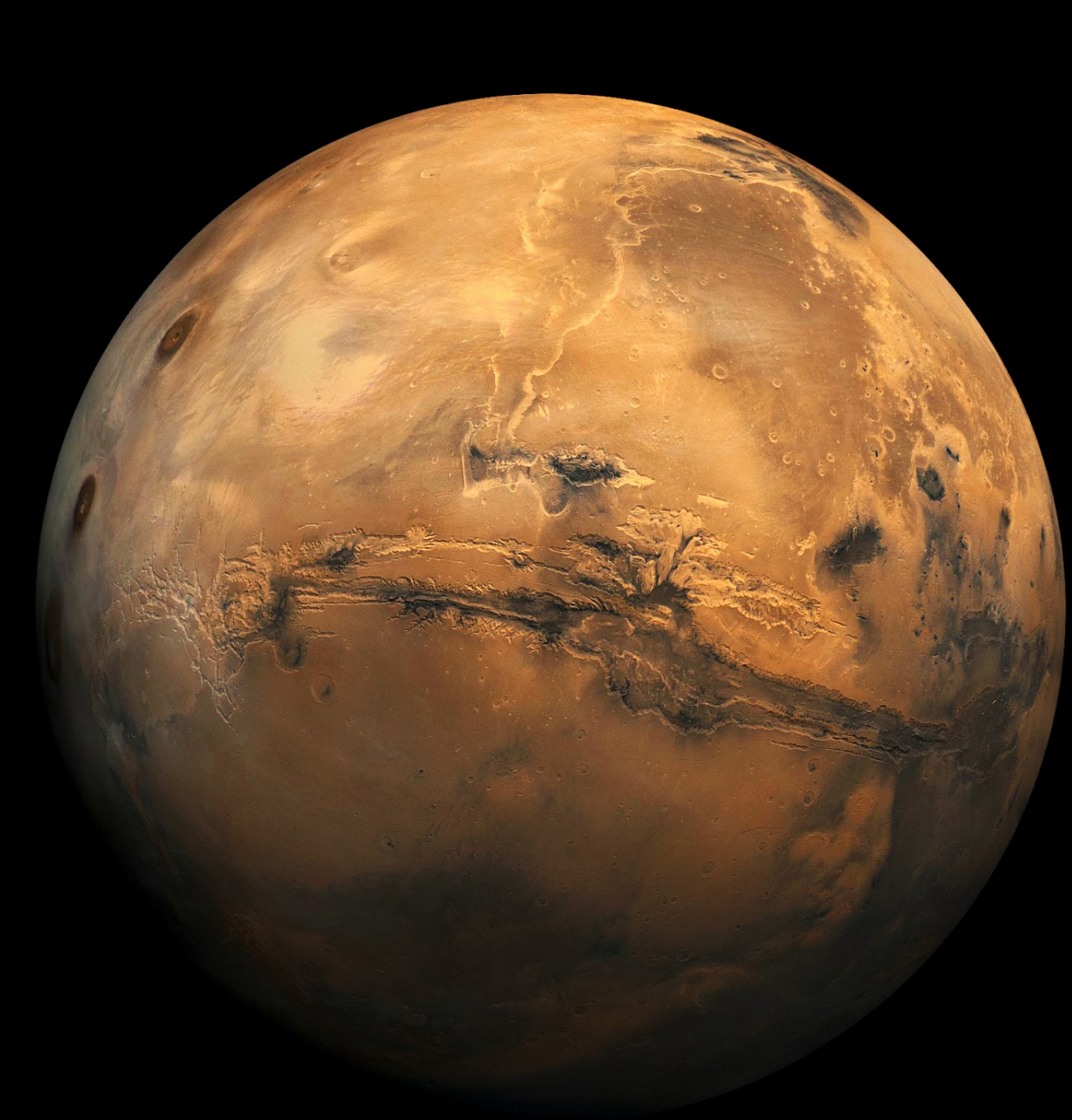


Mars: History of Exploration

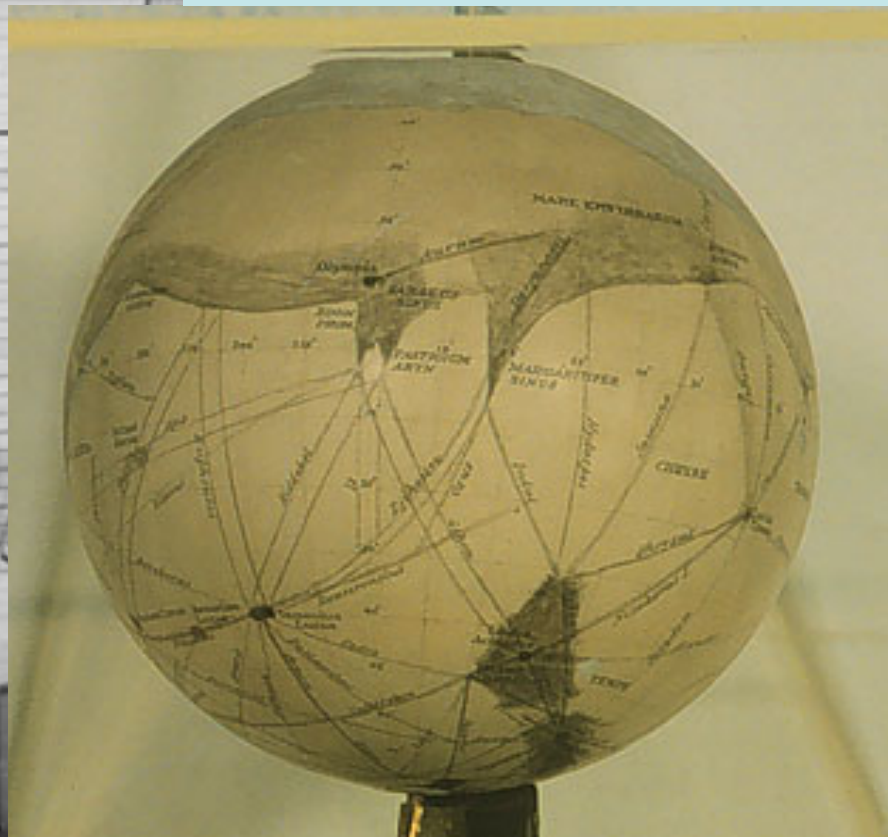
Donna M. Jurdy
Department of Earth and Planetary Sciences
Northwestern University

We choose to do these things...

