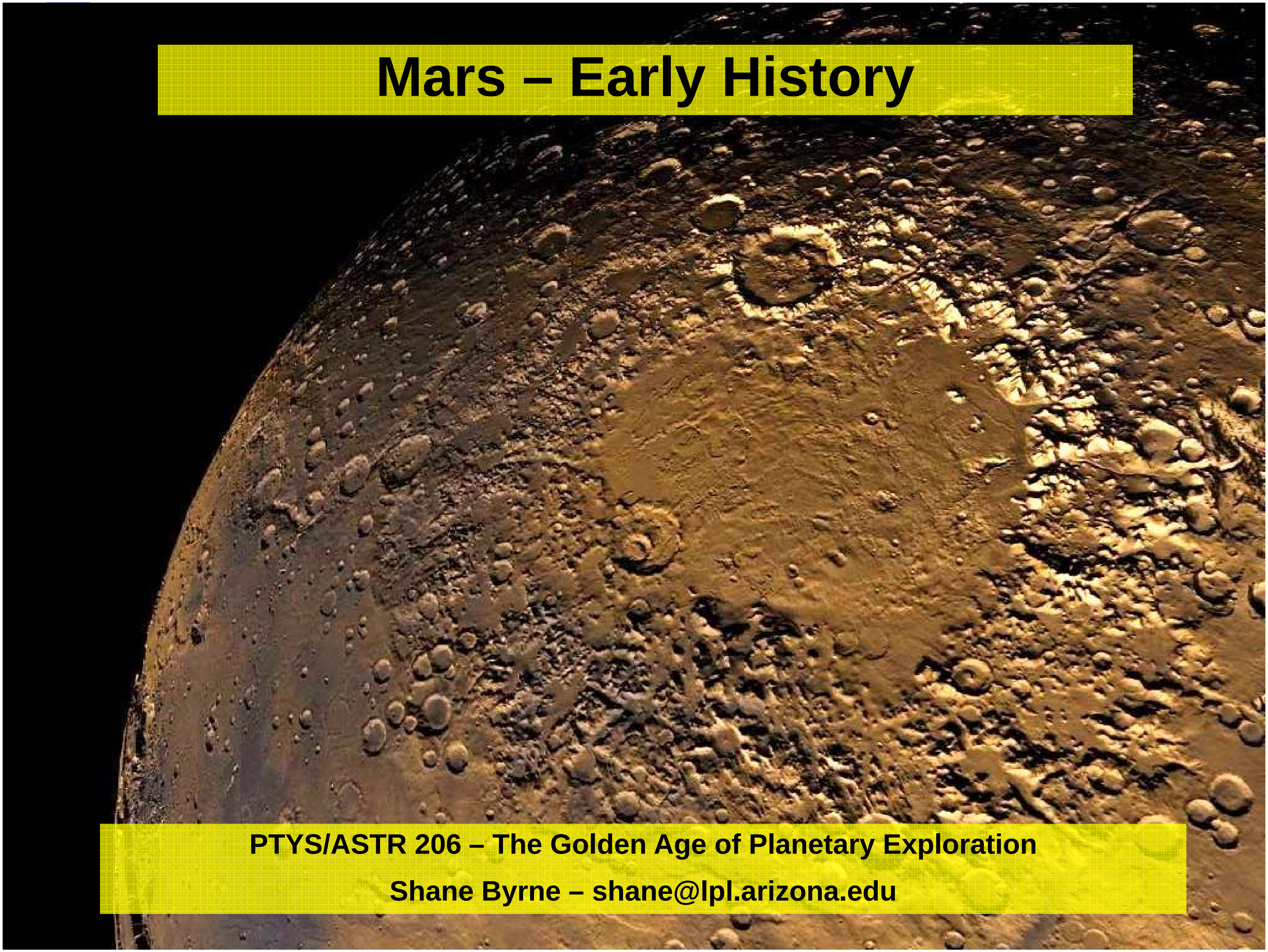
- **Announcements**
  - **Use Priyanka Sharma as TA**
    - **psharma@lpl.arizona.edu**
    - **Office hours: Tuesday 10.30am-12.30pm**
      Room 316, Kuiper Building

Mars – Early History



PTYS/ASTR 206 – The Golden Age of Planetary Exploration

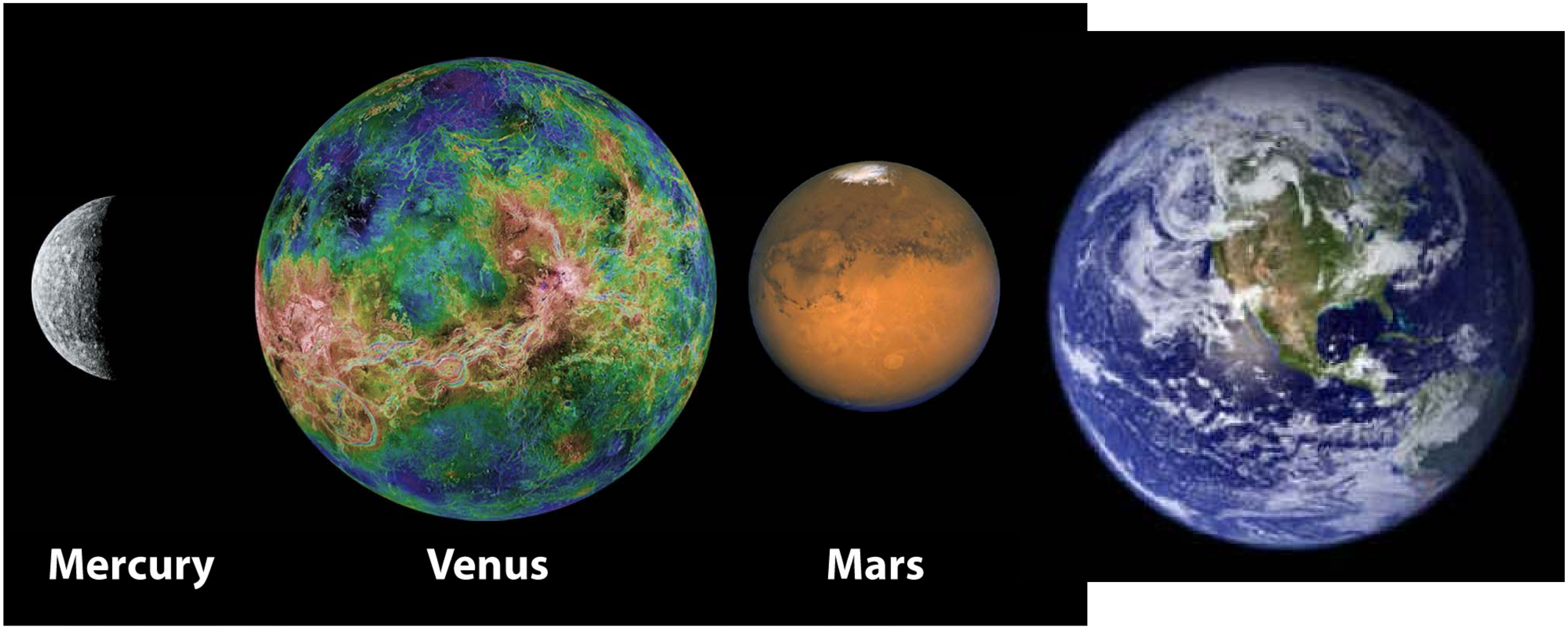
Shane Byrne – shane@lpl.arizona.edu

In this lecture…

- **Introduction**
  - **Comparisons to Earth**
  - **Seasons on Mars**
  - **Early ideas**
- **Spacecraft exploration**
  - **Not Earth-like after all**
  - **Familiar landforms**
- **Early Martian History**
  - **Crustal dichotomy**
  - **Large impacts and volcanic activity**
  - **Magnetic fields**
  - **Valley networks**

Introduction

- **One of the larger terrestrial planets**
  - **Intermediate between Mercury/Moon and Earth/Venus**



Chapter 11 Opener
Universe, Eighth Edition

- **Comparison to the Earth**
  - **A mini-Earth?**

Mars	
Size	53% of the Earth
Mass	11% of the Earth
Density	3934 kg m^{-3} (Earth/Venus ~ 5500 kg m^{-3})
Solar Distance	1.52 AU
Year	687 days, 1.9 Earth years
Obliquity	25° (Earth = 23½°)
Rotation period	24hrs 37 minutes (Earth = 1 day)
Surface	Earth-like rocks and landforms Some parts heavily cratered

Roughly The Same Internal Structure

Days and Seasons similar to the Earth

Similar Surface

- **Comparison with the Earth II**
  - **How much solar radiation does Mars receive?**
  - **Remember:** **Solar power = 1367 W m^{-2} / R^2**
  - **Mars is 1.52 AU from the Sun: R=1.52**
  - **So:** **Solar power = 1367 W m^{-2} / 1.52^2**
  - **Solar power at Mars is 592 W m^{-2} (about half that of Earth)**
- **Mars is a much colder place…**
  - **Harder for liquid water (& life) to exist**
  - **Not always the case though… Early Mars was quite different**

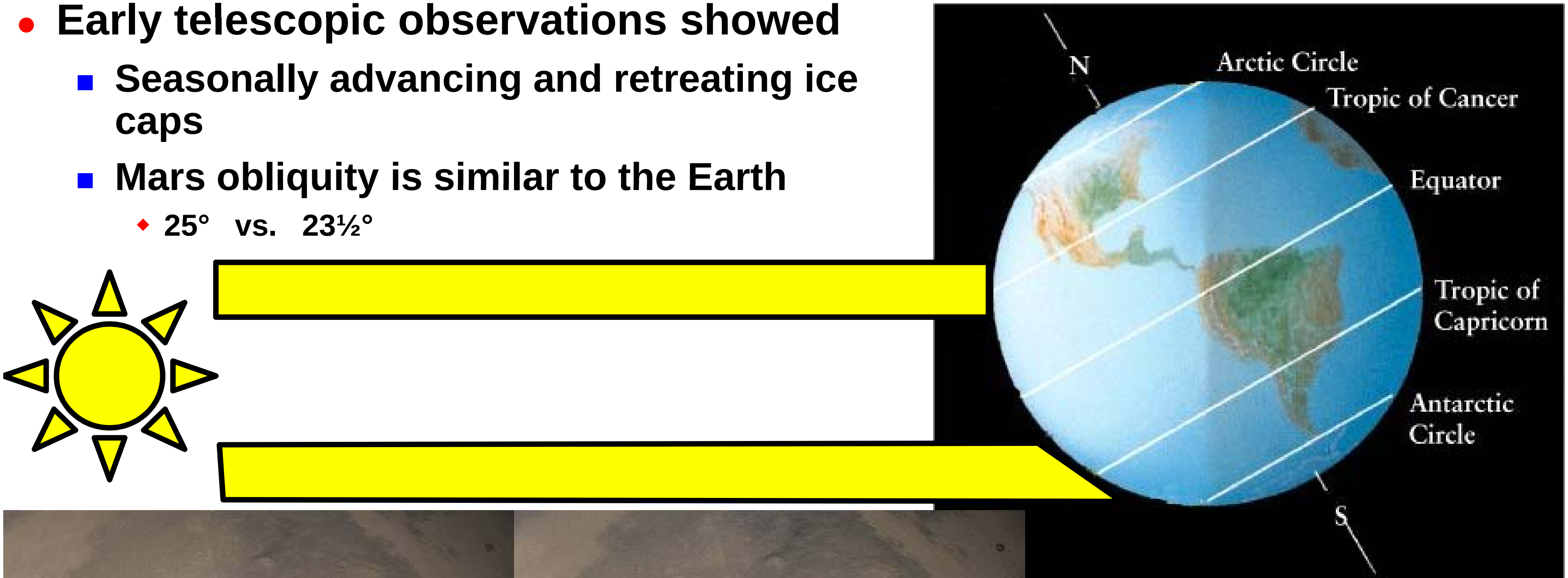
- **Differences from the Earth**

Mars	
Atmosphere	Mostly CO_2 (Earth = Mostly nitrogen)
Pressure	0.006 bars (Earth = 1 bar)
Surface Temp.	200K (Earth = 300 K)
Clouds	Water ice and dust (Earth = water vapor)
Magnetic field	None (Earth has a strong field)
Seasonal ice	Carbon dioxide (Earth has water frost)

Very Different Atmosphere

Seasons on Mars

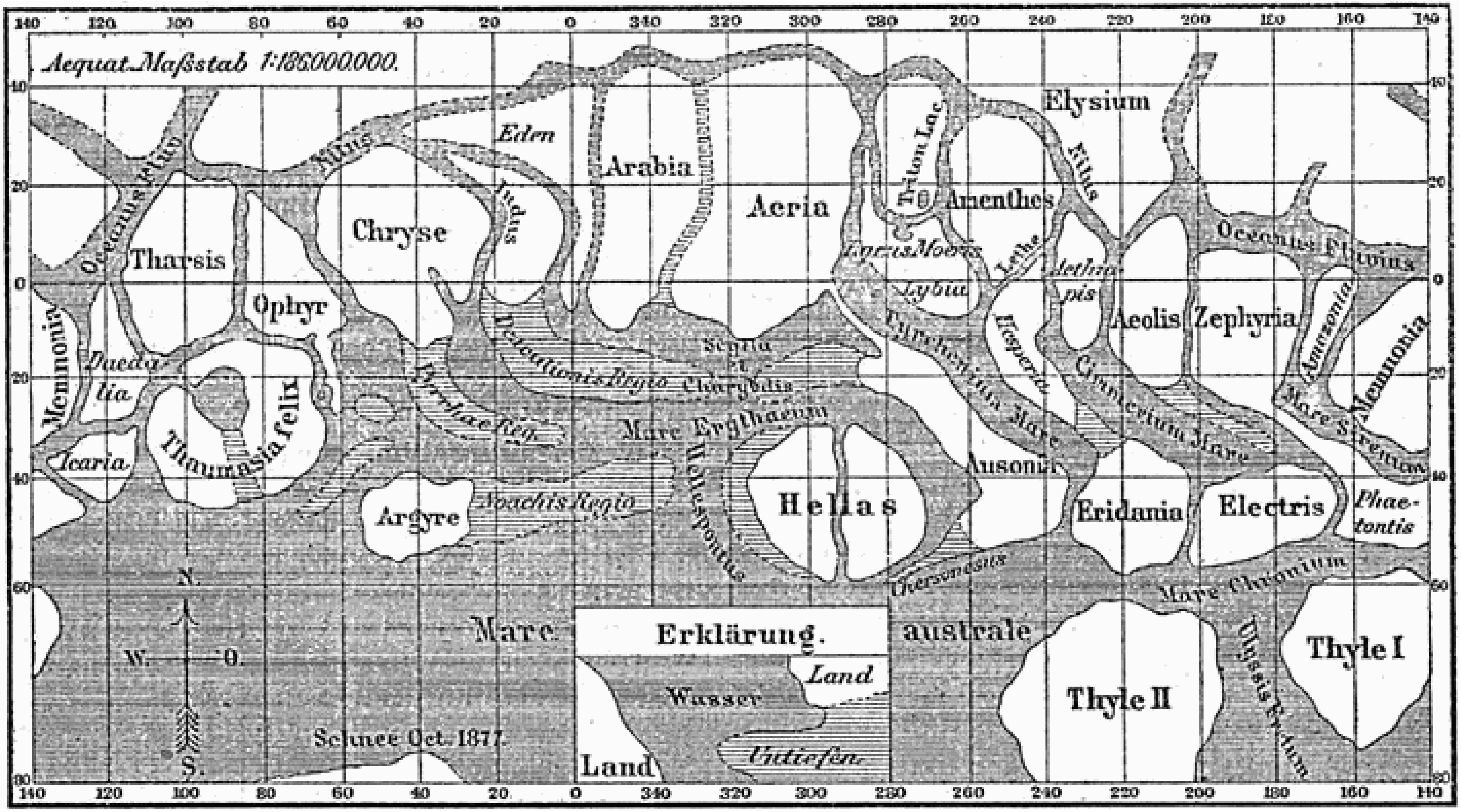
- **Early telescopic observations showed**
  - **Seasonally advancing and retreating ice caps**
  - **Mars obliquity is similar to the Earth**
    - **25° vs. 23½°**



