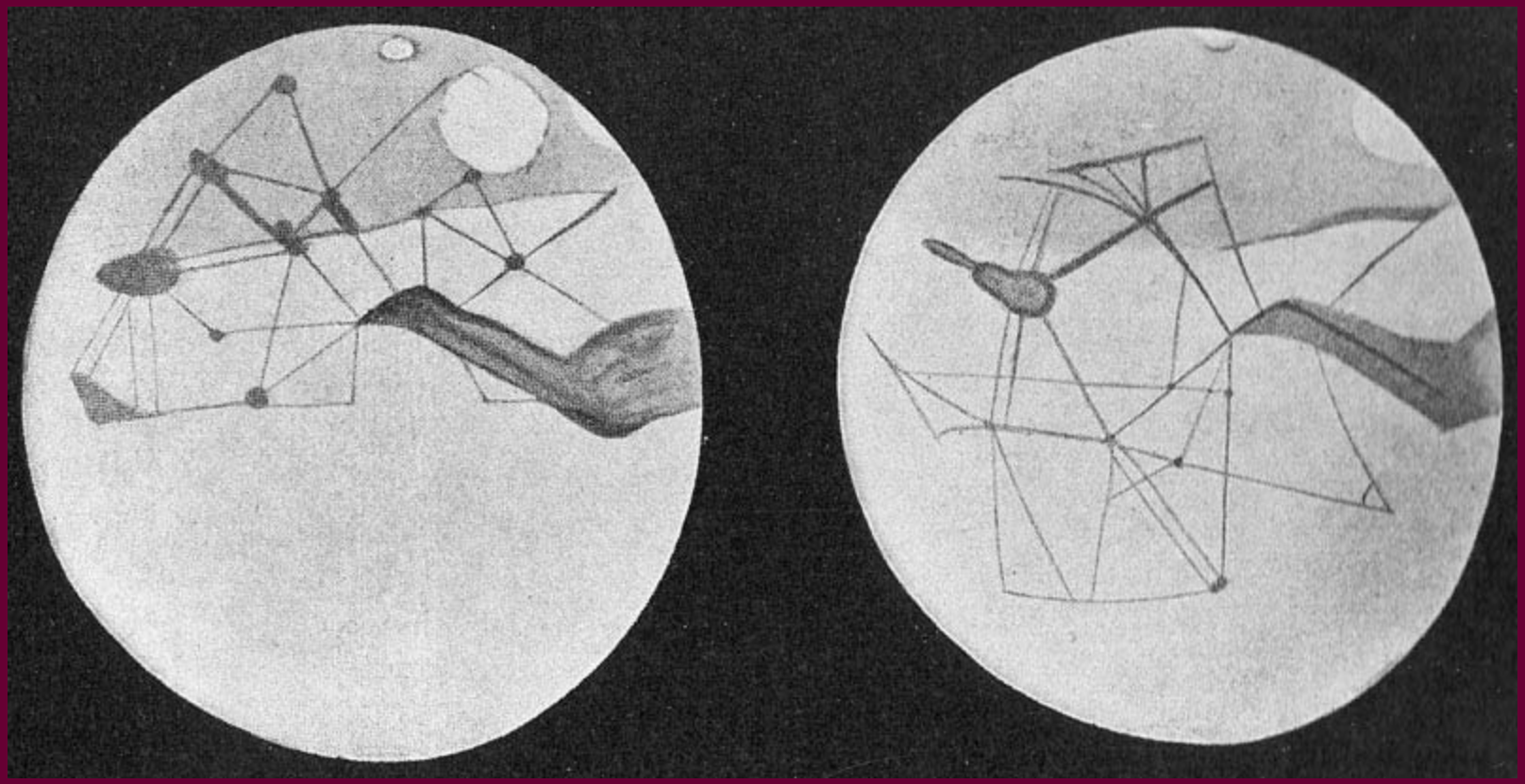
Two Hemispheres

- Northern Plains
- Southern Highlands



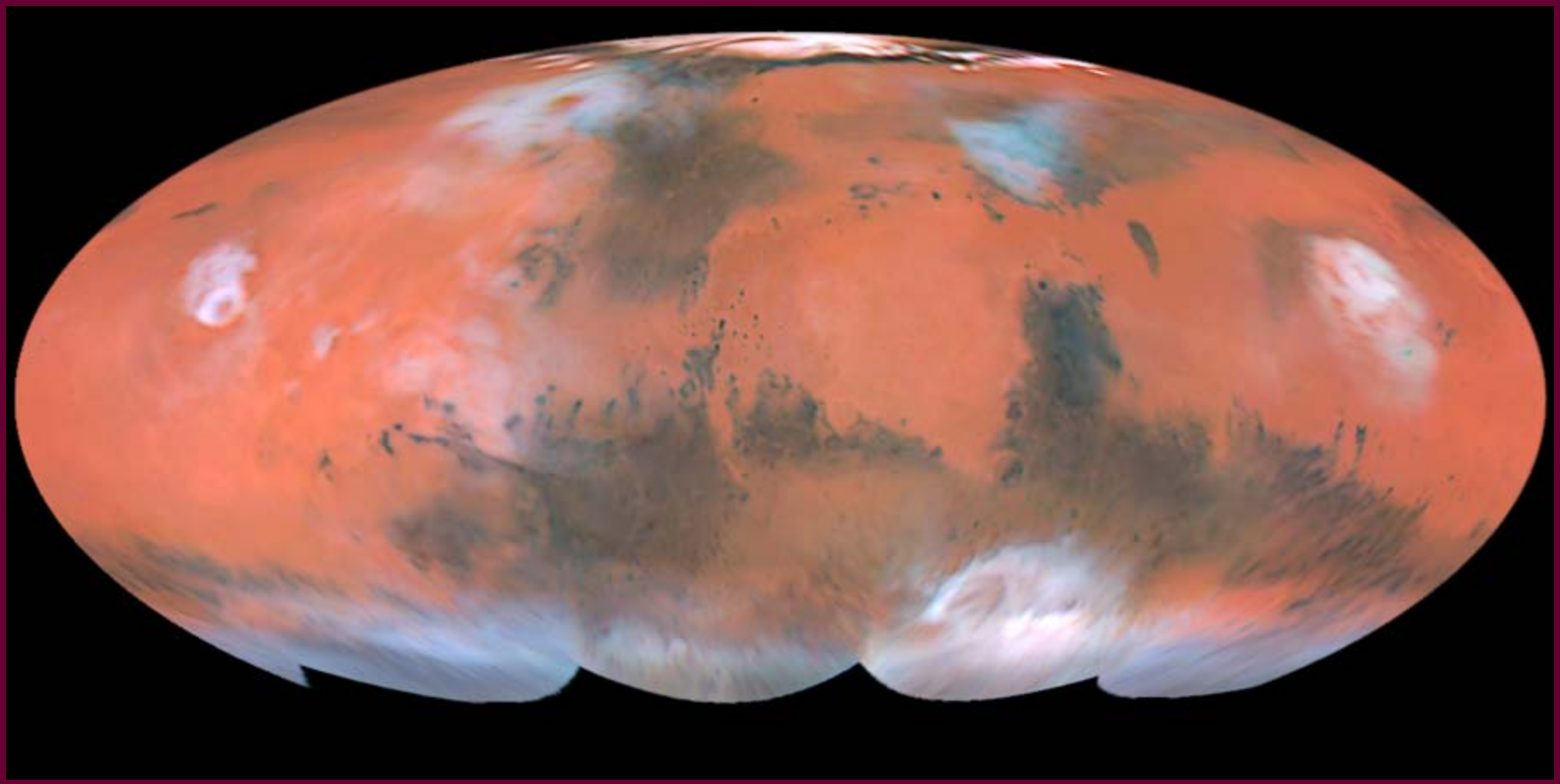
In September 1877, Italian astronomer Giovanni Schiaparelli used a 22 cm telescope to help produce the first detailed map of Mars. These maps notably contained features he called canali, which were later shown to be an optical illusion.