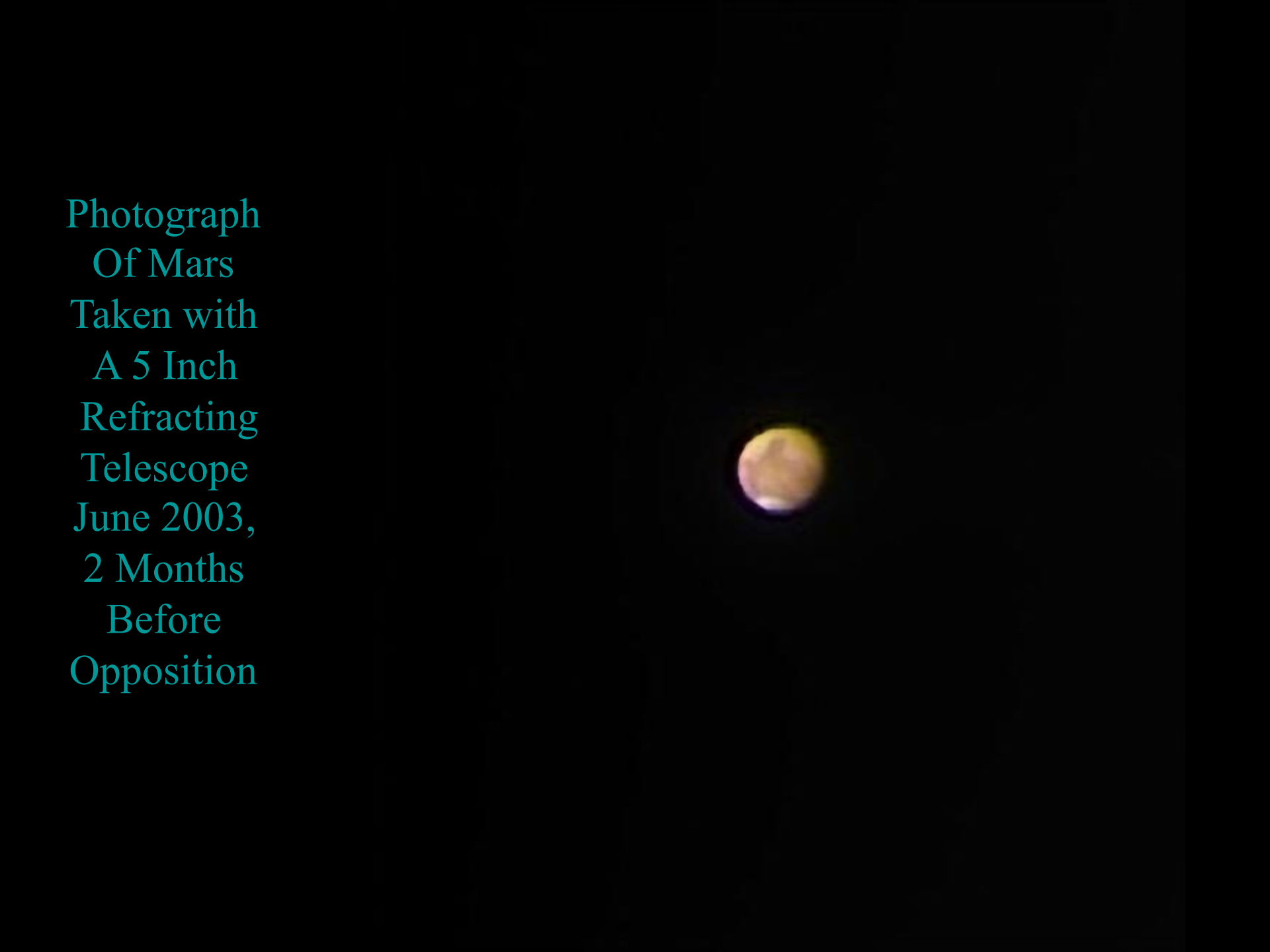
President John F Kennedy address at Rice University, 1962

PERCIVAL LOWELL AT THE 24 INCH REFRACTOR, FLAGSTAFF, ARIZONA OBSERVING MARS DURING FAVORABLE OPPOSTION (PERIHELIC OPPOSTION) OF 1894

BELOW IS A GLOBE CONSTRUCTED FROM HIS DRAWINGS

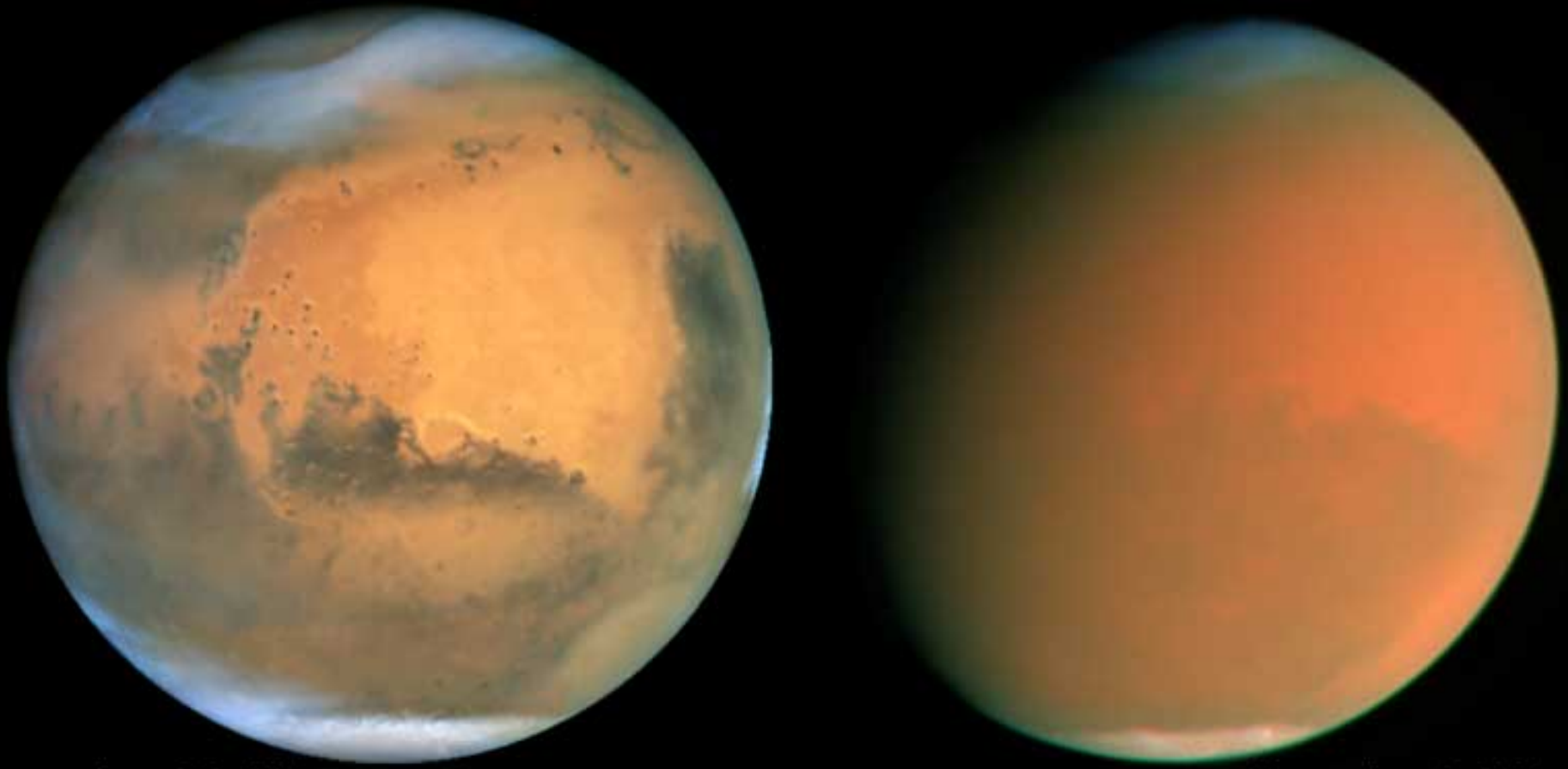


Photograph Of Mars Taken with A 5 Inch Refracting Telescope June 2003, 2 Months Before Opposition