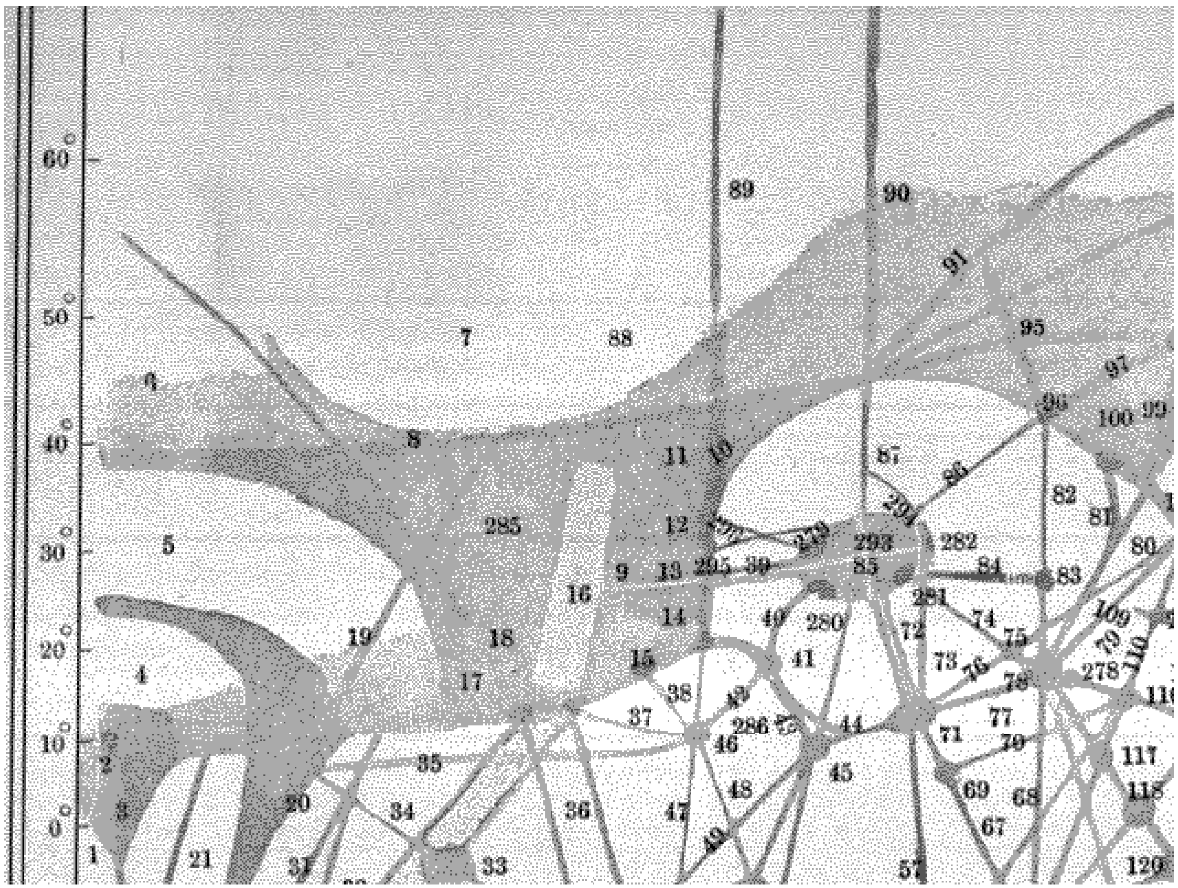
- **Mars has similar seasons to Earth**
- **Mars has similar day/night cycles**
- **Mars has seasonal ice that comes and goes**

- **Mars has changing patterns on the surface**
  - **Seasonal vegetation growth?**
  - **Unfortunately not…**

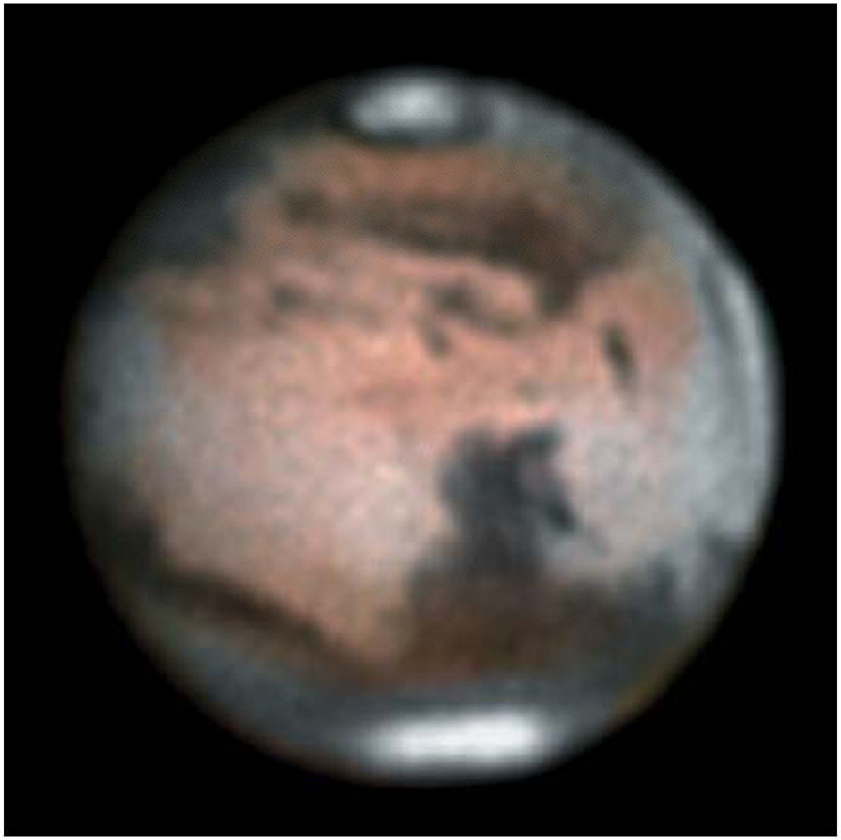
- **Early telescopic maps were pretty crude…**
  - **Giovanni Schiaparelli made maps with ‘channels’ (Canali in Italian)**

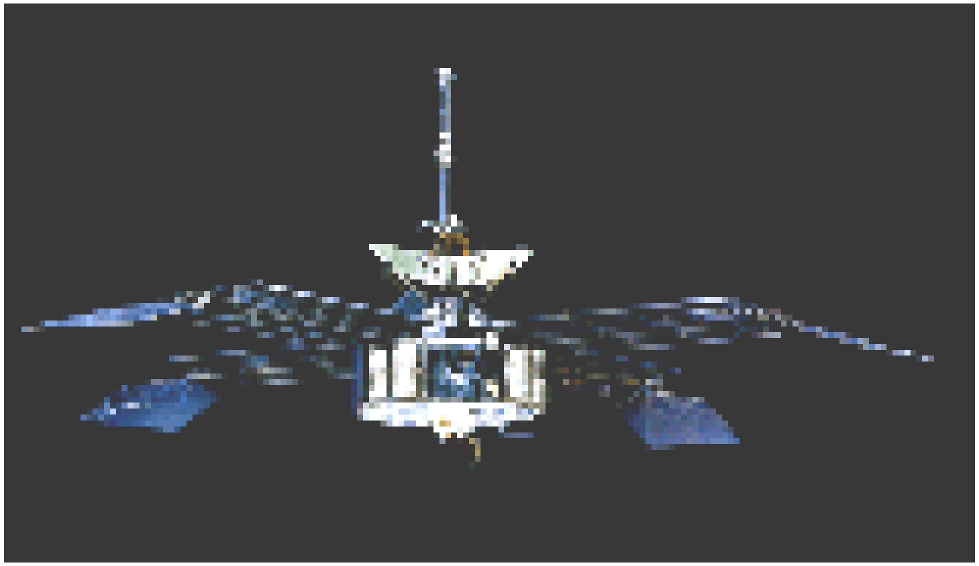


- **Percival Lowell made many telescopic observations of Mars**
  - **Translated Canali as Canals**
  - **Popularized a vision of Mars that was inhabited by intelligent life**
  - **Changing marks of the surface were vegetation**
  - **“Canals” were transporting water from the polar caps to the equator**

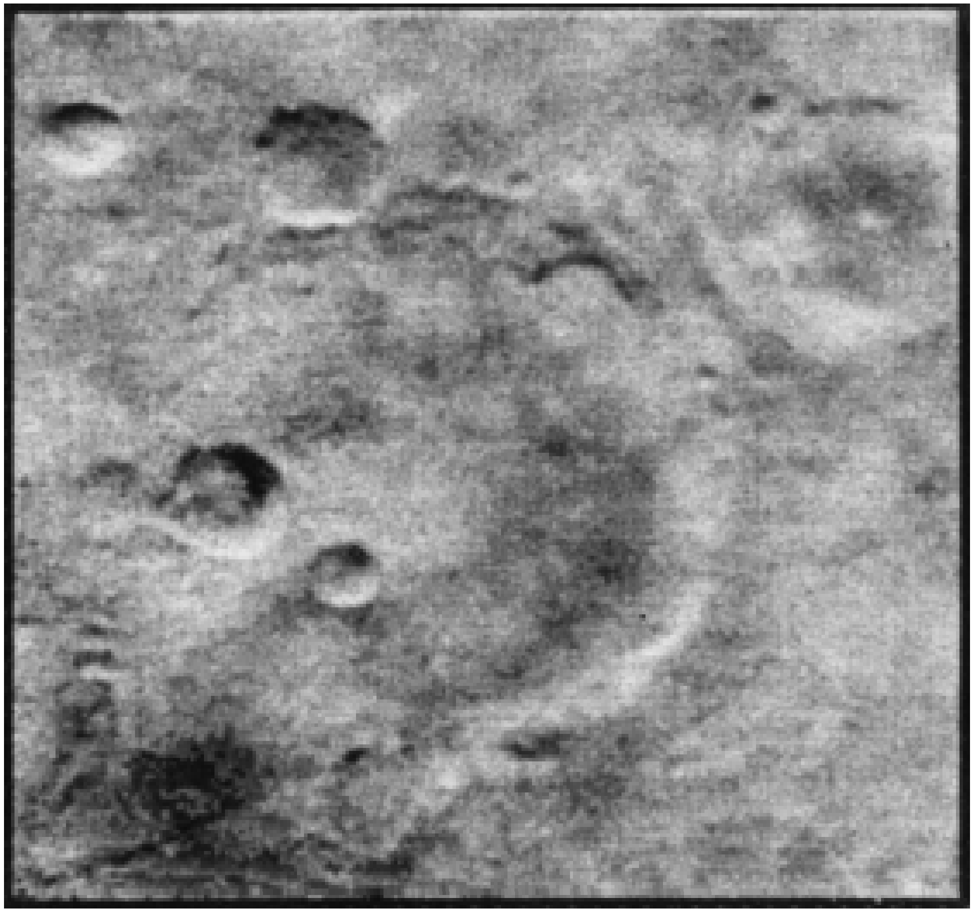


- **Mariner 4 was the first spacecraft to visit Mars… July 1965**
  - **Flyby mission -**



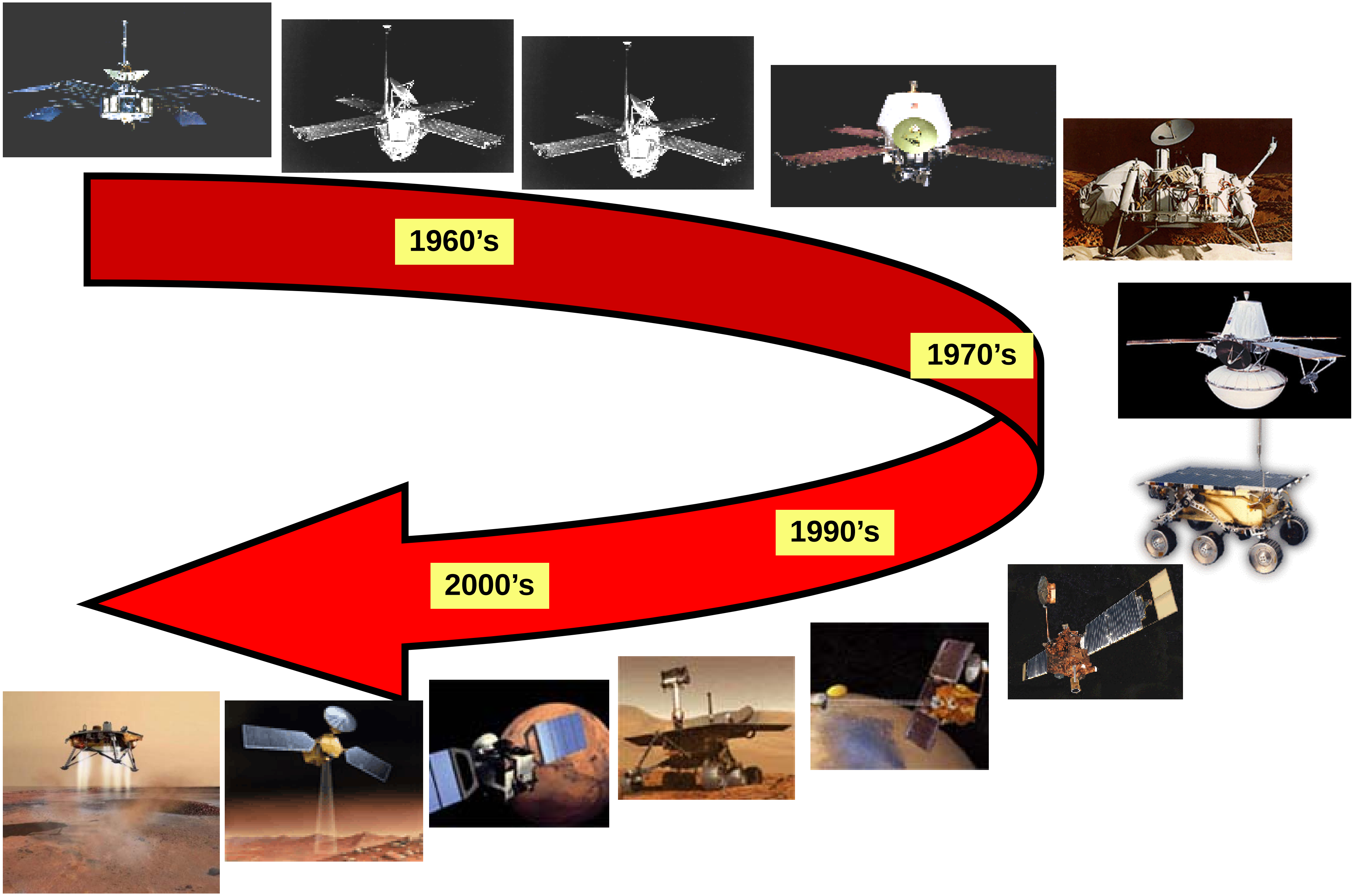


- What did Mariner 4 see?
  - First planetary (non-lunar) mission to carry a camera