http://upload.wikimedia.org/wikipedia/commons/d/dd/Karte_Mars_Schiaparelli_MKL1888.png



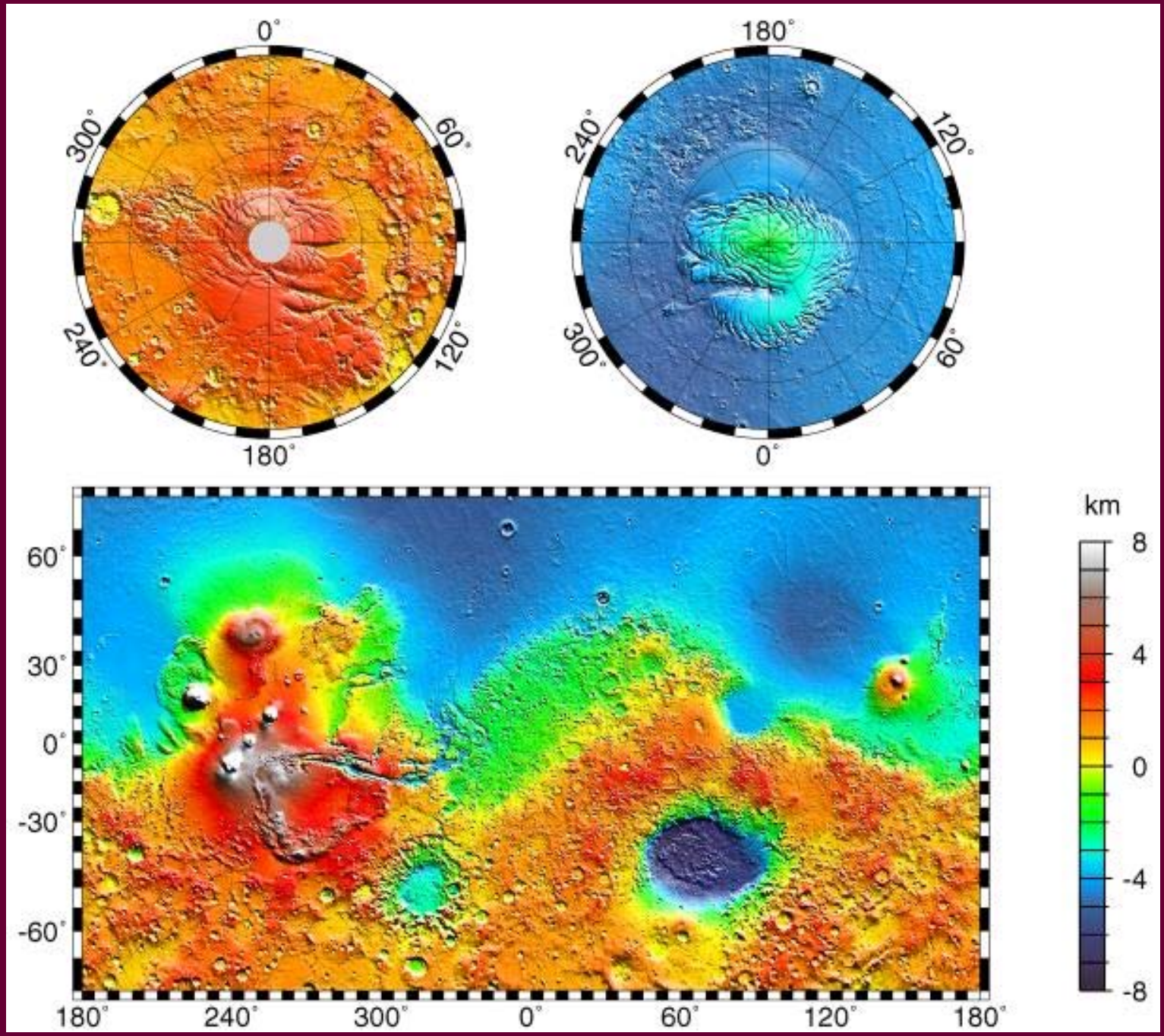
- Percival Lowell map of Mars from ~1914

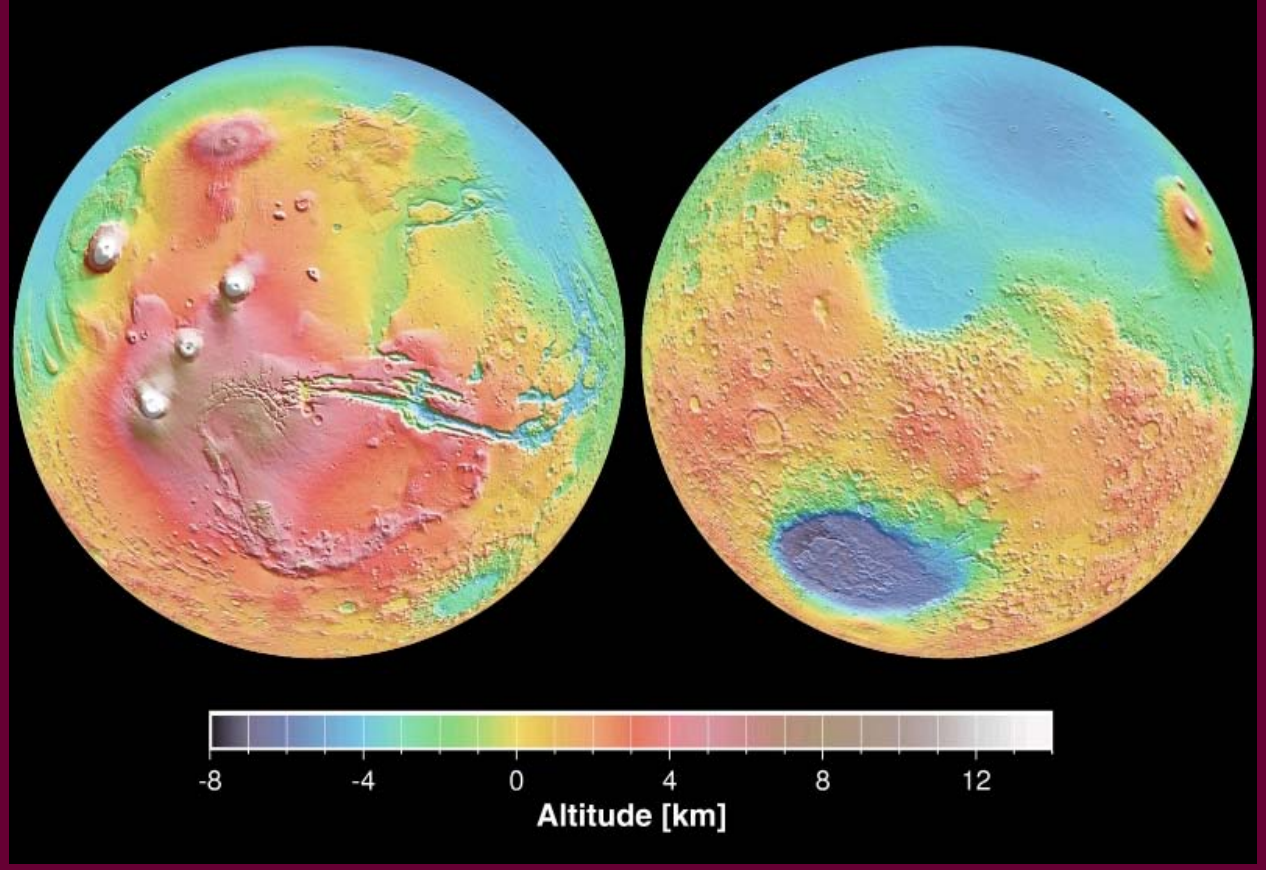
http://en.wikipedia.org/wiki/Image:Lowell_Mars_channels.jpg