H.G. Wells
The War of the Worlds
(1898)

Mars • Global Dust Storm



June 26, 2001

September 4, 2001

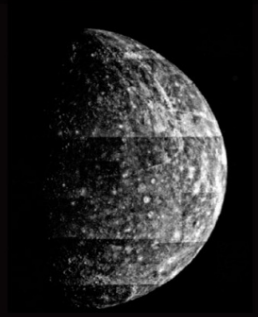
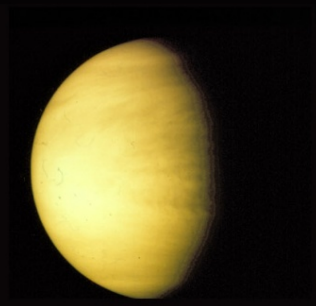
Hubble Space Telescope • WFPC2

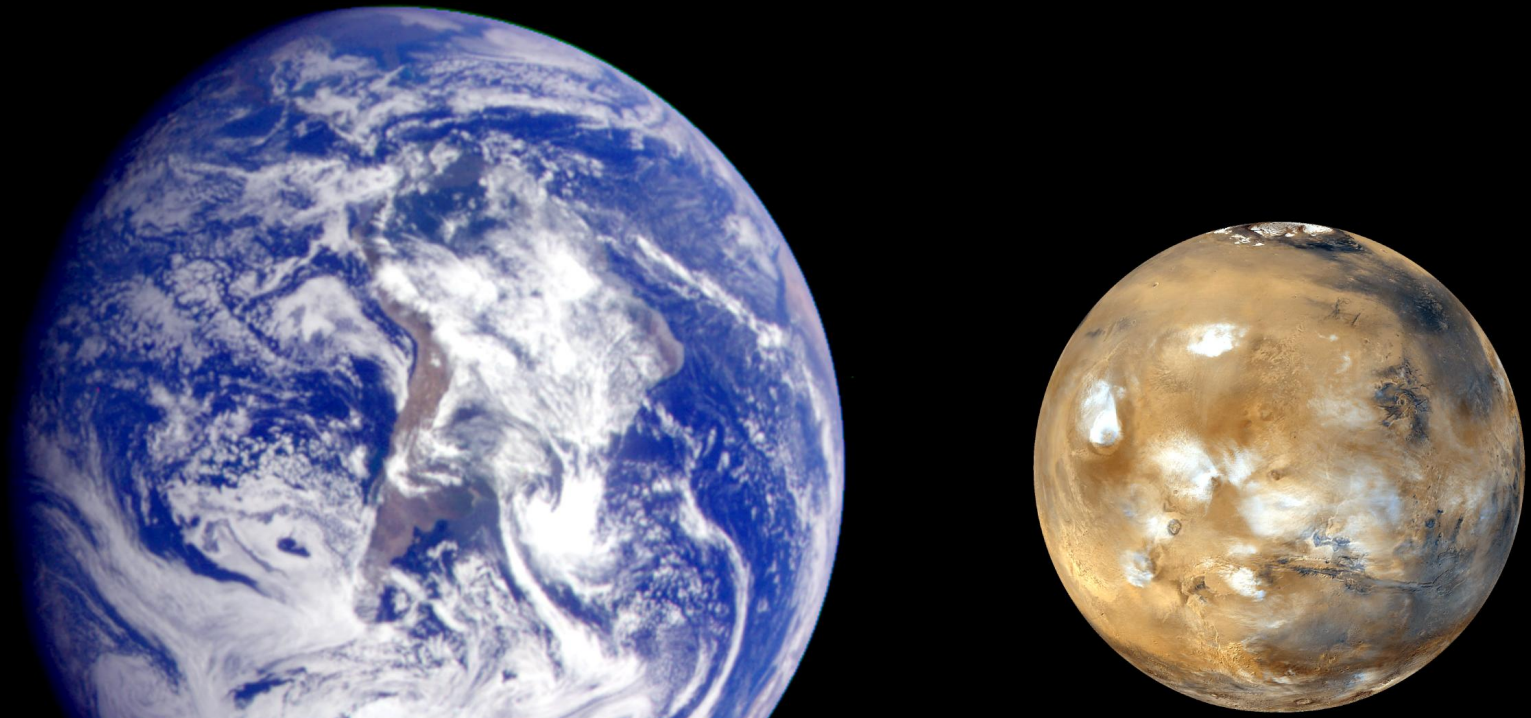
NASA, J. Bell (Cornell), M. Wolff (SSI), and the Hubble Heritage Team (STScI/AURA) • STScI-PRC01-31


mission
to
mars
(C) 2000 The Disney Corporation

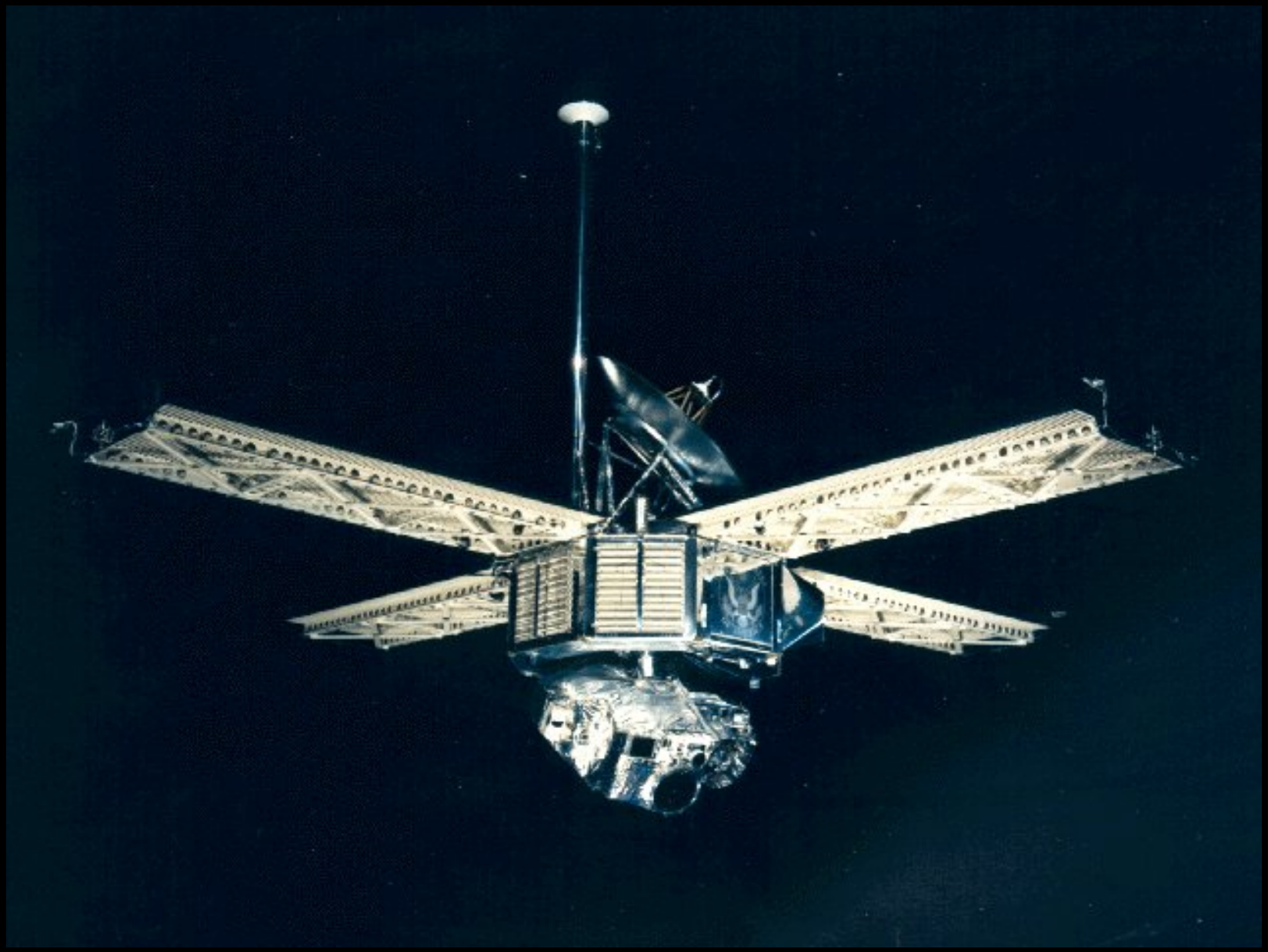
When is a face not a face?