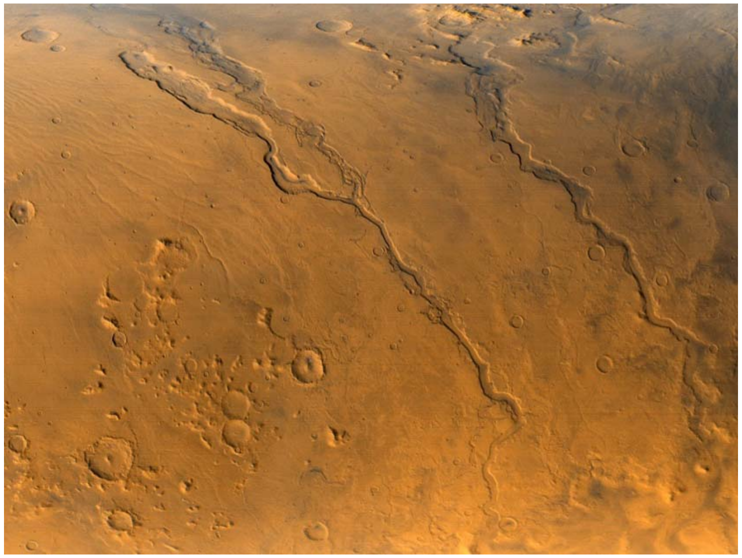


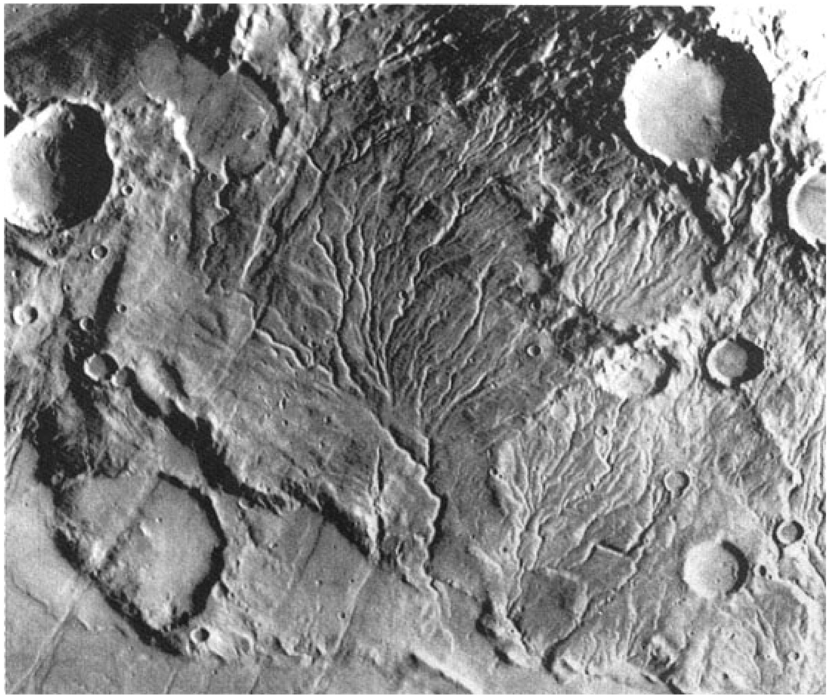
  - Craters
    - Not good for life
  - A very thin atmosphere
    - Not good for life
  - No protective magnetic field
    - Not good for life
  - Looked pretty much like the Moon
    - Disappointing…
    - Dry, cold, dead….

- **The best-explored planet! (apart from Earth)**

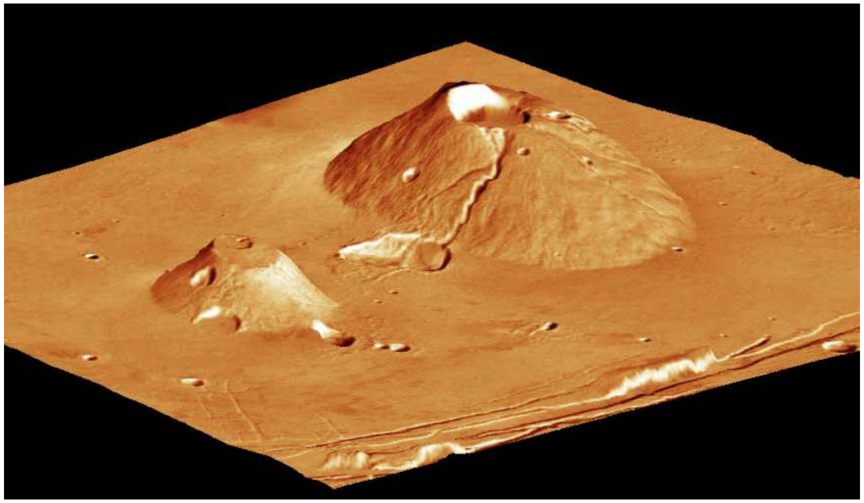


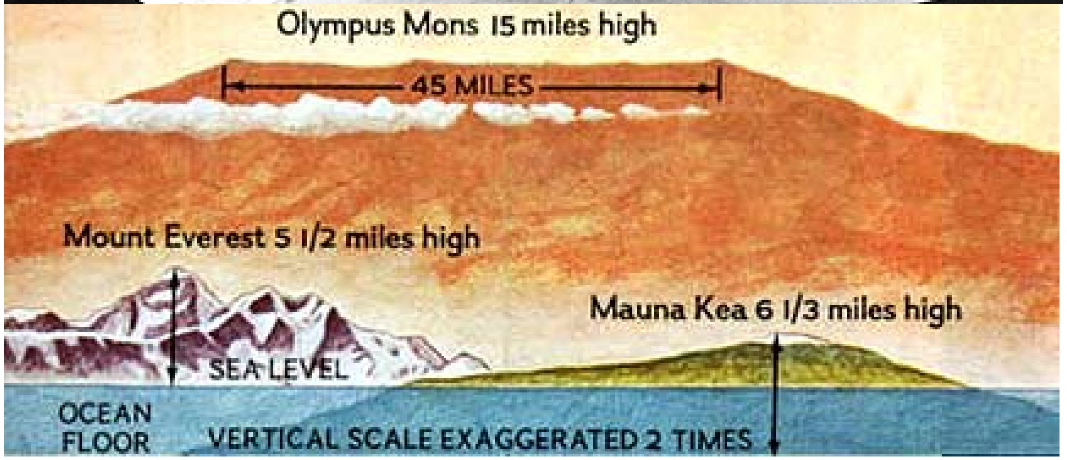
- **Subsequent spacecraft saw MUCH more interesting stuff**
  - **Fluvial channels – several billion years old**



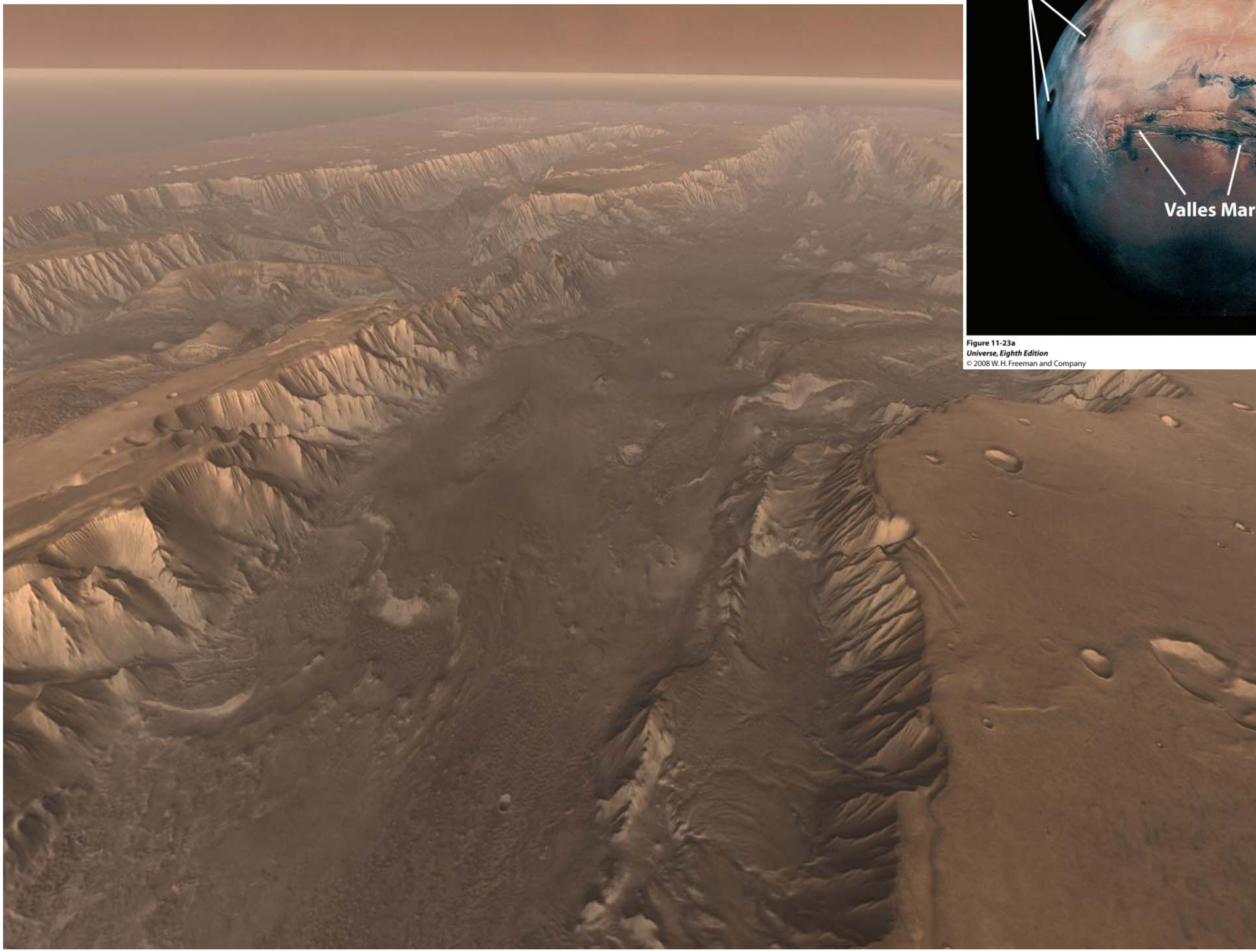


- **Giant volcanoes**
  - **Lava flows up to ~1Myr old**





- **The giant Valles Marineris**



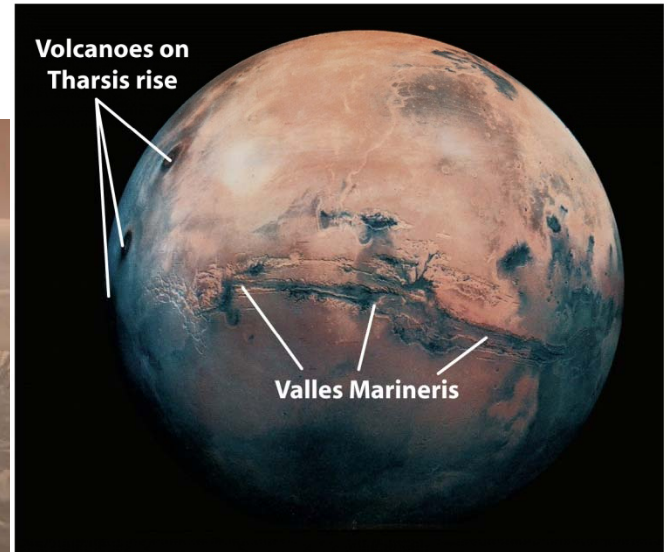
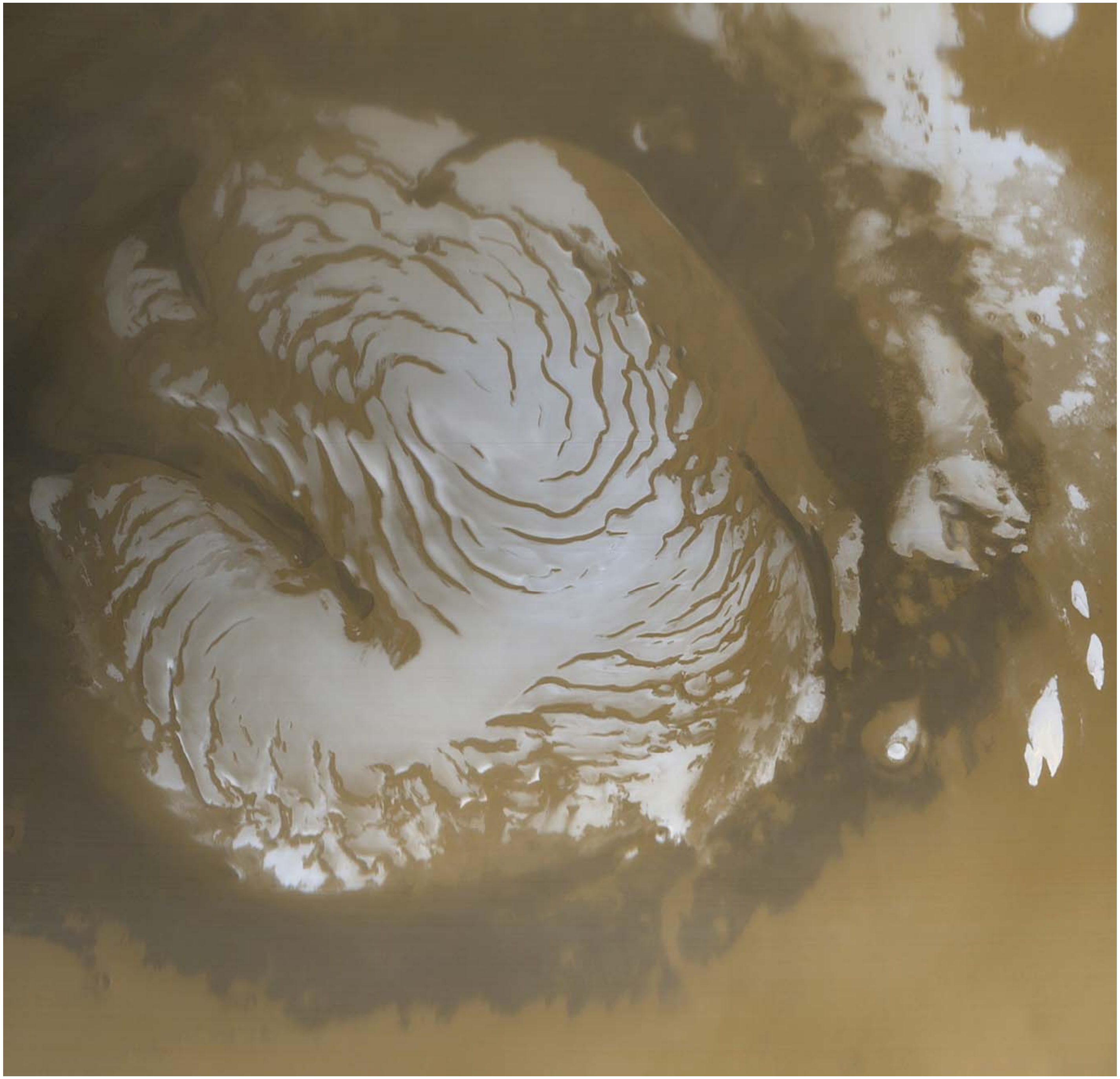
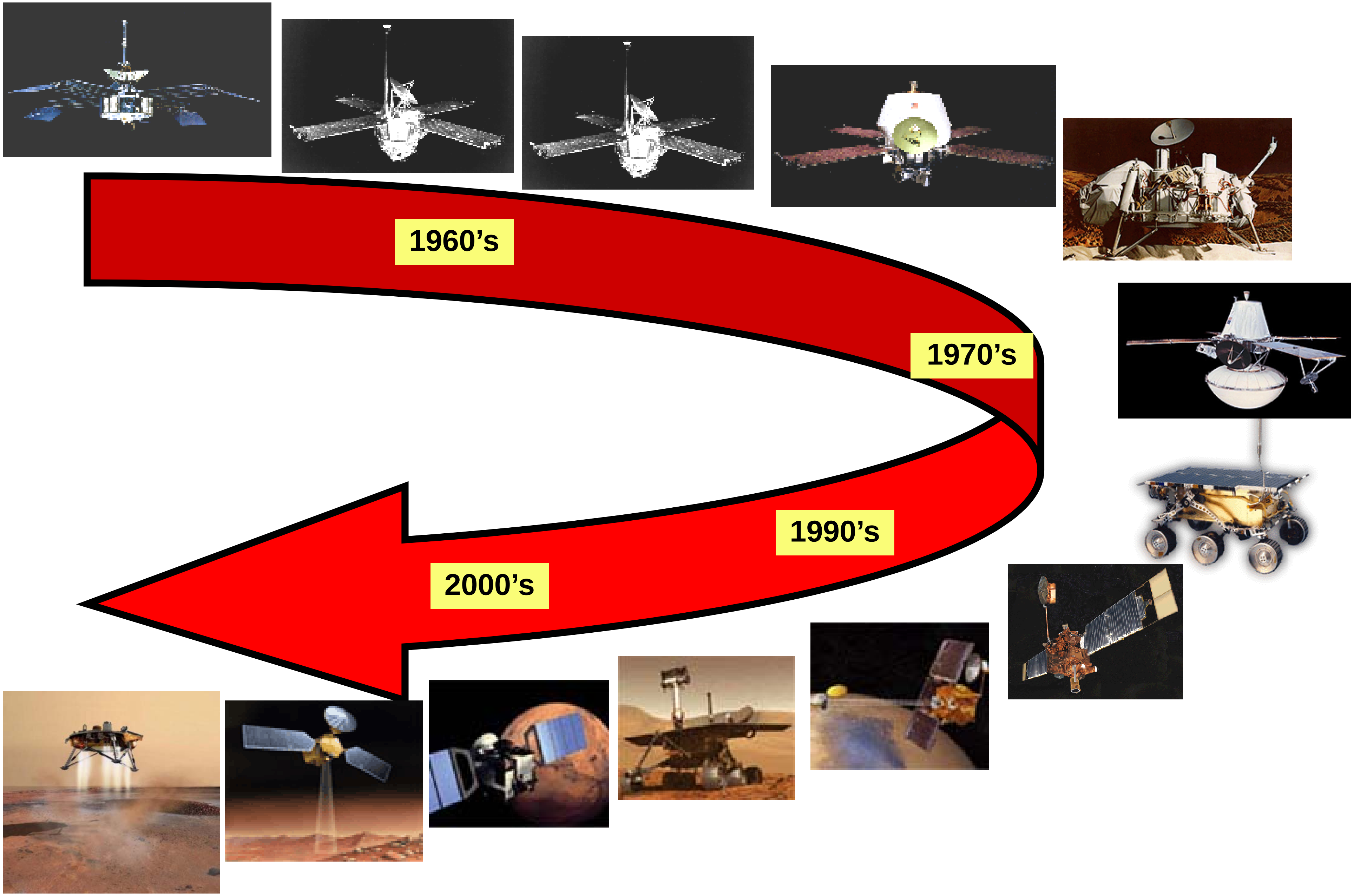