- Hubble image from 1999

http://en.wikipedia.org/wiki/Image:Mars_HST_Mollweide_map_1999.png


0°
300°
60°
240°
120°
180°
180°
240°
120°
300°
60°
0°
60°
30°
0°
-30°
-60°
180°
240°
300°
0°
60°
120°
180°
km
8
4
0
-4
-8



- blue is low
- red/white are high
- These two hemispheres are centered on the Tharsis plateau (including the Valles Marineris and the large volcanos) and on the Isidis impact basin (with the Hellas basin to the south)

Epochs (Ages) on Mars

- Epochs are defined by the number of impact craters on the ground surface
- Older surfaces have more impact craters.

Geologic History of Mars

- Noachian epoch (named after Noachis Terra):

- Formation of the oldest surfaces of Mars, 4.6 billion years ago to 3.5 billion years ago. “Noachian age surfaces are scarred by many large impact craters.” The Tharsis bulge is thought to have formed during this period.

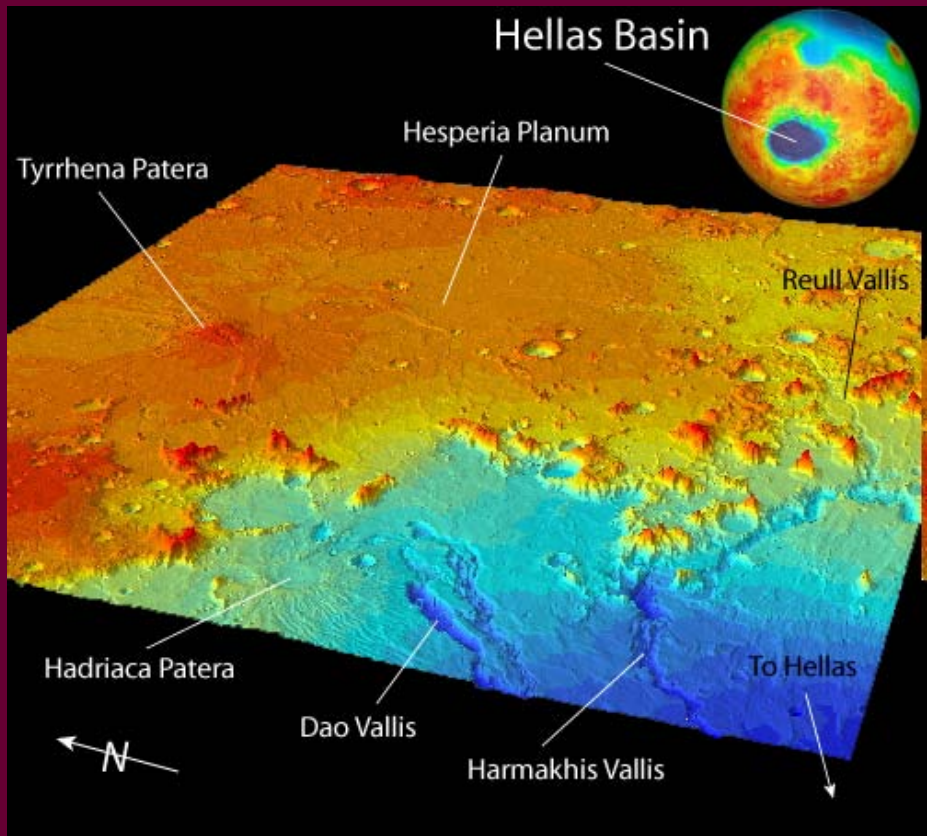
- Noachis Terra ("Land of Noah") is an extensive southern landmass (terra) of the planet Mars.

- http://www.google.com/mars/

Geologic History of Mars

- Hesperian epoch (named after Hesperia Planum) :

- 3.5 billion years ago to 1.8 billion years ago. The Hesperian epoch is marked by the formation of extensive lava plains.

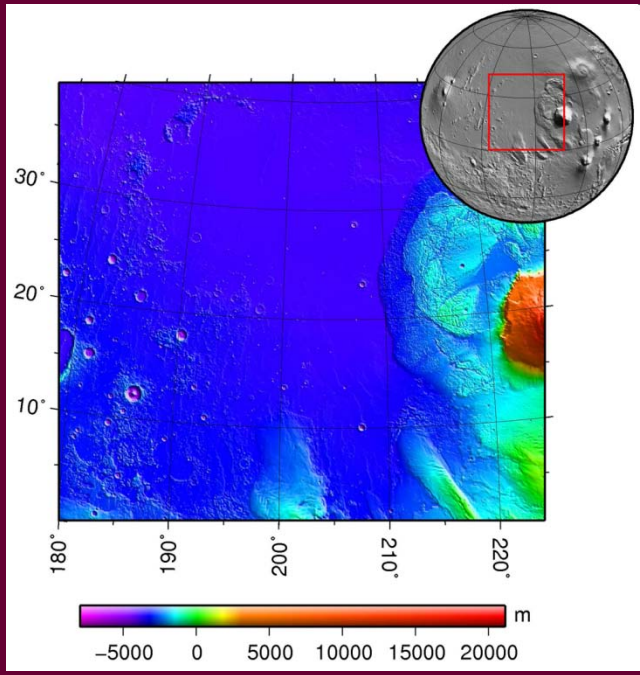


http://www.psi.edu/NE_Hellas_Hesperia.jpg

Geologic History of Mars

- Amazonian epoch (named after Amazonis Planitia)