Agyre Basin Happy Face

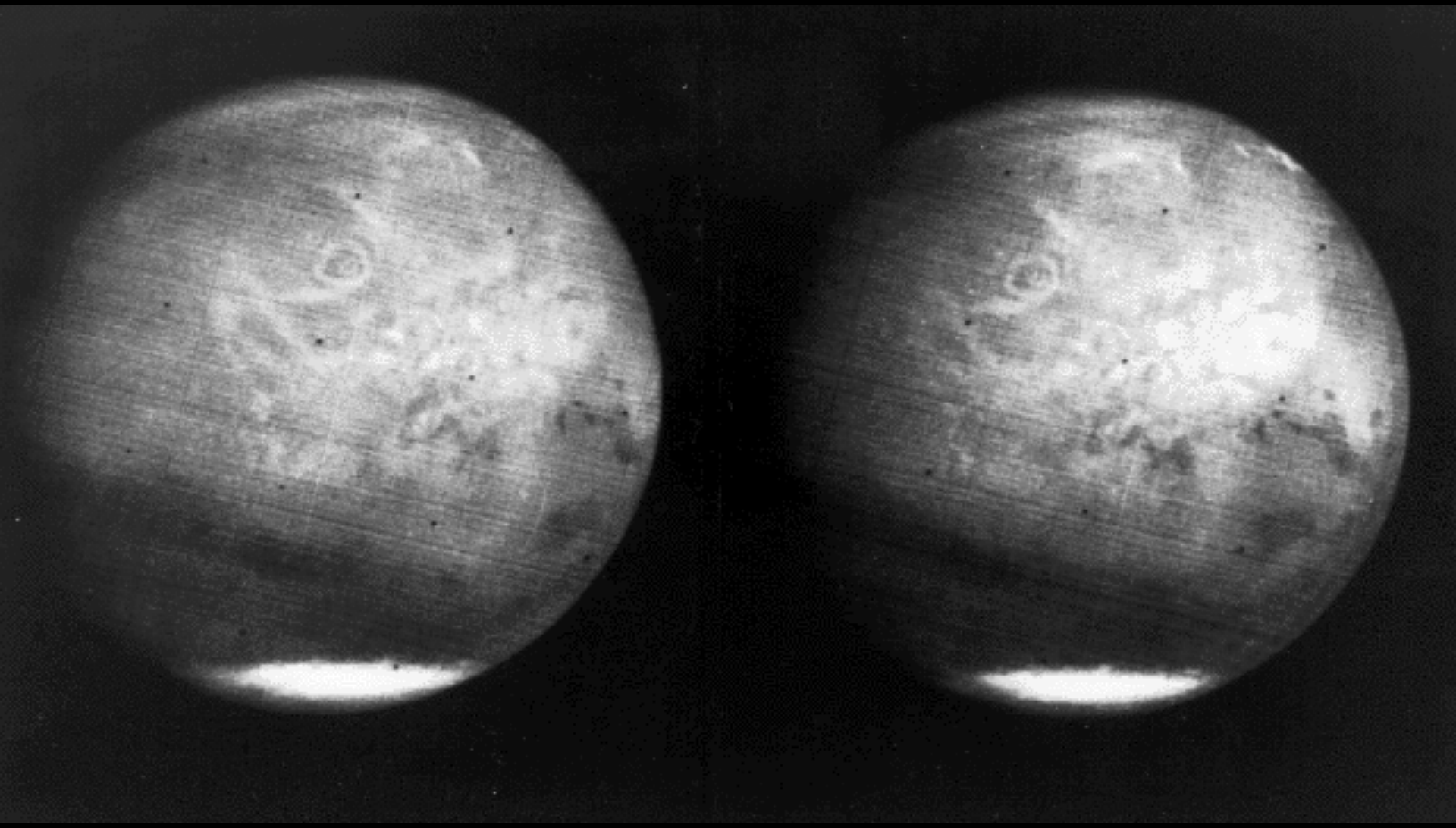
	Mercury	Venus	Earth	Moon	Mars
					
Radius (km)	2439	6052	6378	1738	3398
Mass (kg)	3.30×10^{23}	4.87×10^{24}	5.98×10^{24}	7.35×10^{22}	6.42×10^{23}
Density (kg/m^3)	5420	5250	5520	3340	3940
Distance from the Sun (A.U)	0.387	0.723	1.000	---	1.524
Mean Surface Pressure (bars)	---	92	1	---	0.006
Mean Surface Temp (K)	452	726	281	250	230
Atmosphere	---	CO_2	N_2, O_2	---	CO_2



Mariner 7 (1969)