Figure 11-23a
Universe, Eighth Edition

- **Polar ice caps**

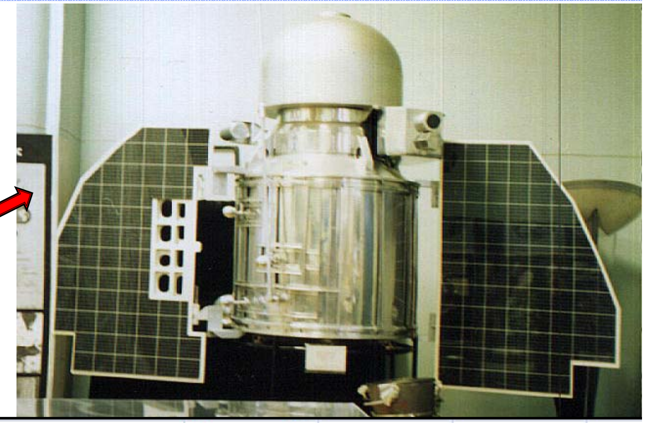


- **The best-explored planet! (apart from Earth)**

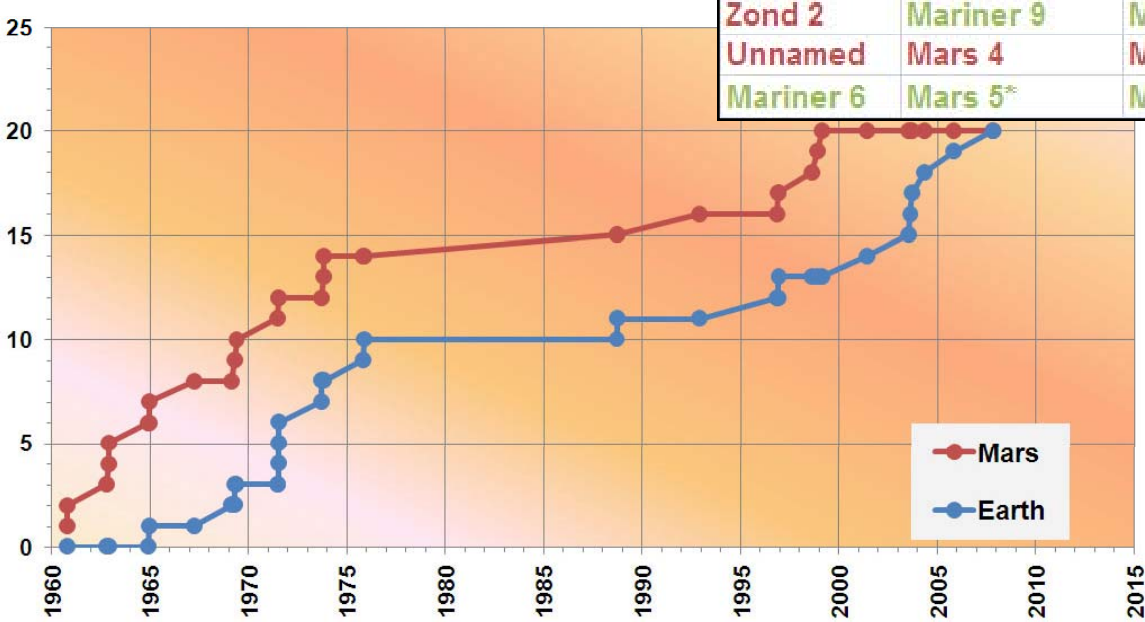


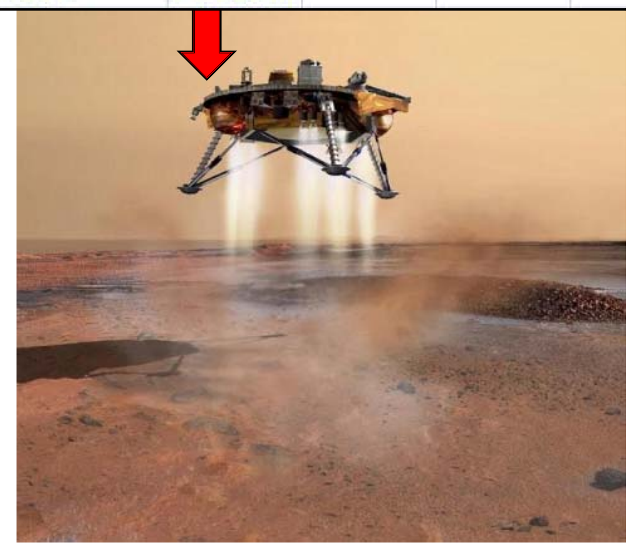
- **A Mars Curse?**
- **Earth *vs*. Mars**
  - **Almost 50 years of exploration**
  - **40 attempts to explore Mars**
  - **Mars in the lead… until now…**
  - **Today's Score**

20 : 20

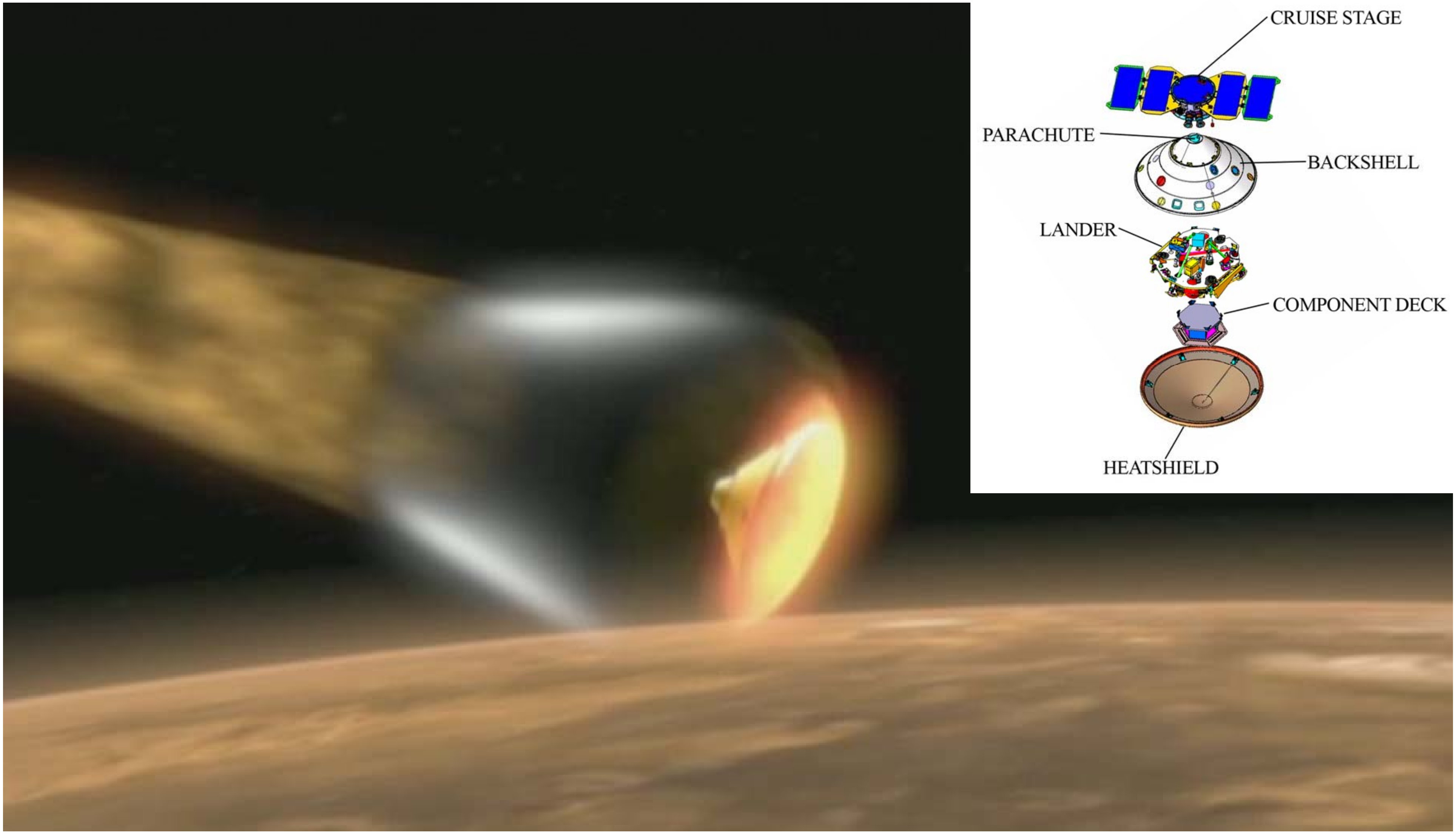


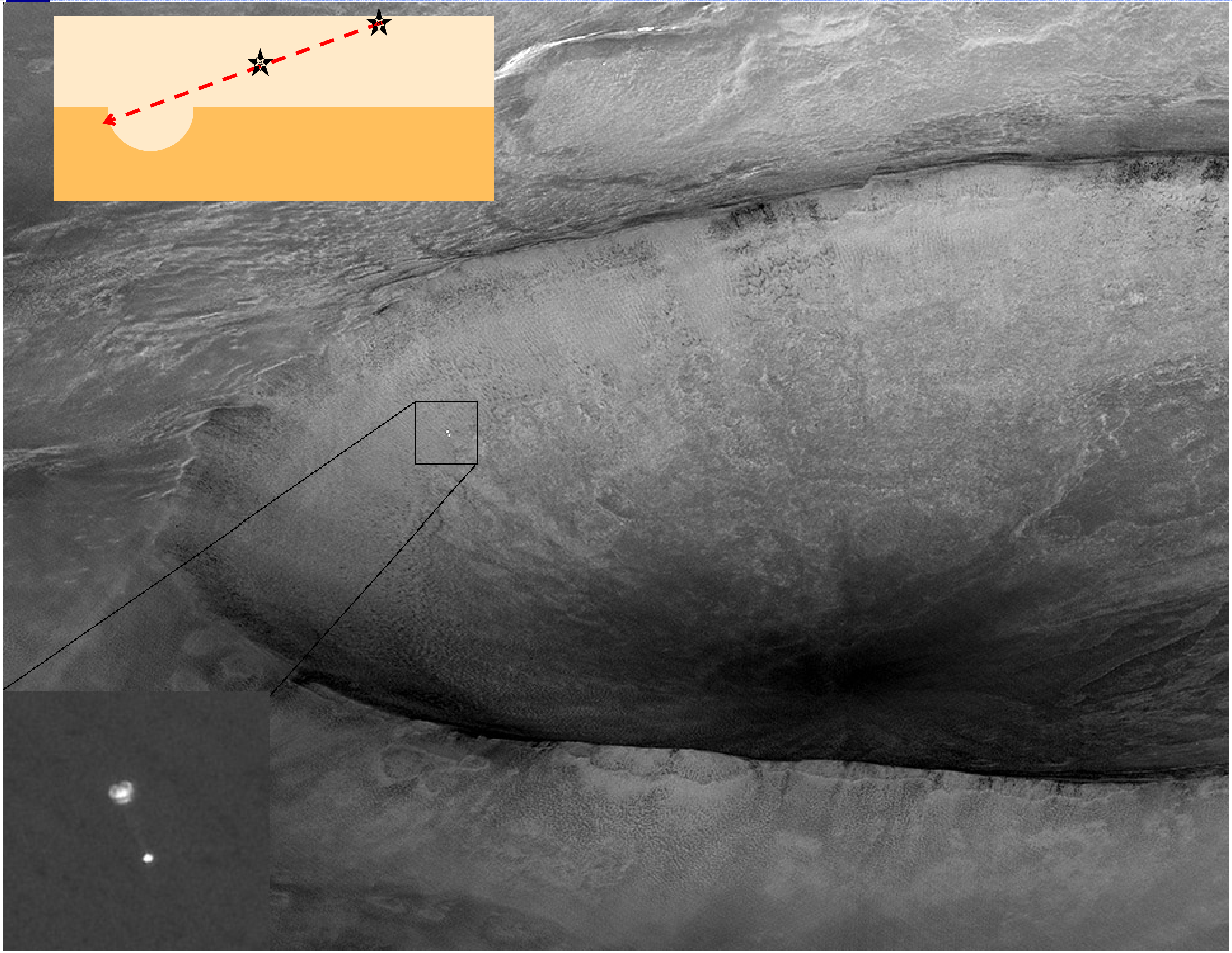
Marsnik 1	Mars 1969A	Mars 6*	Nozomi
Marsnik 2	Mariner 7	Mars 7	Mars Climate Orbiter
Sputnik 22	Mars 1969B	Viking 1	Mars Polar Lander
Mars 1	Mariner 8	Viking 2	Mars Odyssey
Sputnik 24	Cosmos 419	Phobos 1	Mars Express*
Mariner 3	Mars 2*	Phobos 2*	Spirit
Mariner 4	Mars 3*	Mars Observer	Opportunity
Zond 2	Mariner 9	Mars Global Surveyor	Mars Reconnaissance Orbiter
Unnamed	Mars 4	Mars 96	Rosetta
Mariner 6	Mars 5*	Mars Pathfinder	Phoenix