- 1.8 billion years ago to present. Amazonian regions have few impact craters, but are otherwise quite varied. Olympus Mons formed during this period along with lava flows elsewhere on Mars.



http://upload.wikimedia.org/wikipedia/commons/7/7f/Amazonis_planitia_topo.jpg

- The northern hemisphere is much flatter
- The northern hemisphere was formed from lava flows
- The northern hemisphere is also lower than the southern hemisphere, with an elevation difference between the two of about 5 km (3 mi)

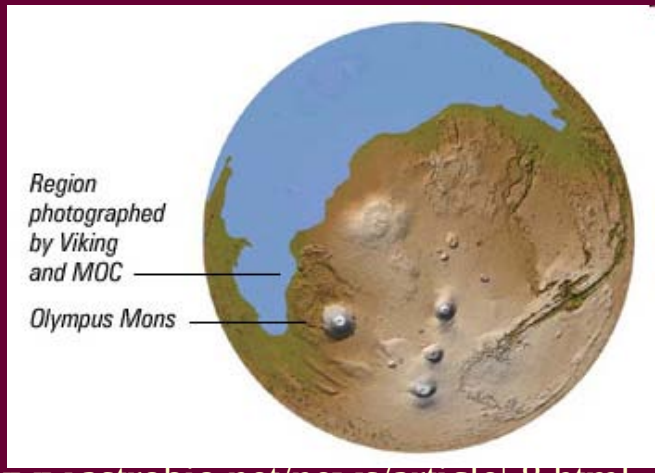
What caused this difference?

What caused this difference?

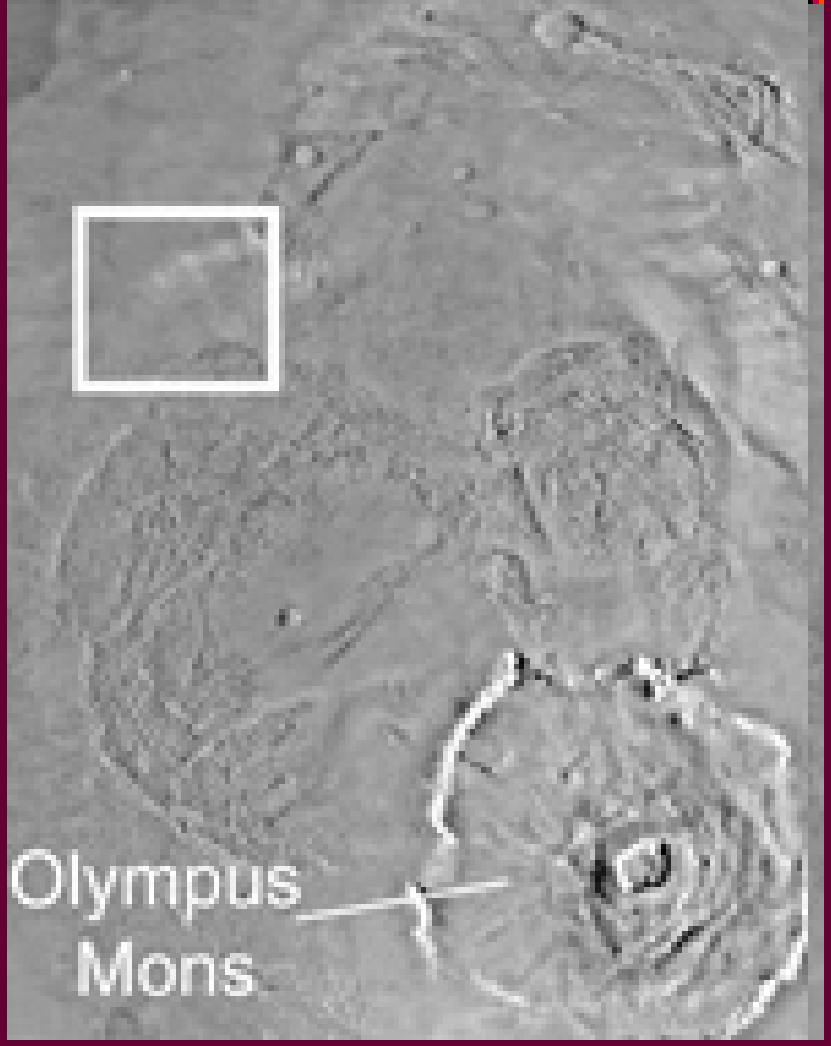
- Glancing impact
  - "The impact would have to be big enough to blast the crust off half of the planet, but not so big that it melts everything"

http://www.world-science.net/othernews/080625_mars.htm

- Huge ocean covered Northern Hemisphere?