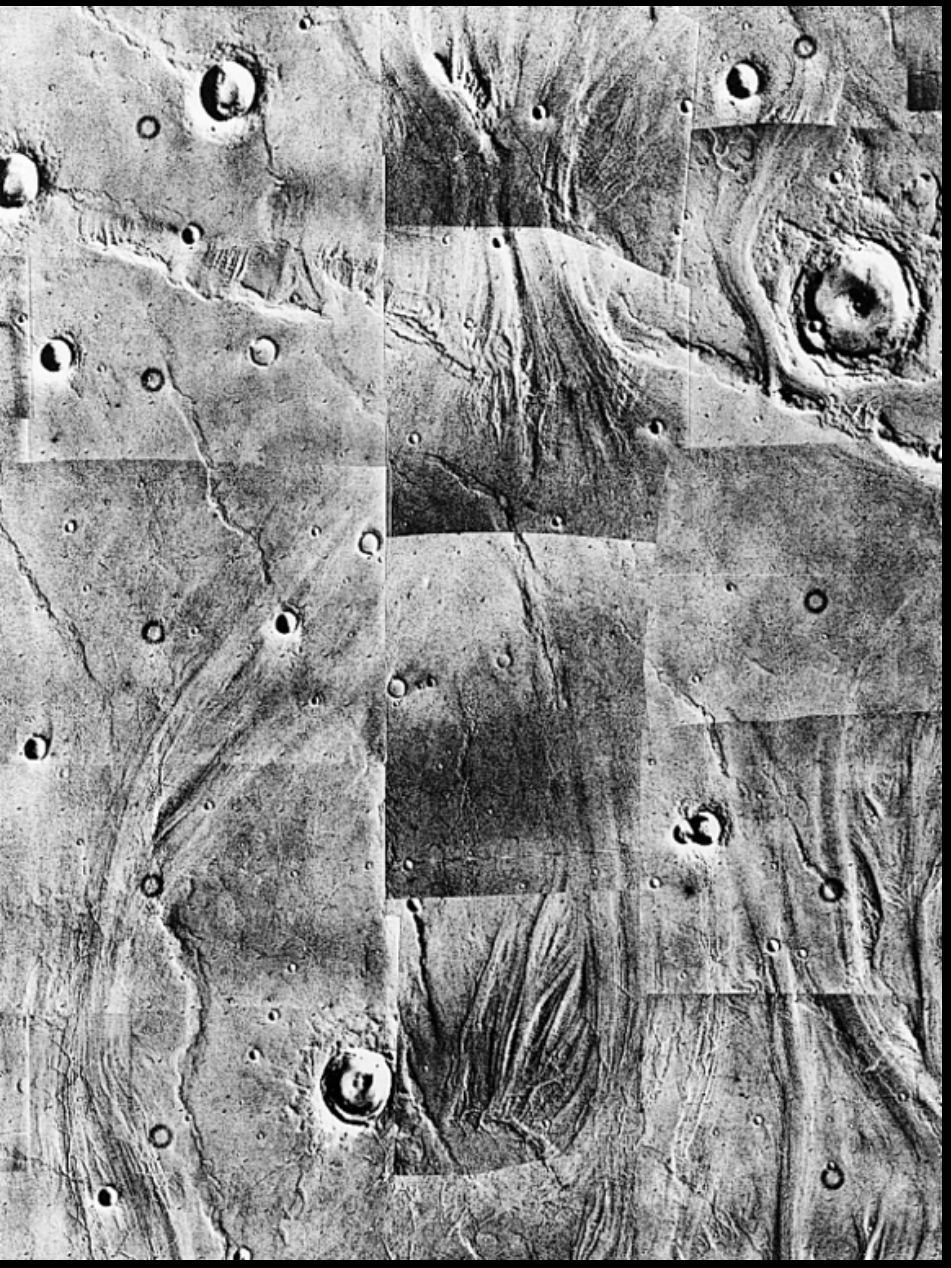
Mariner 7 Approach to Mars



Olympus Mons, as seen from Mariner 9 (1971)

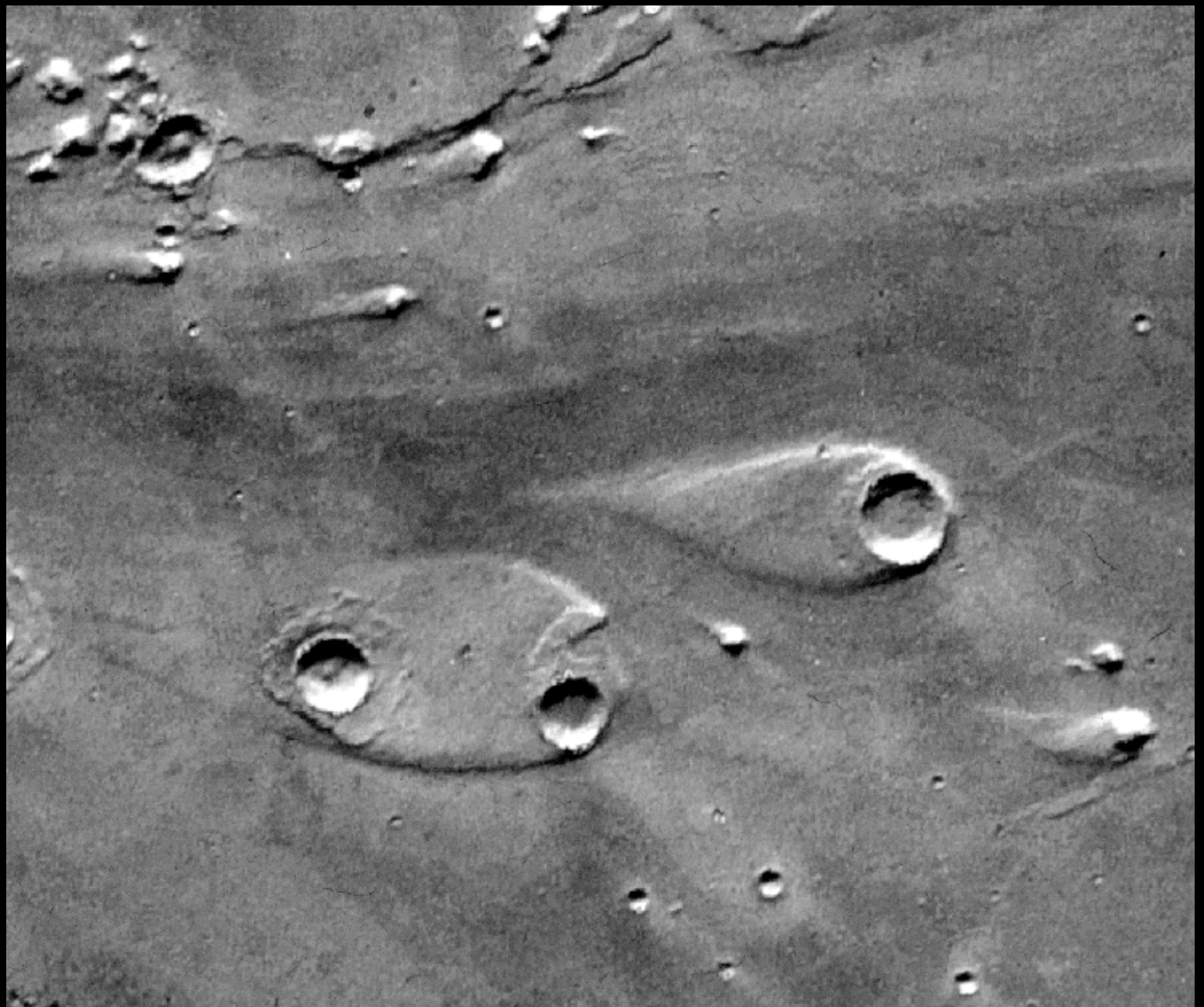
Olympus Mons Caldera

Water on Mars



- Ancient Mars had flowing water on its surface.
- These images clearly show the results of what appears to have been flowing water.
- The Viking landers actually recorded frost forming, then evaporating.
- There does not seem to be any liquid water on Mars today.
- It is possible that there may be surface water in shallow lakes under ice.