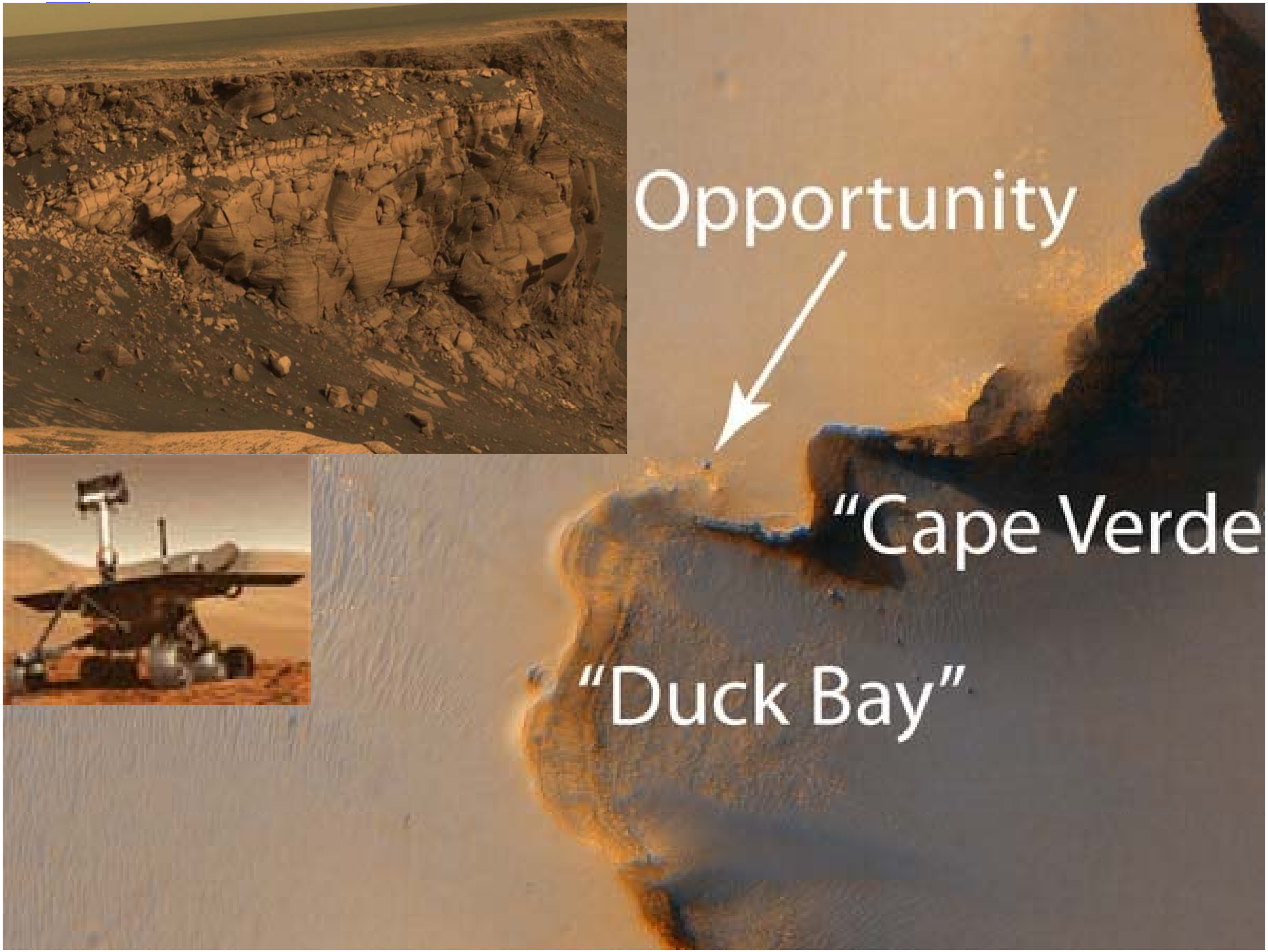


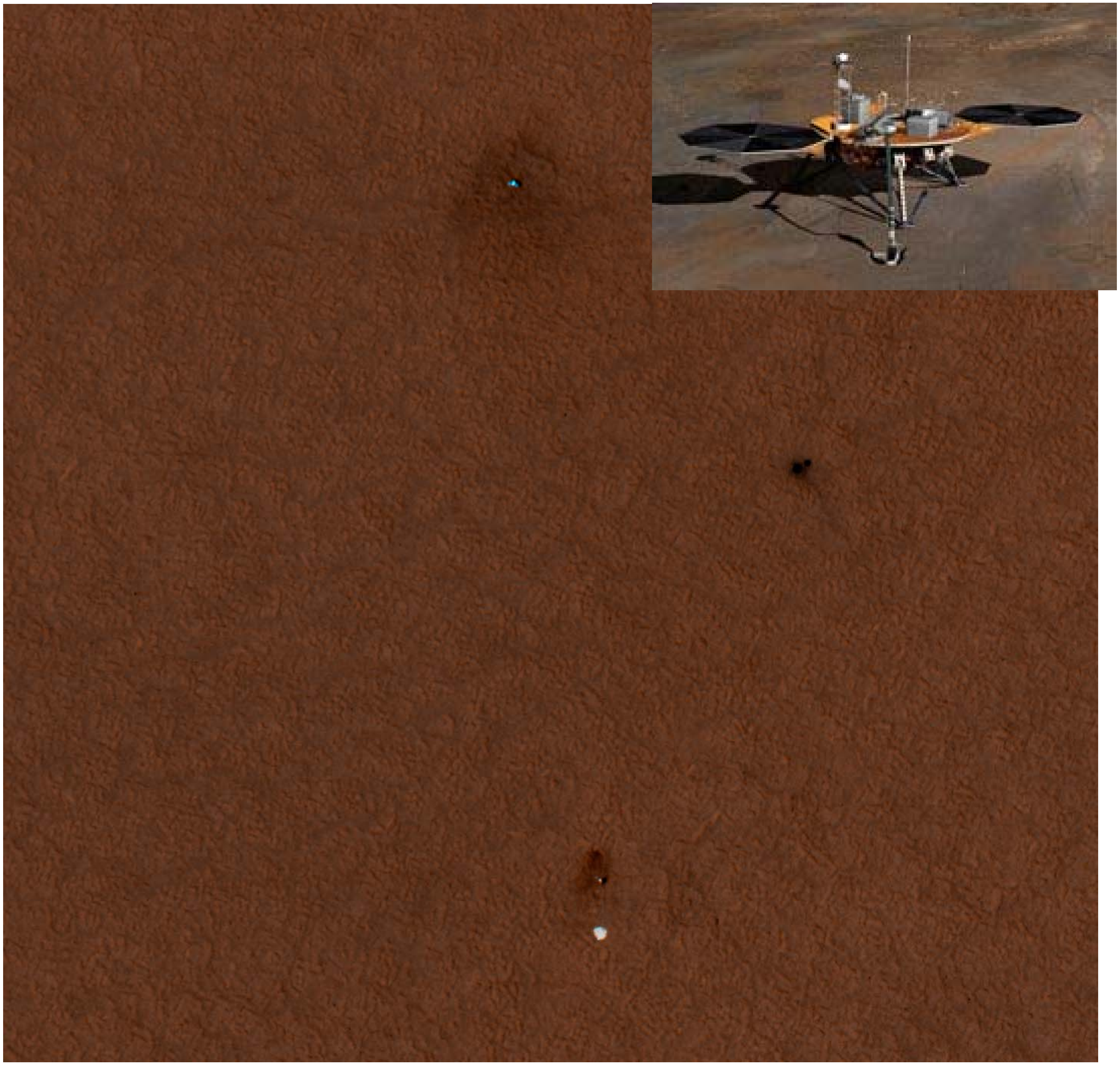


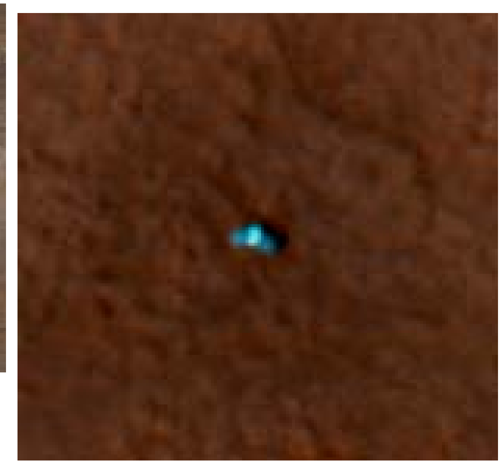
Phoenix EDL Movie





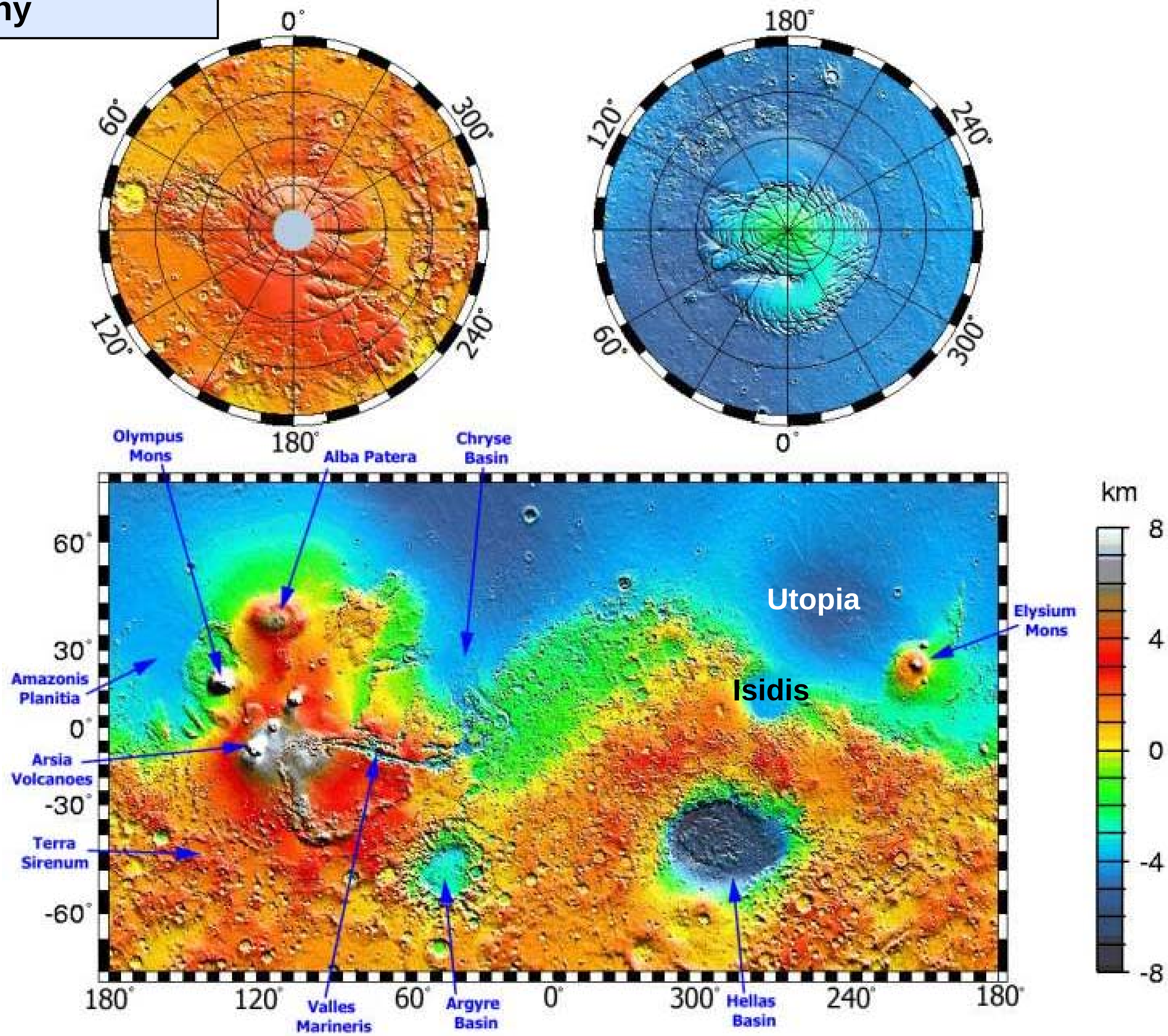

Opportunity
“Cape Verde
“Duck Bay”





Geography

- Hemispheric dichotomy
- Volcanic provinces
- Impact basins
- Polar Layered deposits