http://www.astrobio.net/news/article58.html

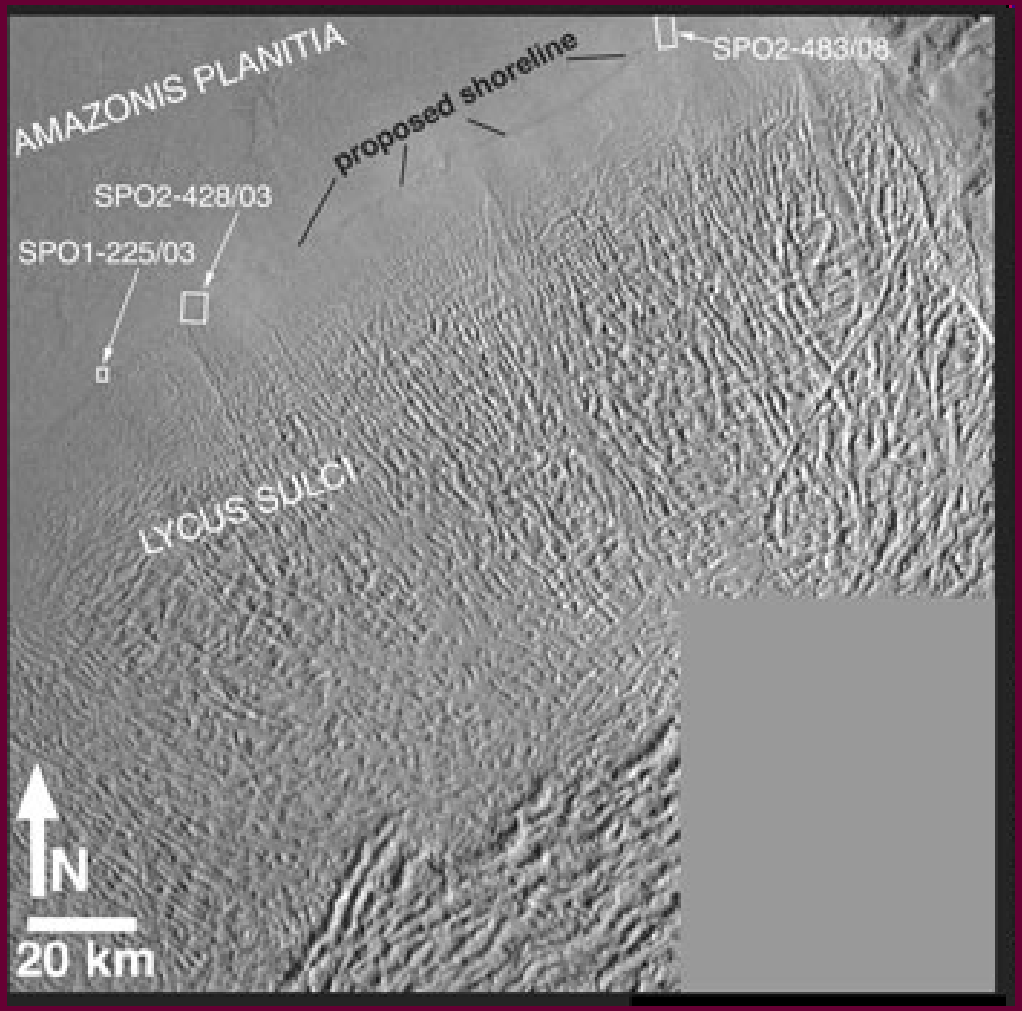


Location of proposed shoreline with respect to Olympus Mons.
Since the proposed cliff faces toward the smooth plains,
it was suggested that this feature might be the signature of a
cliff that forms from erosion by waves in a body of water as
they break against a coastline.

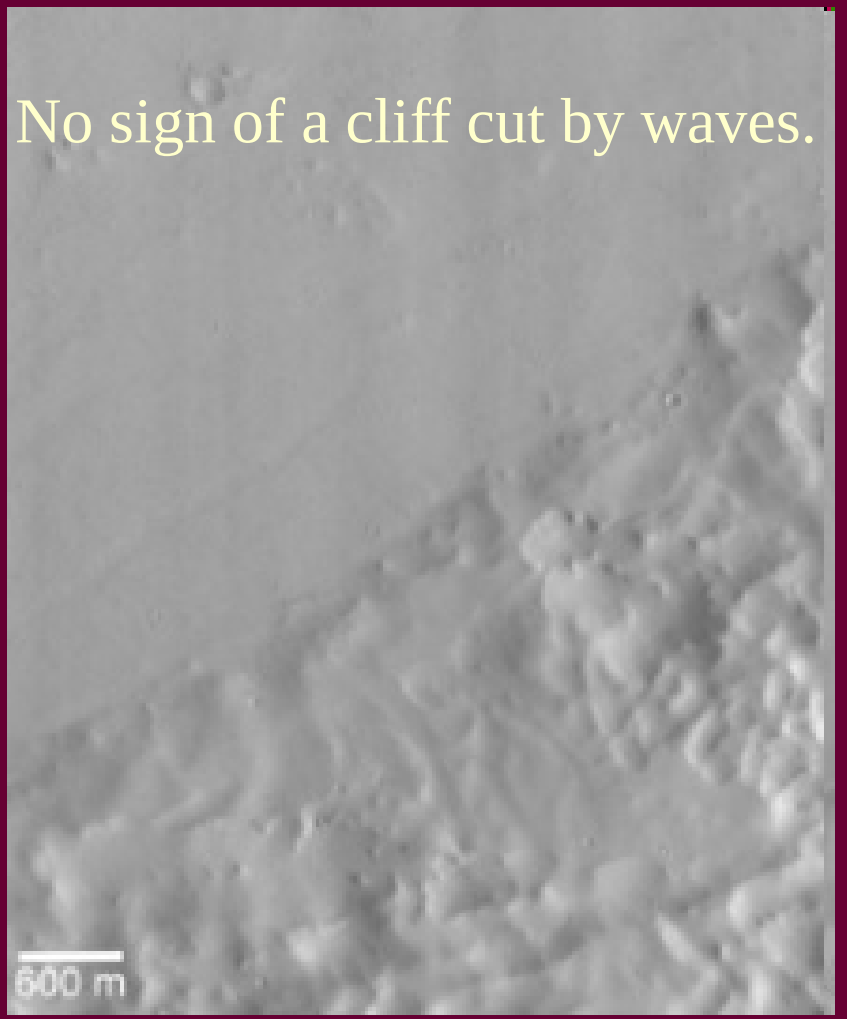
Olympus Mons

- The shield volcano, Olympus Mons (*Mount Olympus*), is at 26 km the highest known volcano and mountain in the solar system.

Shorelines



Viking Image



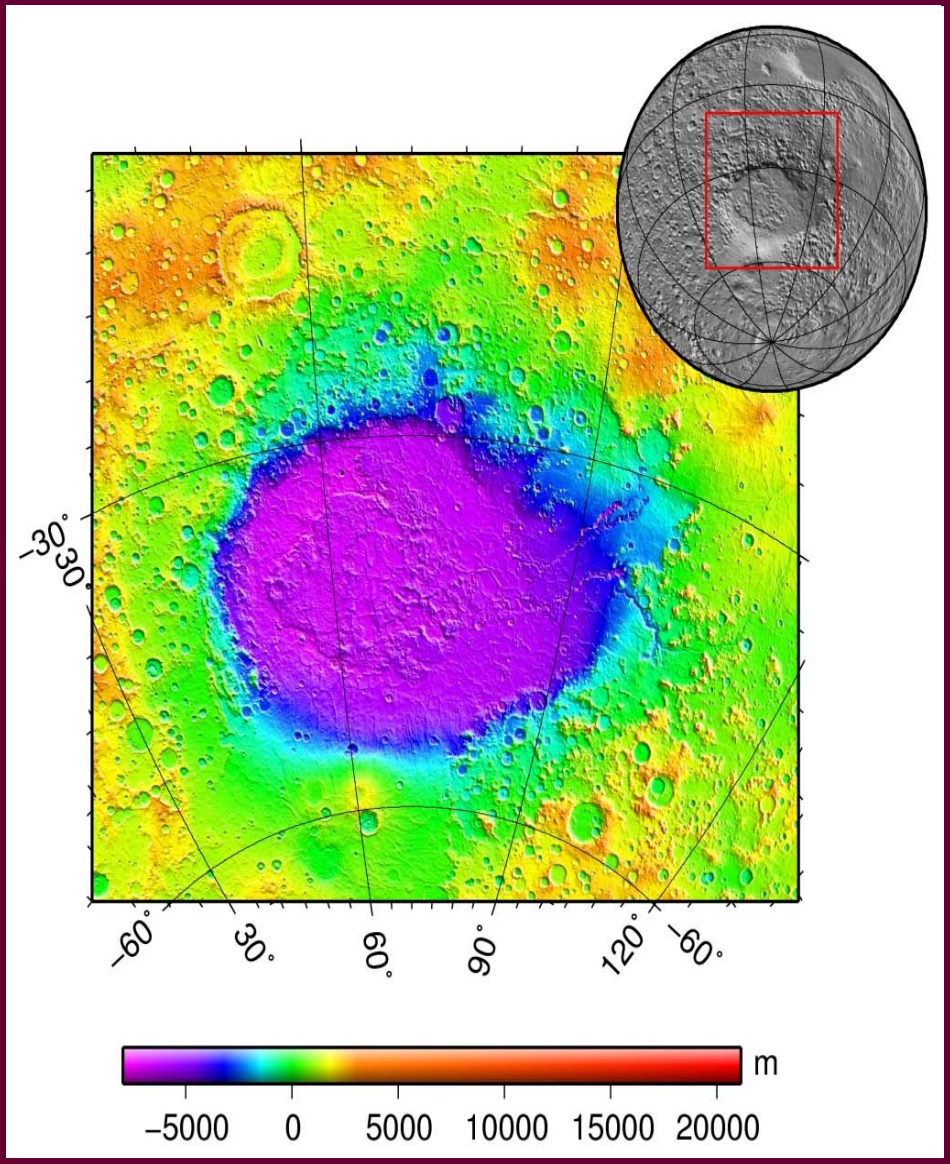
Mars Orbital Camera (MOC) image from Mars Global Surveyer