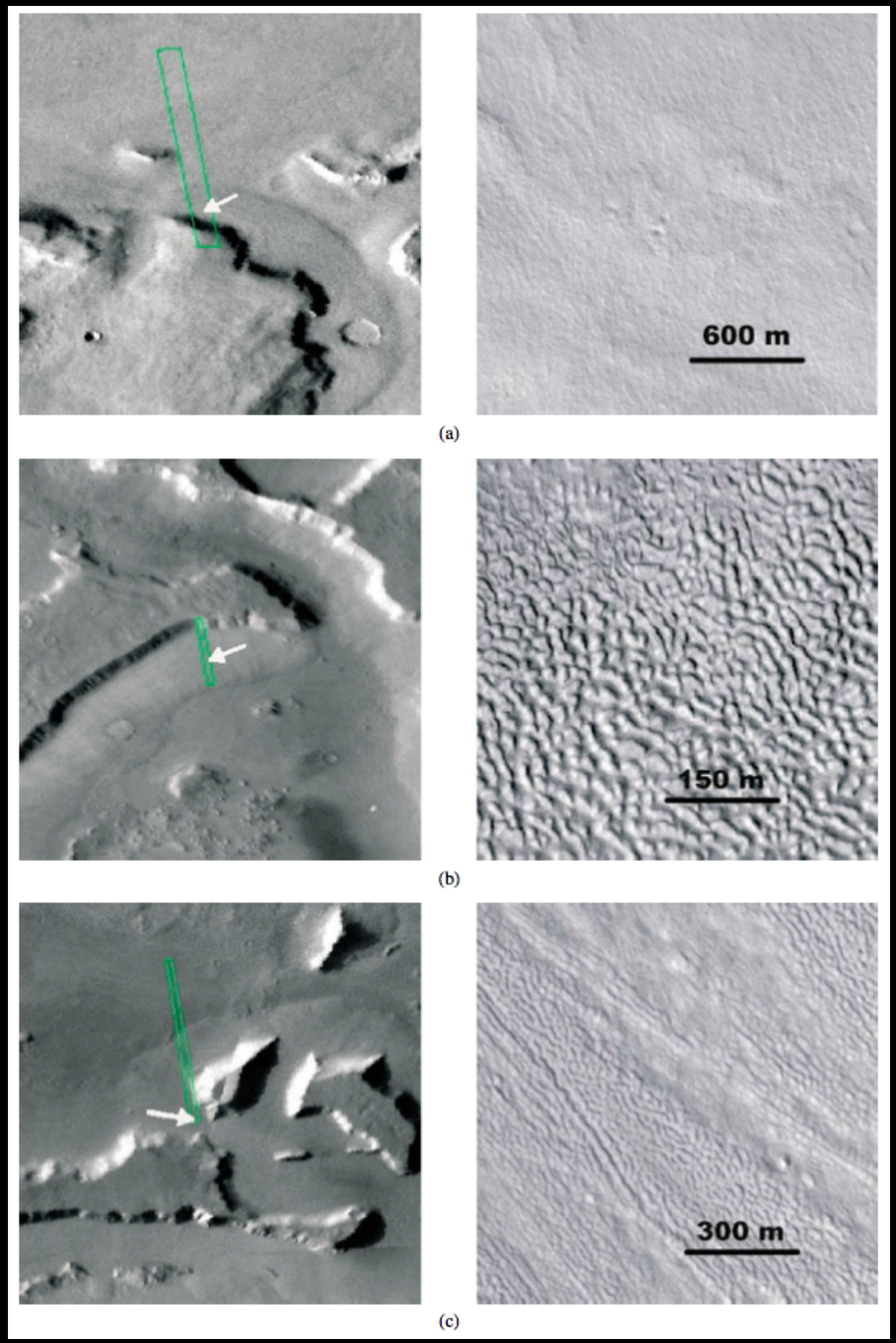
Channel Islands



Erosion, Lobate Ejecta

River Channels

Debris Aprons



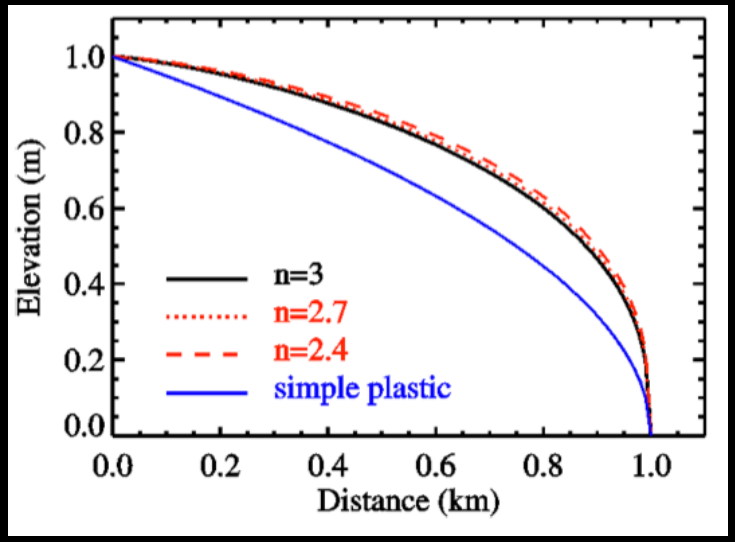
(a) Smooth surface texture may represent original apron surface

(b) Pitted surface texture may develop through ice sublimation induced collapse

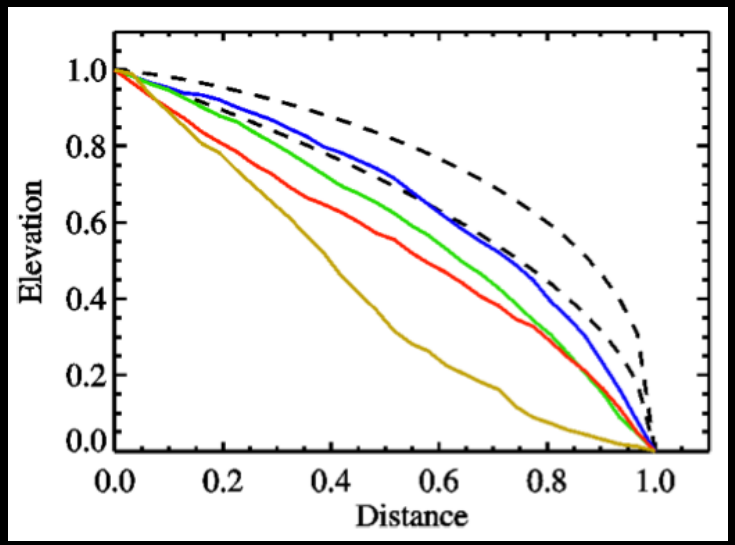
(c) Ridged texture

Li, Robinson, Jurdy (2005)