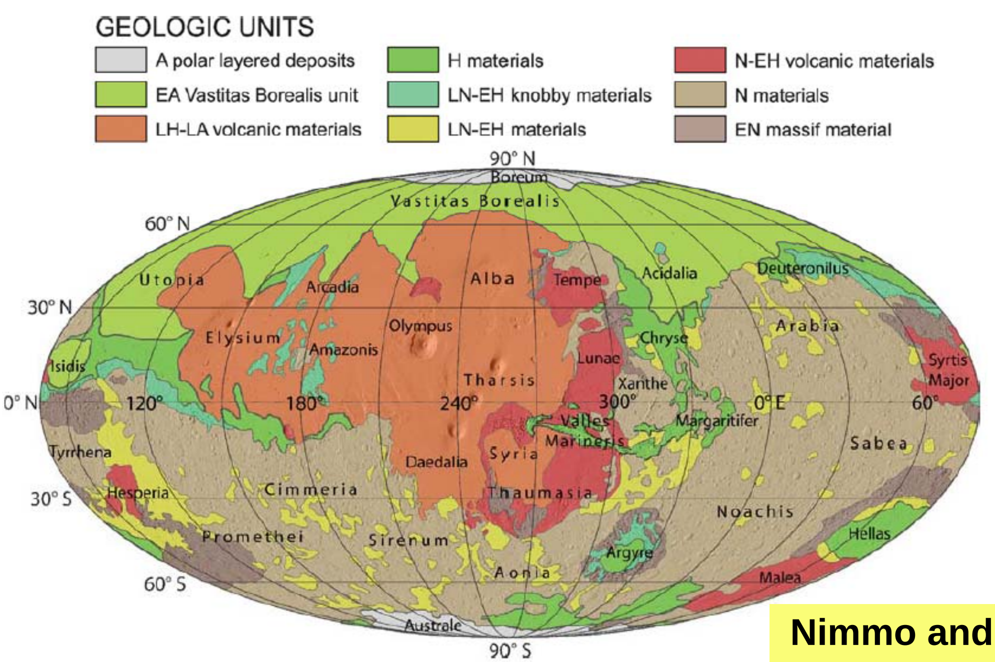
- **Three geologic periods**
  - **Noachian** **4.1 - 3.93 Ga**
  - **Hesperian** **3.93 - 3.1 Ga**
  - **Amazonian** **3.10 - 0.0 Ga**

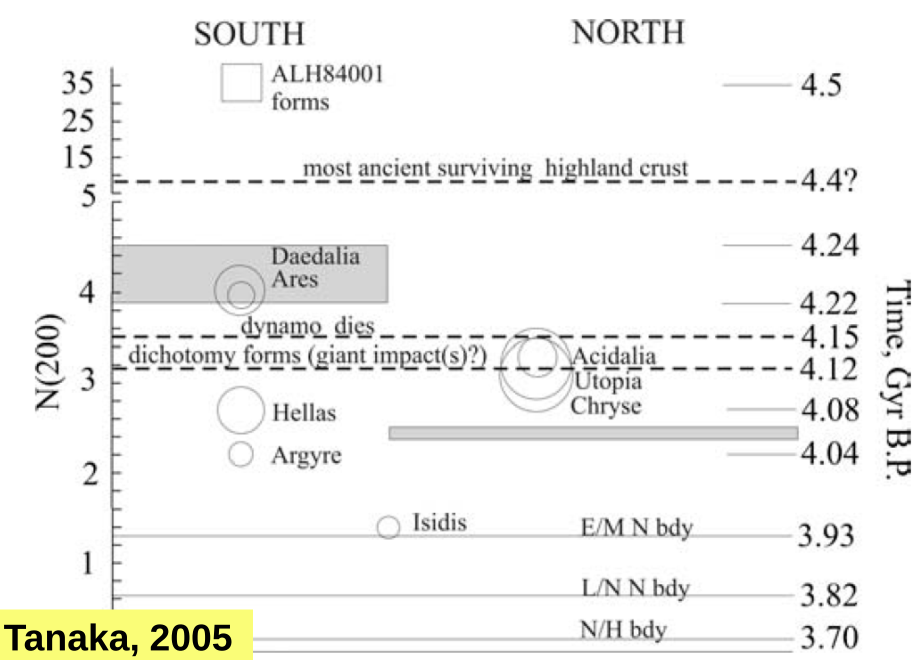
Surface history of Mars is available throughout the past 4.5 Gyr

Surfaces of Earth and Venus record only recent history

Surfaces of Moon and Mercury record only ancient history

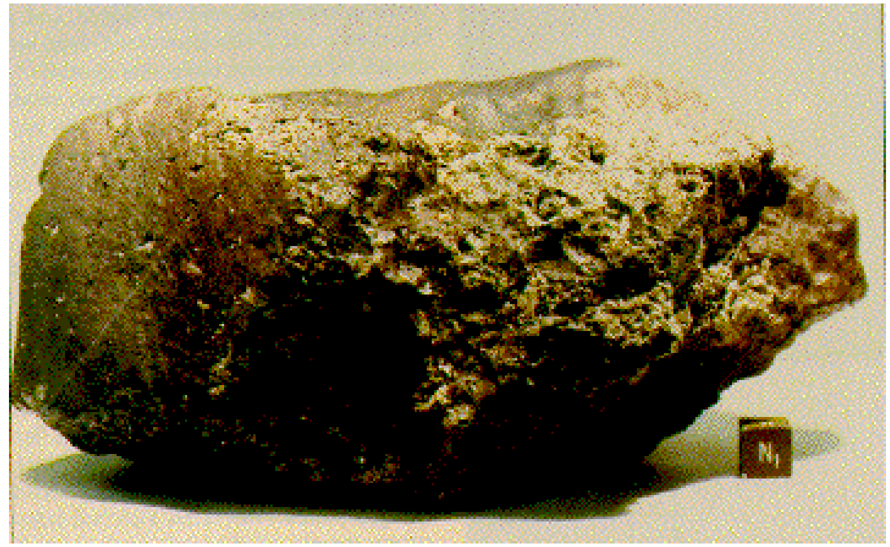
- **Early Mars corresponds to the Noachian geologic period**
  - **Starts with the Hellas basin impact**



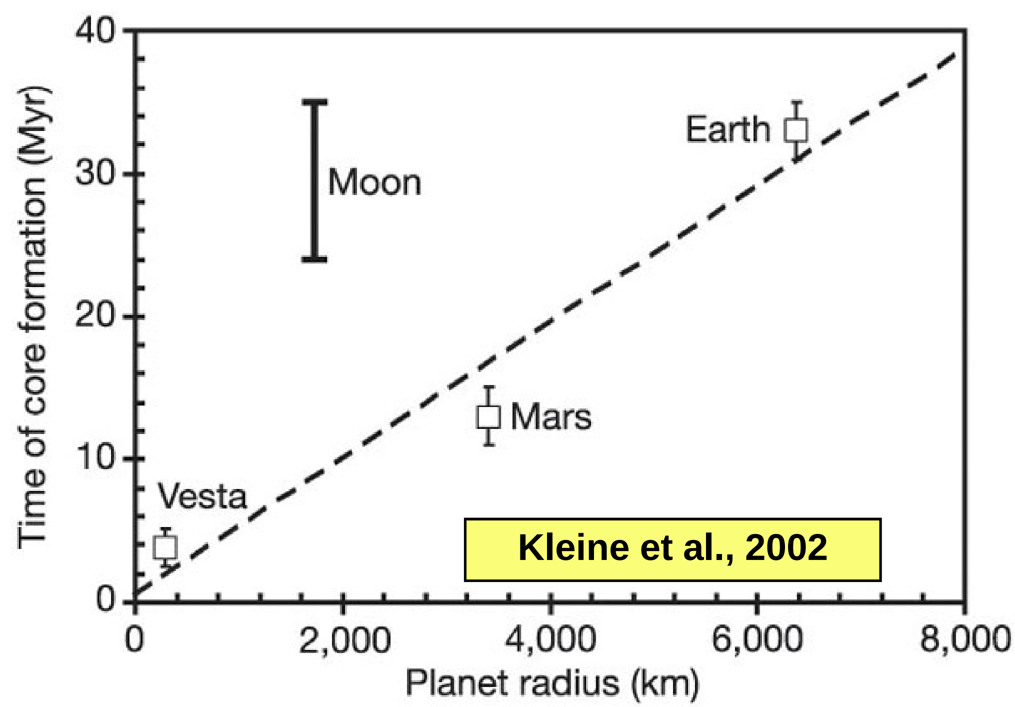


Nimmo and Tanaka, 2005

- **Crystallization age of ALH84001**
  - **4.5 Ga – a very old rock**
  - **Indicates stable crust already existed**
  - **Shock heating event at 3.9Ga**

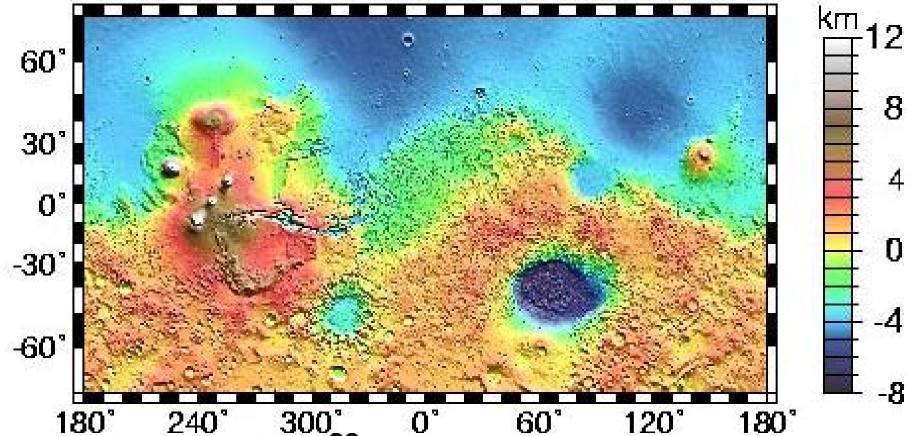


- **Mars accretion was fast**
  - **The element Tungsten usually goes into the core in molten planets**
  - **Extra Tungsten produced by radioactive decay in the crust *after* core forms**
  - **Amount of this extra Tungsten dates the core formation**
  - **Implies martian core formation 13±2 Myr after earliest solar system solids formed**

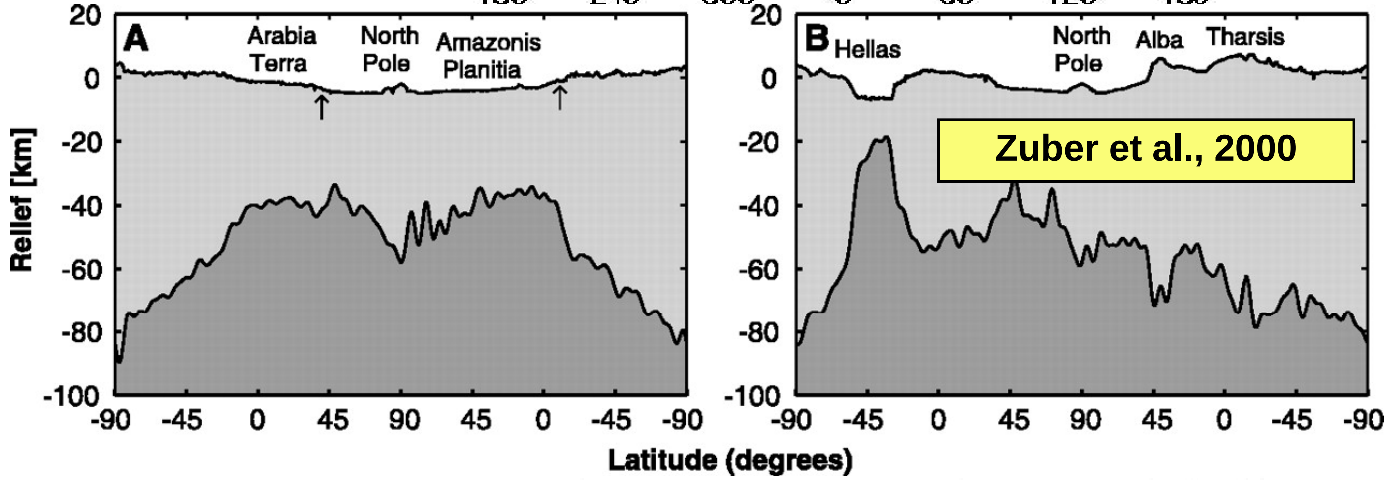


Crustal Dichotomy

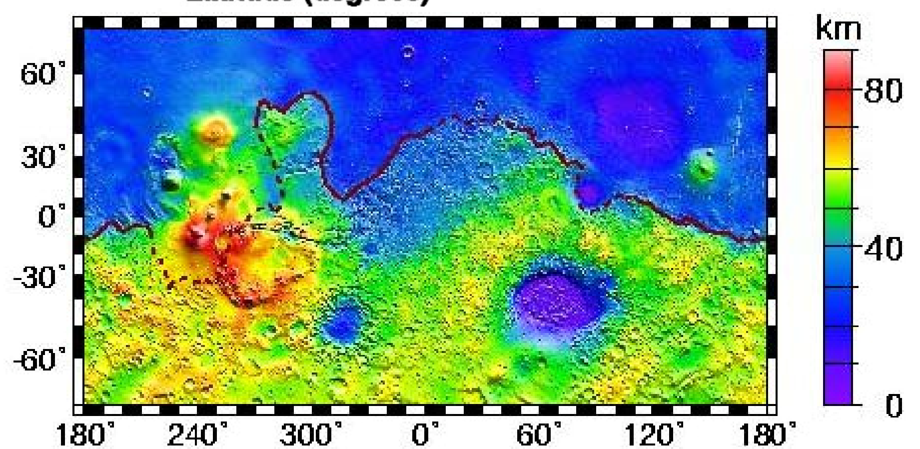
- **Northern and southern hemispheres of Mars are very distinct:**



  - **North**
    - **Low elevation**
    - **Few Craters**
    - **Young**
    - **Smooth terrain**
    - **Thin Crust**