http://www.astrobio.net/news/article58.html

Hellas Basin

9 km depth

2,300 km in diameter

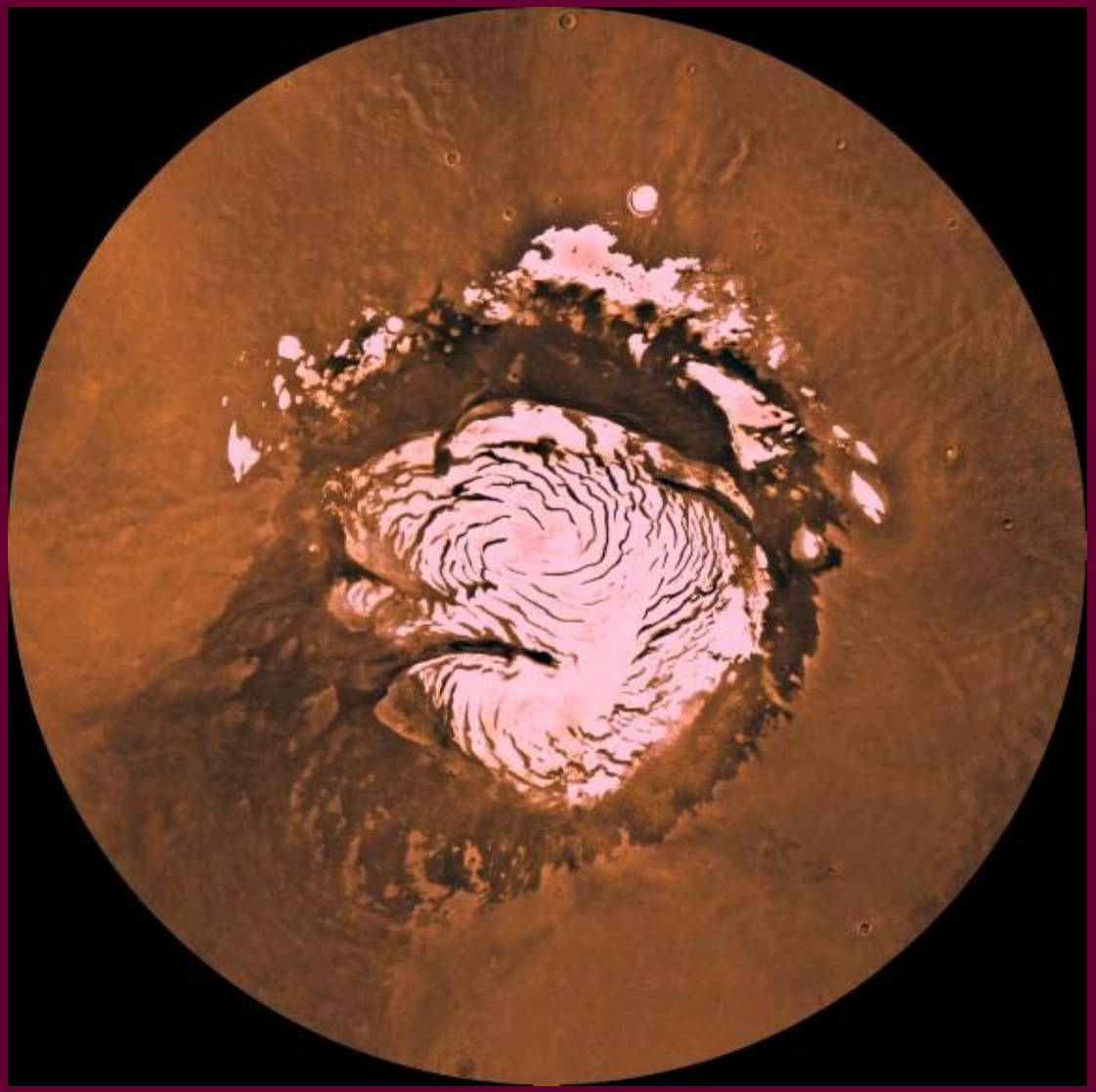


http://upload.wikimedia.org/wikipedia/commons/f/fc/Hellas_basin_topo.jpg

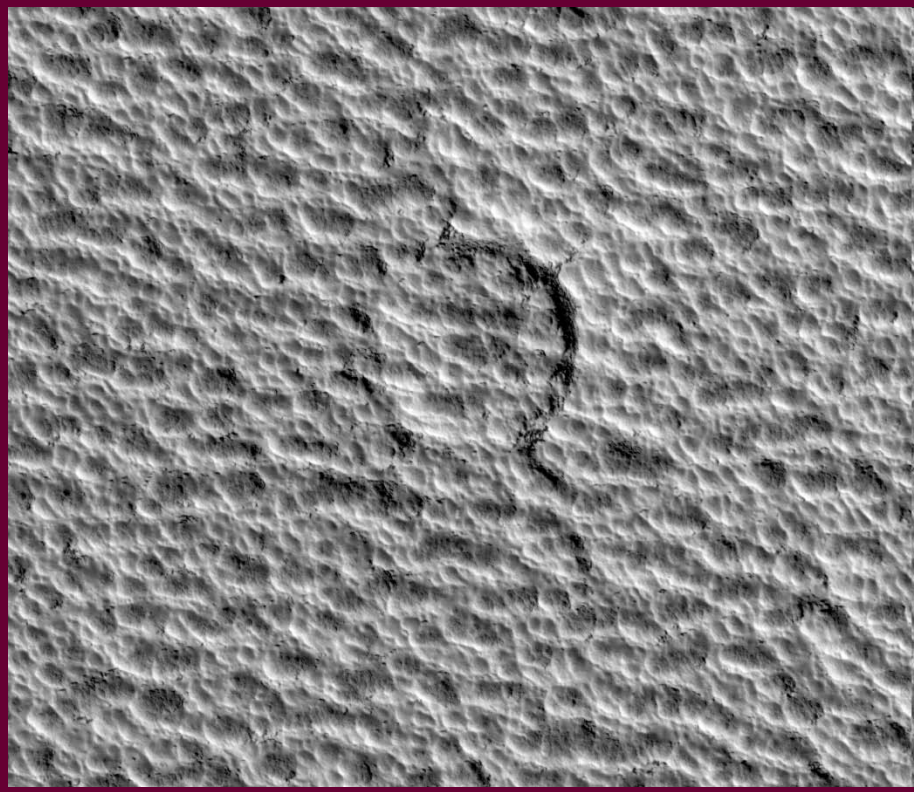
Hellas Basin

- It is the second or third largest impact crater and the largest visible impact crater known in the Solar System.