Debris Aprons

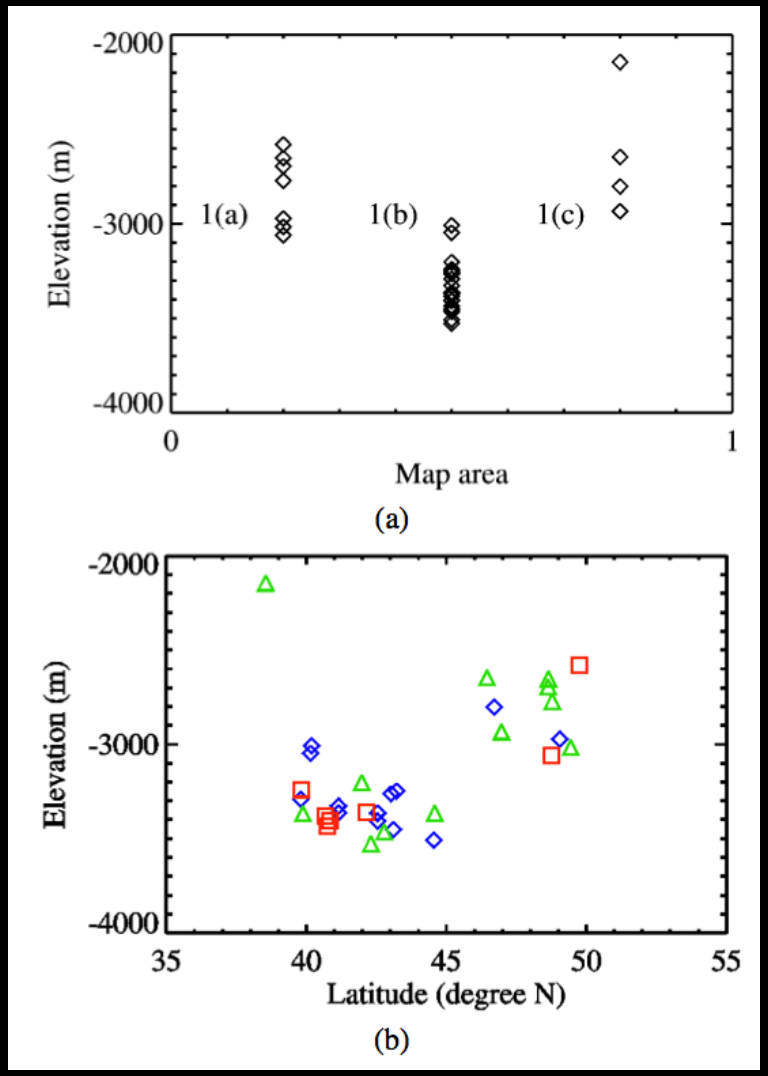


Above: Longitudinal profile predicted by viscous power law model when *n* varies within the range of 2.4 to 3.



Left: Composite profiles of three types of lobate debris aprons and Valles Marineris landslide, normalized to unit length and thickness.

Li, Robinson, Jurdy (2005)

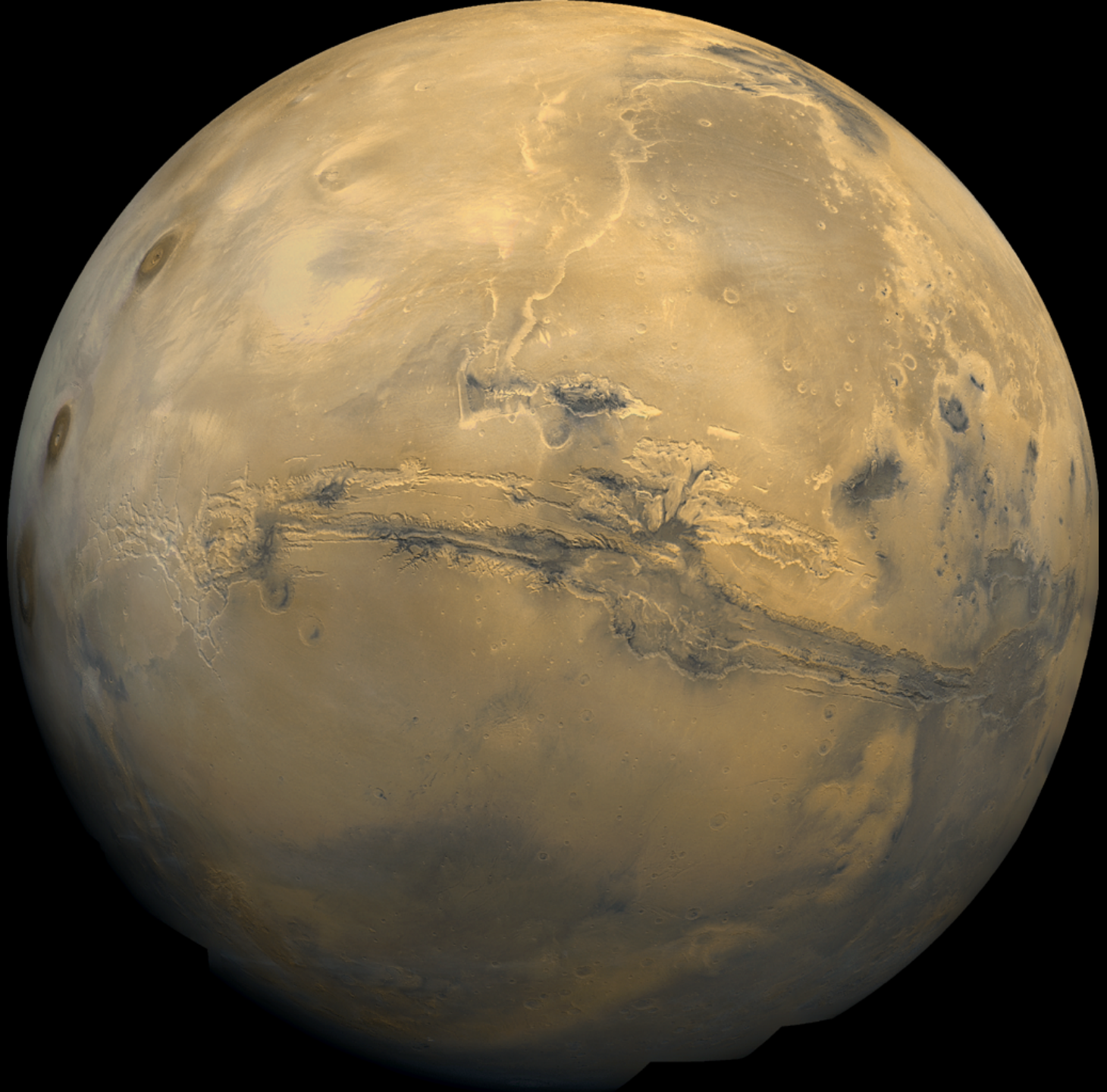


Above: Relationships between apron type and (a) elevation and (b) latitude (type I blue diamond shape, type II green triangle, type III red square).