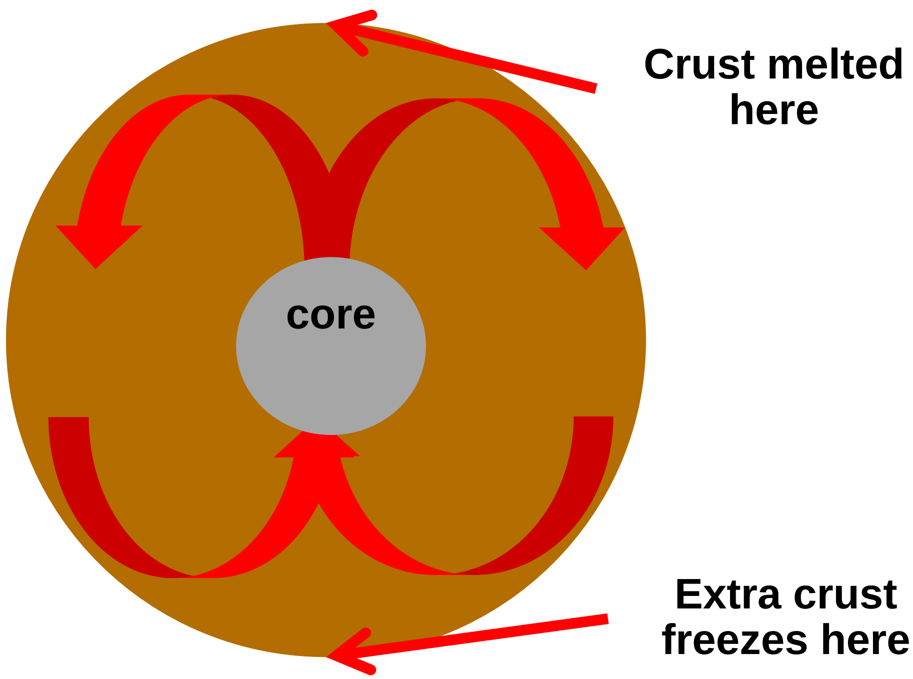


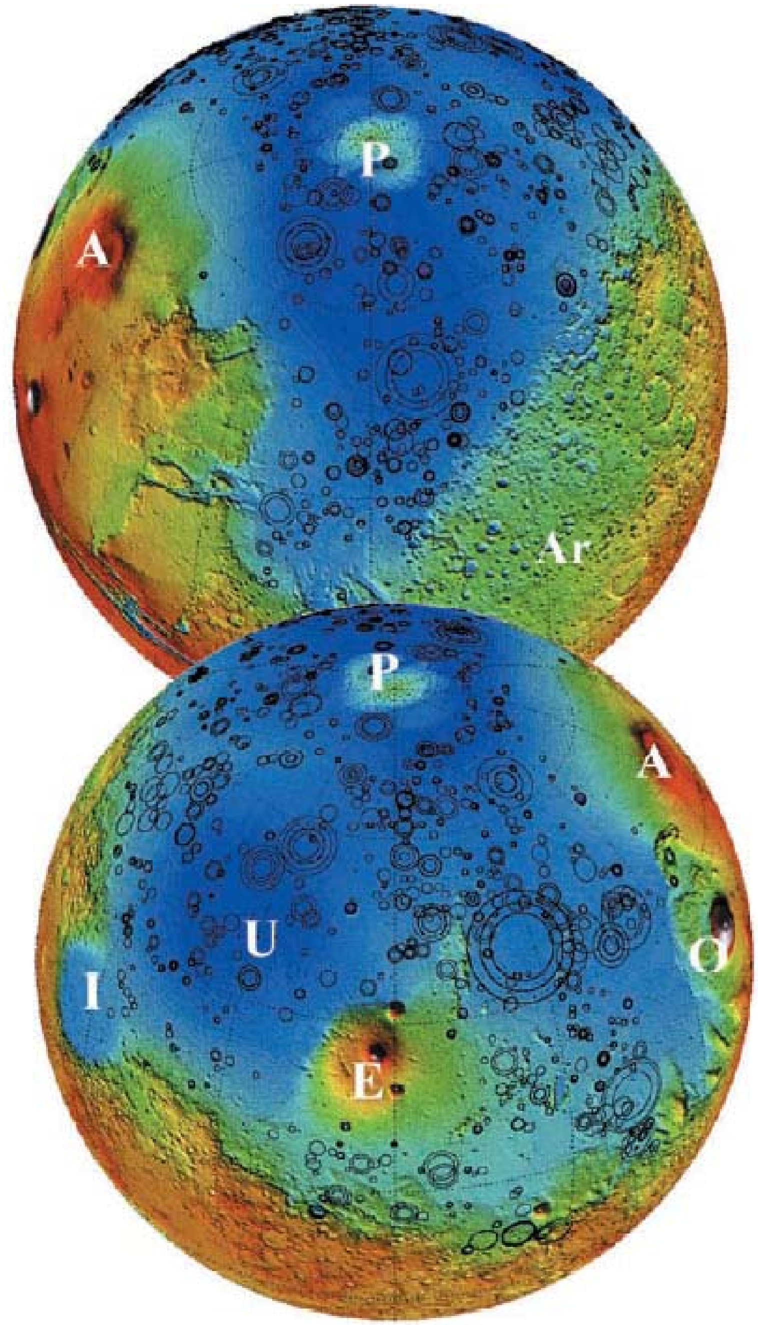
  - **South**
    - **High elevation**
    - **Heavily cratered**
    - **Old**
    - **Rough terrain**
    - **Thick crust**



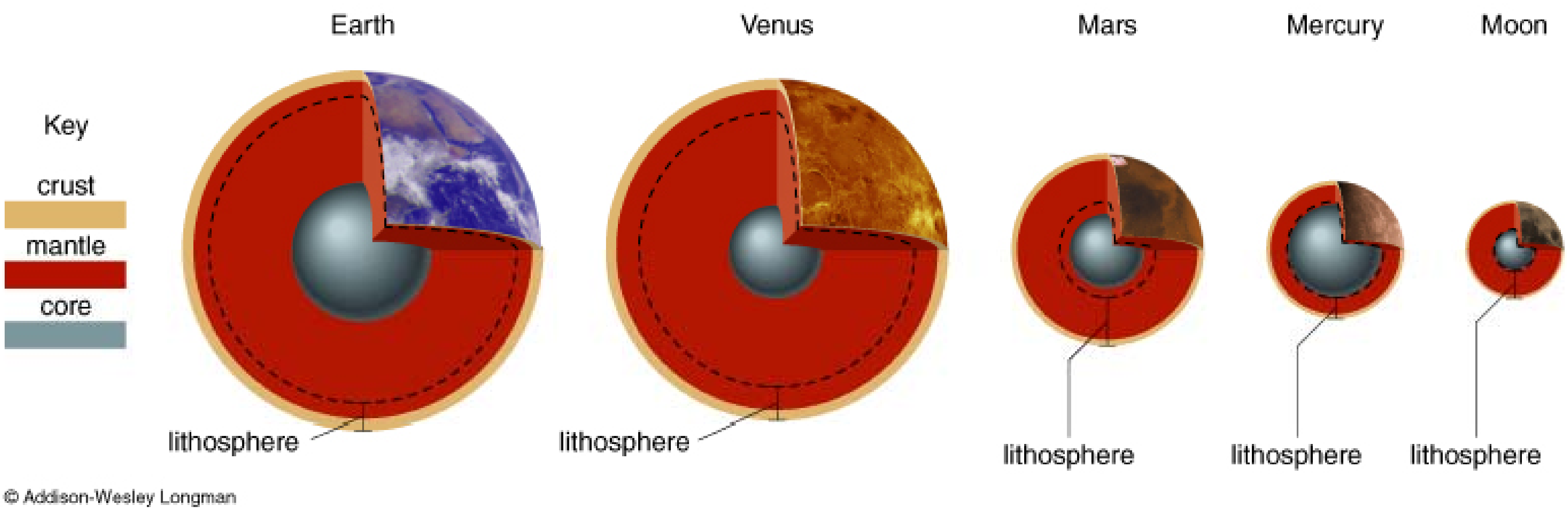
- **Many buried impact basins**
  - **Northern lowlands look like the southern highlands after all**

- **Forming the dichotomy**
  - **One Giant impact?**
  - **Many not-so-giant impacts?**
  - **Degree-1 convection?**

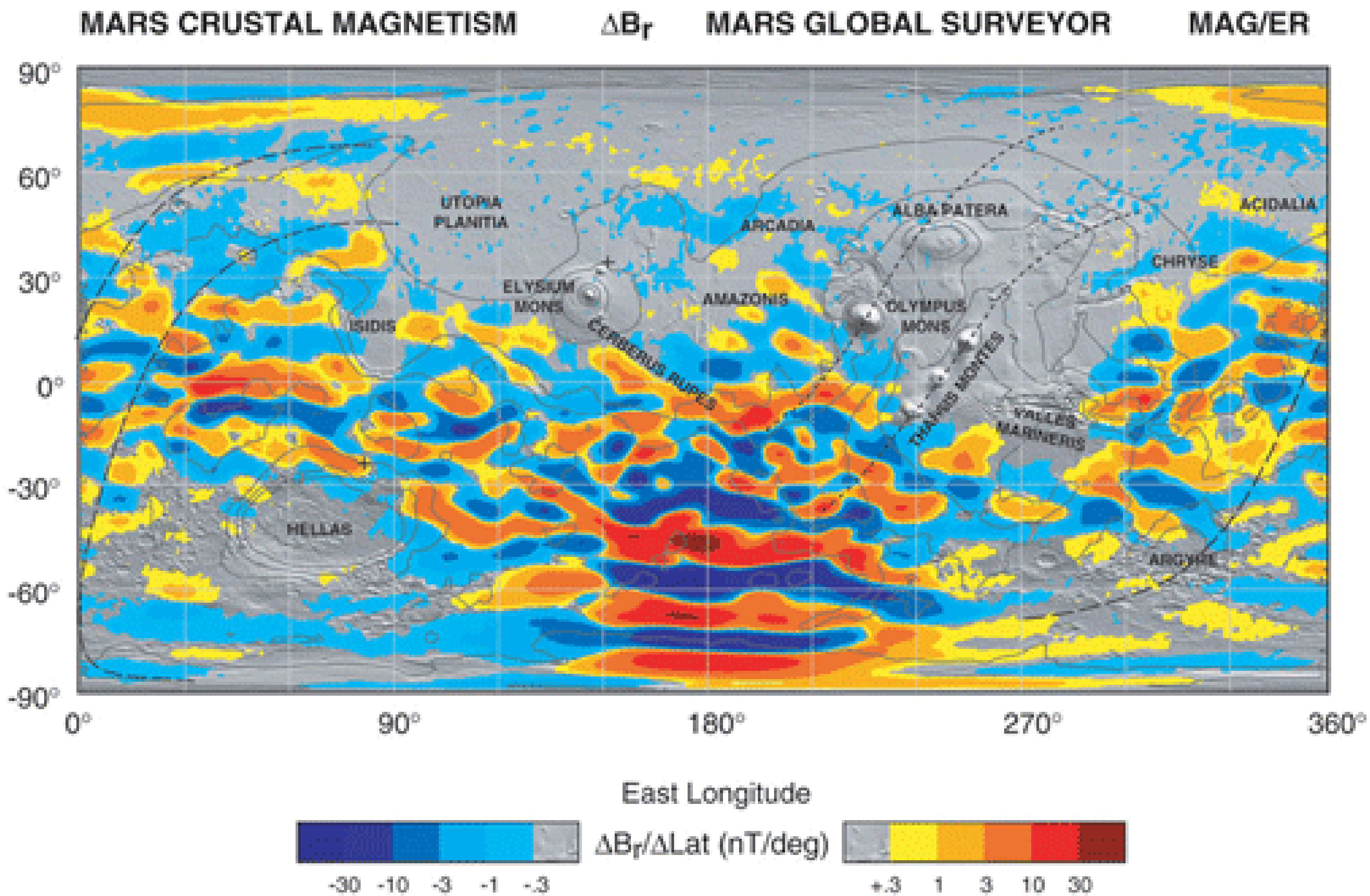




- **Mars had a liquid metal core**
  - **Cools off faster than Earth due to smaller size**
  - **Once the core froze there was no more magnetic field**

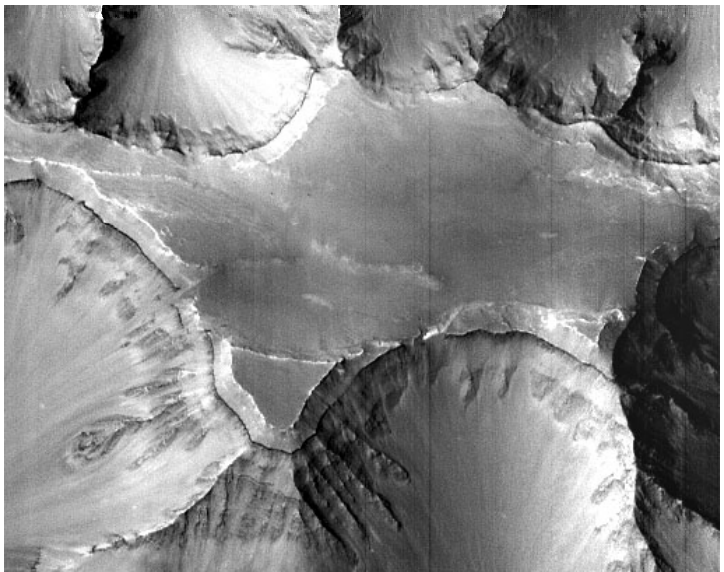


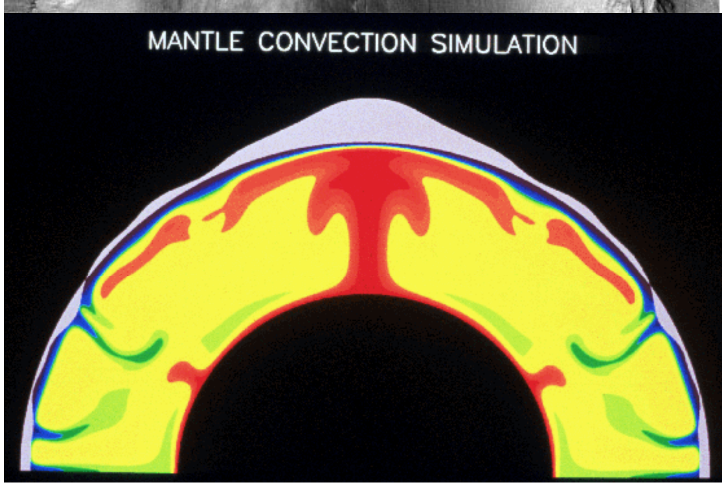
- **The old magnetic field is still preserved in the oldest rocks**
  - **No magnetic field around large impact basins**
  - **They formed after the iron core froze**

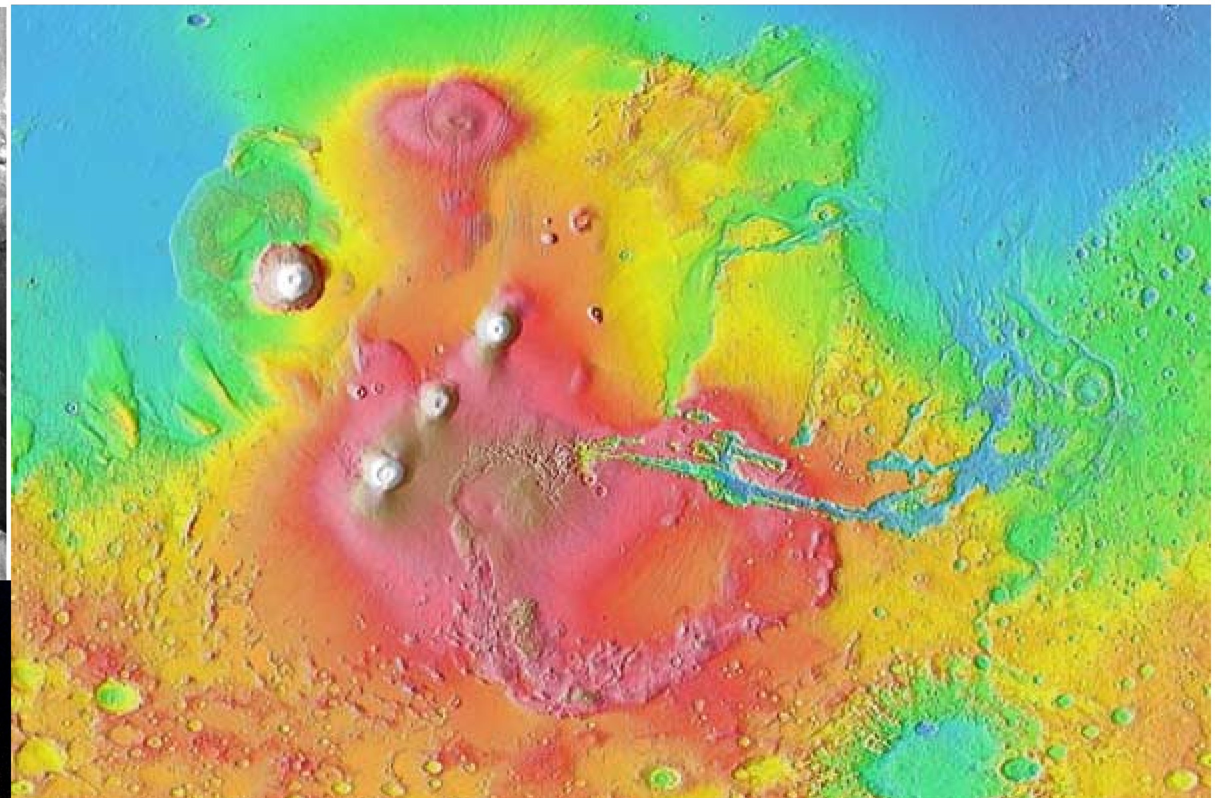


Connerney, J. E. P. et al., (2005) Proc. Natl. Acad. Sci. USA, 102, No. 42, 14970-14975.