Northern Polar Cap



Crater is 80 m in diameter



Permanent ice cap comprised mainly of water and carbon dioxide ice

http://en.wikipedia.org/wiki/Planum_Boreum

Northern Polar Cap

- The perennial or permanent portion of the north polar cap consists almost entirely of water ice.
- In the northern hemisphere winter, this gains a seasonal coating of frozen carbon dioxide (dry ice) about one meter (three feet) thick.

Basic Definition of Life

- Growth
- Metabolism
- Motion
- Reproduction
- Stimulus response

ALH 84001

- Allan Hills 84001
- Martian meteorite found in Antarctica
- Thought to have evidence for life (1996)

Meteorites from Mars

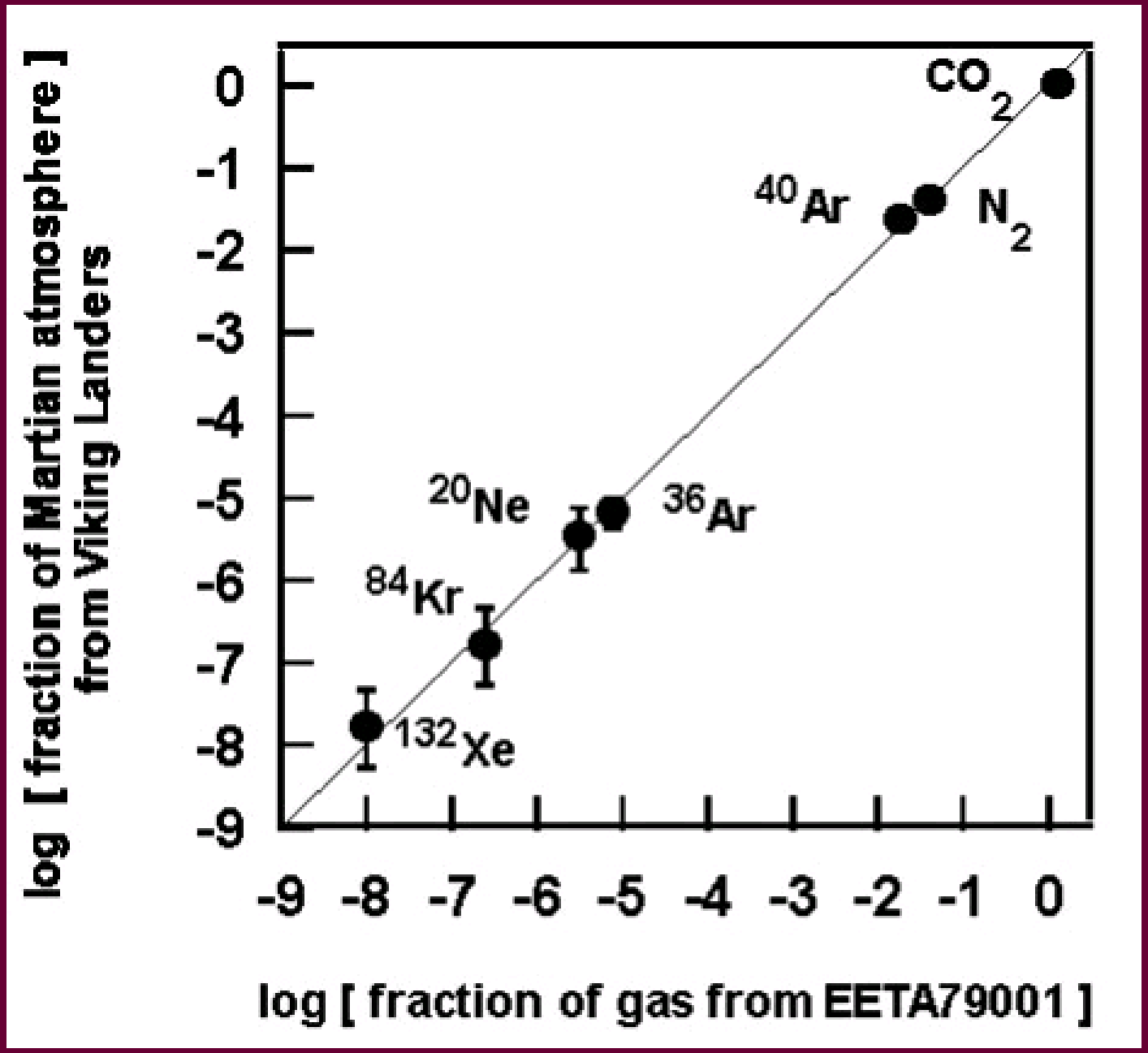
- Are called SNCs
- Shergottites, Nakhlites, Chassignites
  - Shergotty
  - Nakhla
  - Chassigny
- 34 Martian meteorites currently known

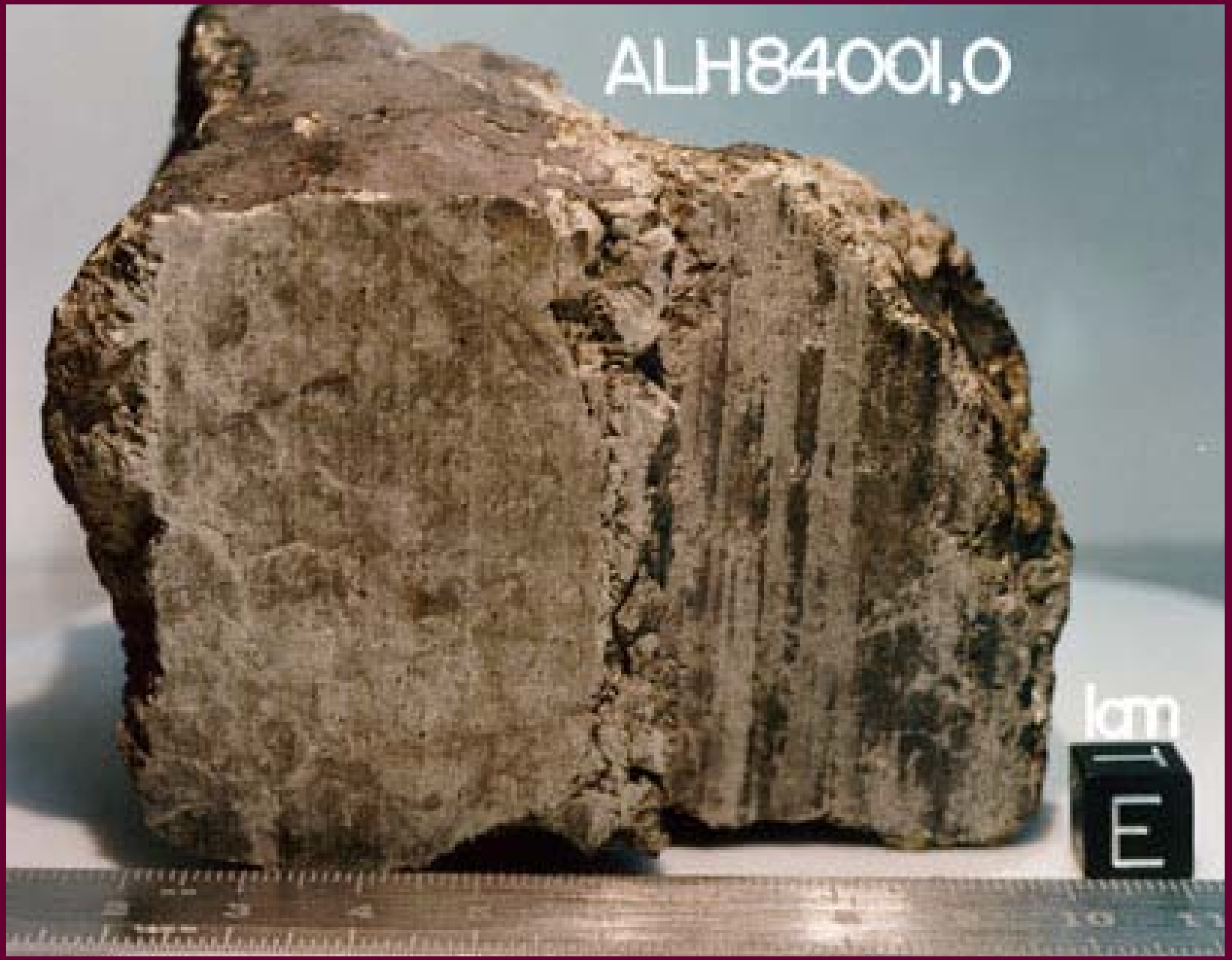
How do we know they are from Mars?

- Most have young crystallization ages (1.35 and 0.15 billion years)
- Gases in glass in meteorites match Mars

Crystallization Age

- Crystallization age is measured from when the rock cooled and the mineral formed
- Certain unstable isotopes are locked into the crystals of the rock, and they begin to decay.


log [fraction of Martian atmosphere]
from Viking Landers
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
CO2
40Ar
N2
20Ne
36Ar
84Kr
132Xe
-9 -8 -7 -6 -5 -4 -3 -2 -1 0
log [fraction of gas from EETA79001]

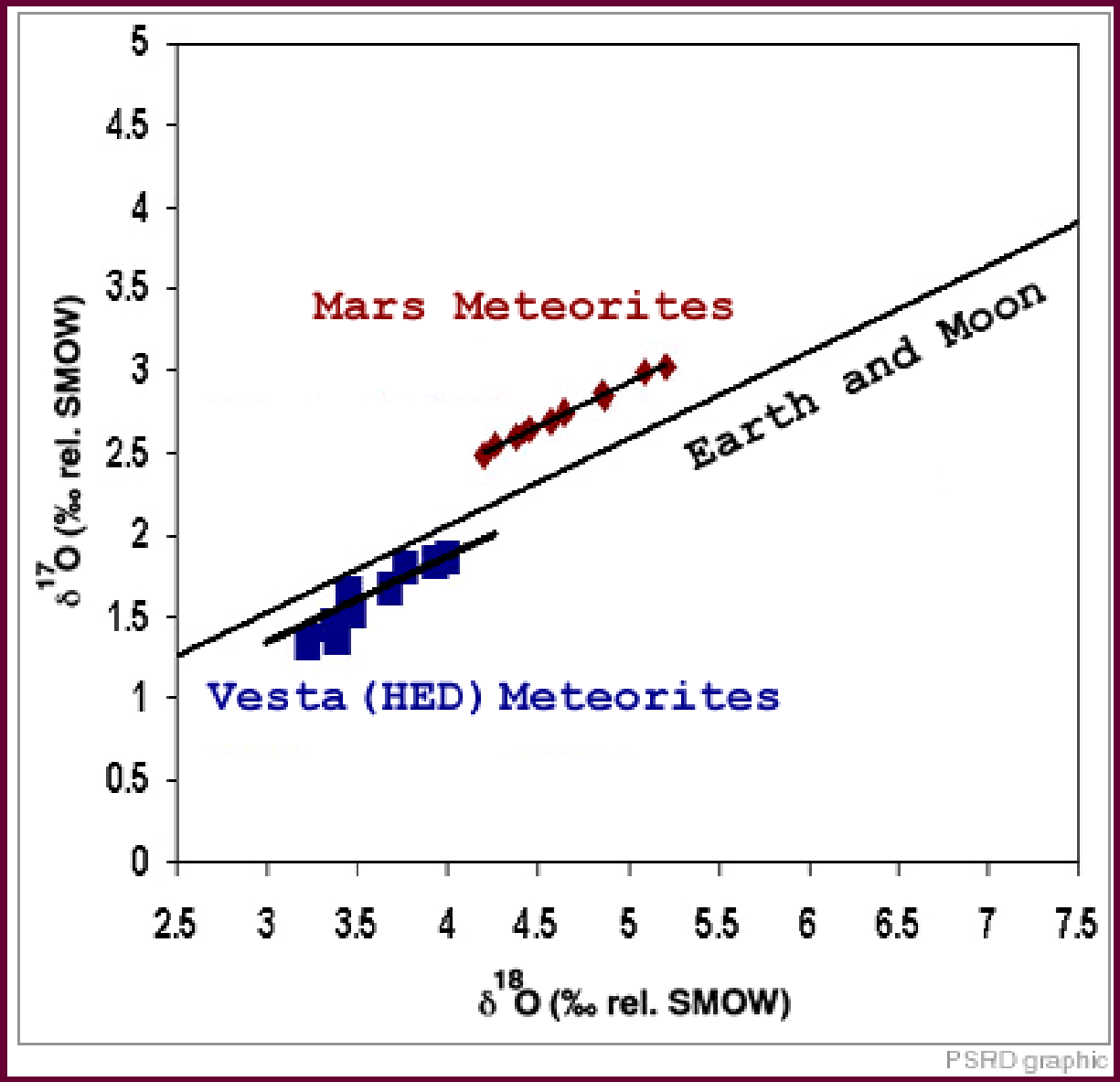

ALH84001,0
lam
E

Evidence

- organic molecules
- Magnetite (Fe_3O_4) that looks like it formed from biologic activity
- nanofossil-like structures

Age of ALH 84001

- ALH 84001 - 4.5 billion years
- But has same oxygen isotope ratio as other Martian meteorites so it comes from Mars
- Oldest meteorites are 4.56 billion years


Mars Meteorites
Earth and Moon
Vesta (HED) Meteorites
δ17O (‰ rel. SMOW)
δ18O (‰ rel. SMOW)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
7.5
PSRD graphic

What are problems with studying Martian meteorites to learn about Mars

Any Questions?