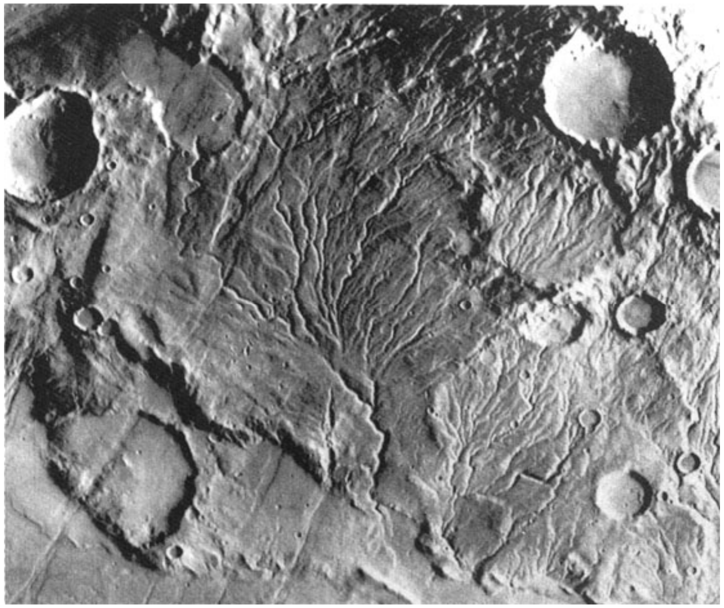
- **The Tharsis volcanic bulge formed**
  - **Thick (>8 kilometers thick) sequence of volcanic rocks**
  - **Large volcanoes built on top of this bulge later**
  - **Outgassing of a lot of volcanic gas can change the climate**

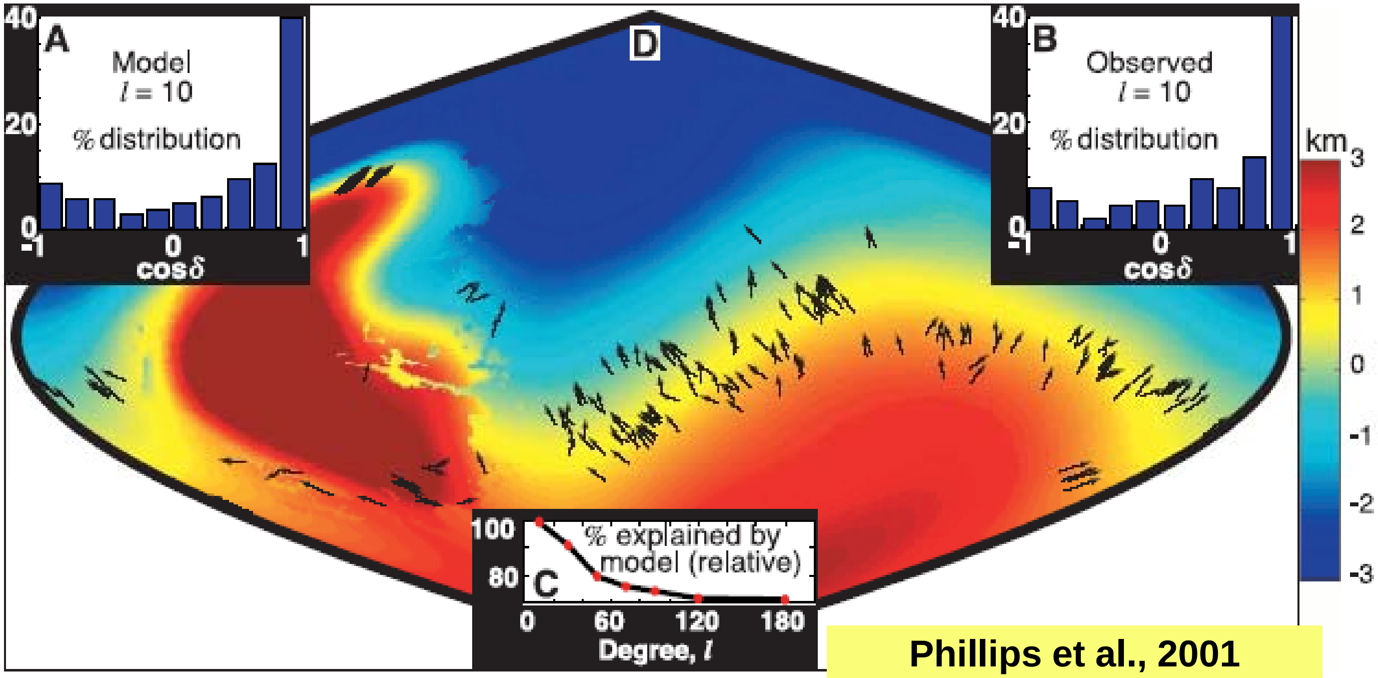




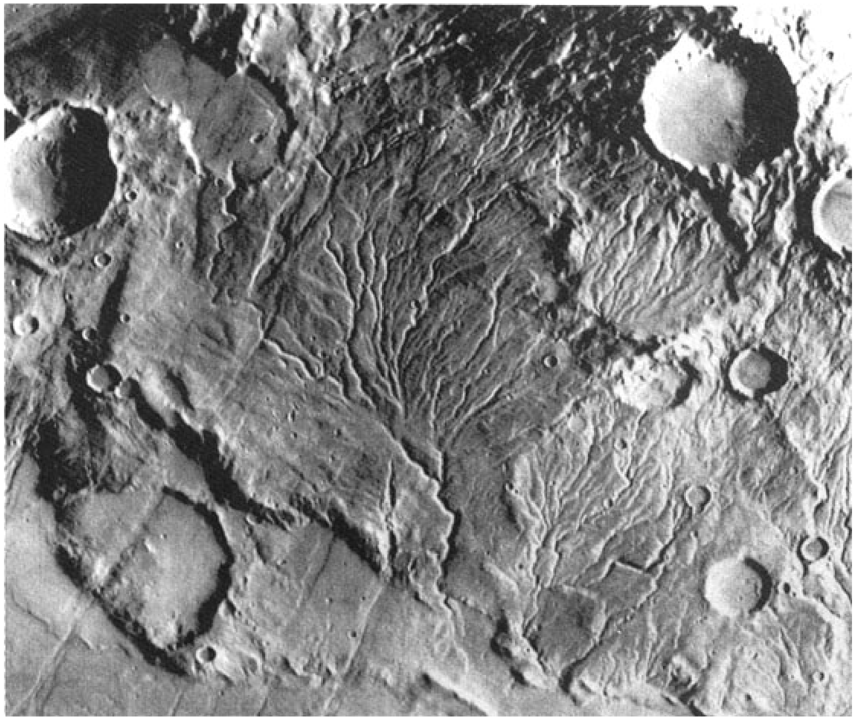


- **Tharsis is huge and controls the shape of the planet**
  - **When water runs downhill on Mars the direction is partly set by the existence of Tharsis**
  - **Sets the timing of ancient valley networks**
  - **i.e. the valleys must have come after the Tharsis bulge was created**



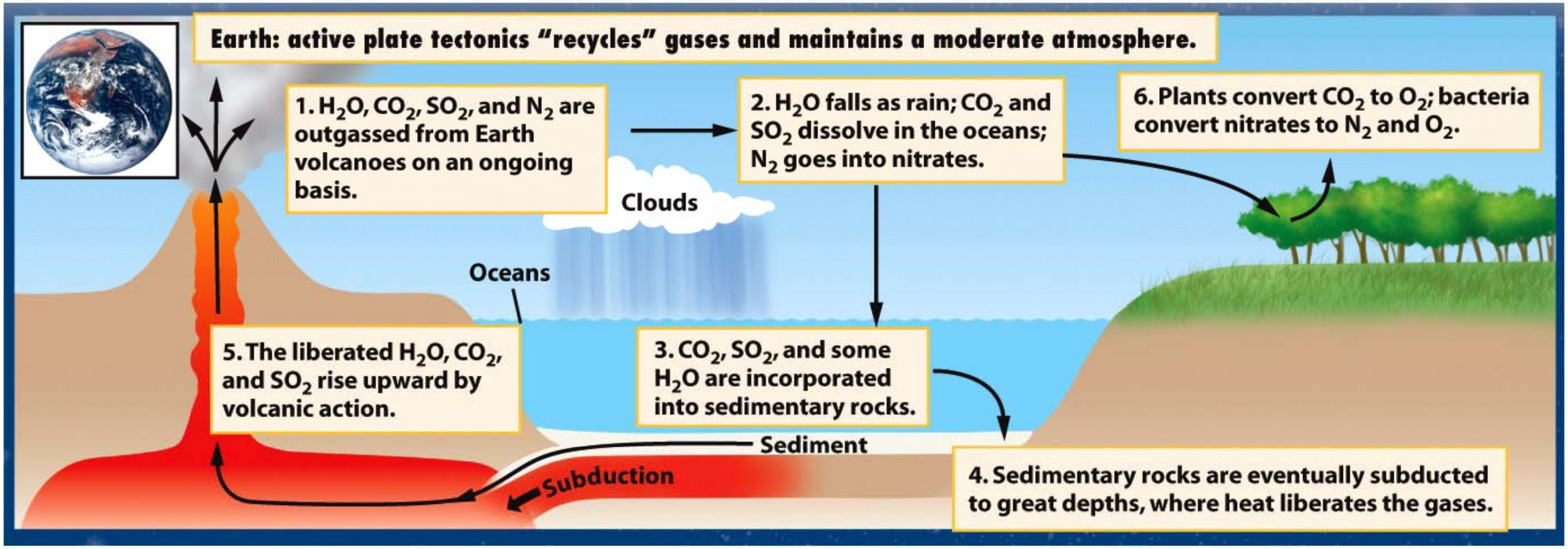


Phillips et al., 2001



- **Mars had a warmer climate then**
  - **Rainfall is a possibility – not believed by everybody**
  - **Groundwater can explain a lot of the ancient fluvial features**
  - **Explaining the warmer climate is a problem due to the faint young sun.**
  - **Lots of CO_2 from Tharsis might explain this with a greenhouse effect**

- **So what happened to Mars…**
  - **Water dissolves atmospheric CO_2**
  - **Weathers rocks**
  - **No plate tectonics means CO_2 is not recycled and stays in the rocks**
  - **Greenhouse effect dies off**
  - **Water is broken up into H^+ and O^{--} and slowly lost to space**



Earth, Venus, Mars

All start with CO_2 and water in their atmosphere

Mars, Earth

CO_2 and water goes into rocks

Earth

Rocks recycled by plate tectonics

Rock cycle

Mars

No plate tectonics–CO_2 stuck in rocks

Runaway icehouse

Venus

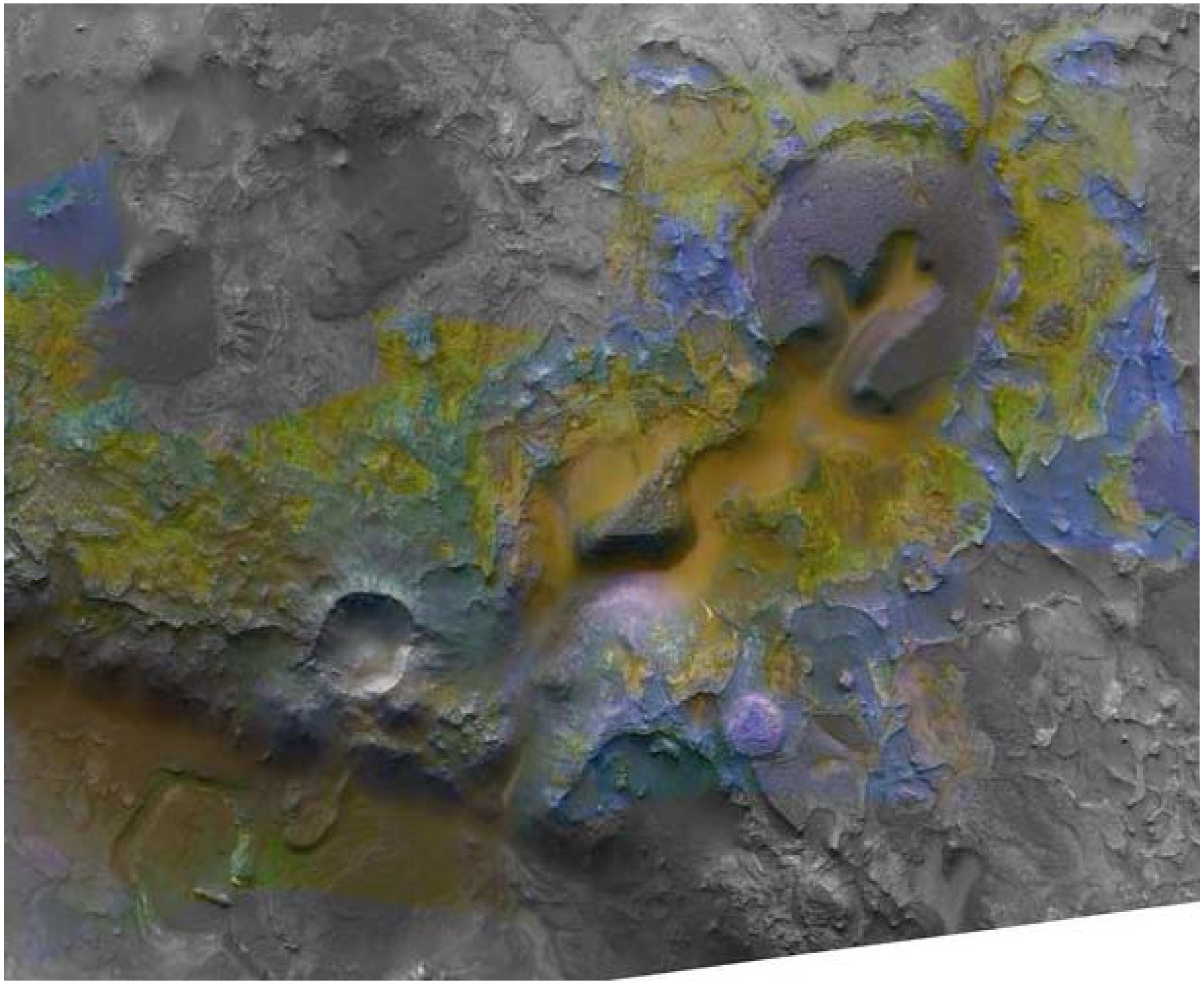
Water not stable as liquid

Venus

CO_2 stays in atmosphere

Runaway greenhouse

- **There's just one problem**
  - **We can't find these CO_2 bearing rocks (carbonates)**
  - **Some recent progress on this…**
  - **Spectral evidence of carbonates discovered and announced 2 months ago**



In this lecture…

- Introduction
  - Comparisons to Earth
  - Seasons on Mars
  - Early ideas
- Spacecraft exploration
  - Not Earth-like after all
  - Familiar landforms
- Early Martian History
  - Crustal dichotomy
  - Large impacts and volcanic activity
  - Magnetic fields
  - Valley networks

Next: Mars - Early History

- **Reading**
  - **Chapter 11-Mars sections to revise this lecture**
  - **Chapter 11-Mars sections for next lecture**