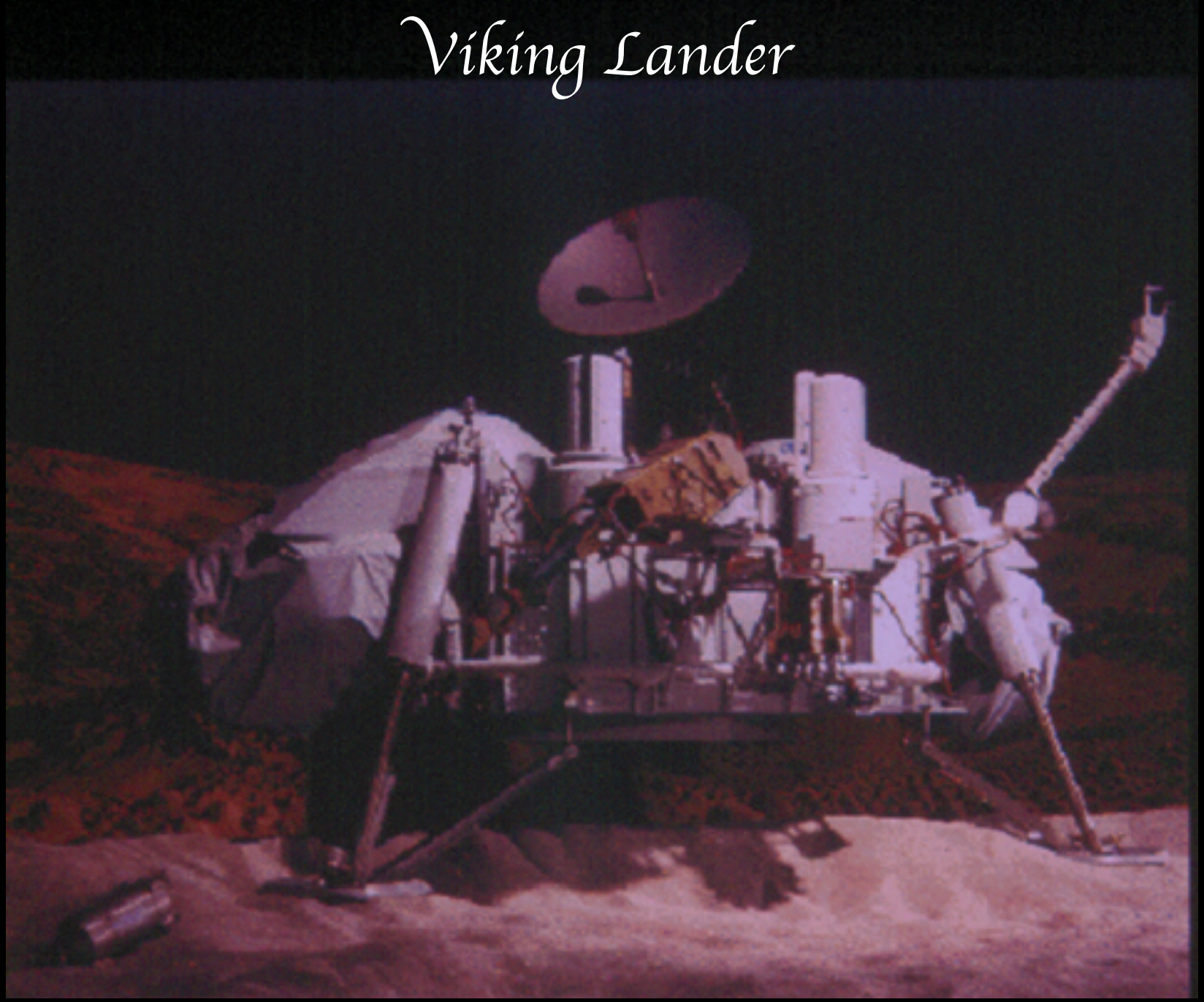
Viking 2 Liftoff, Sept 5, 1975

COMPOSITE IMAGE OF MARS TAKEN FROM SMALL TELESCOPES ONBOARD THE 2 VIKING ORBITERS

Mid 1970's

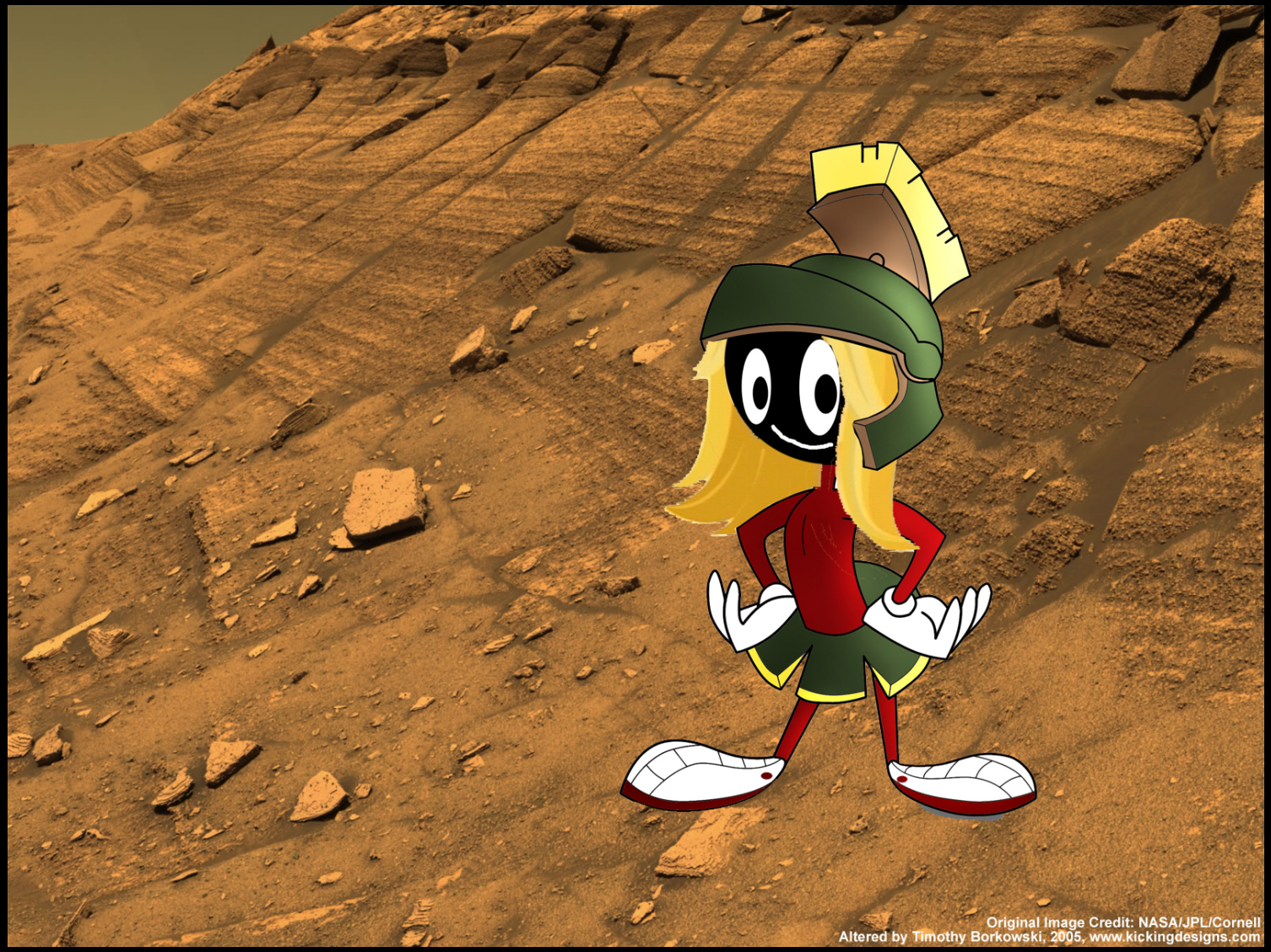


Viking Lander



Viking 2 Landing Site (Sept, 1976)

So, what have we learned about life on Mars?



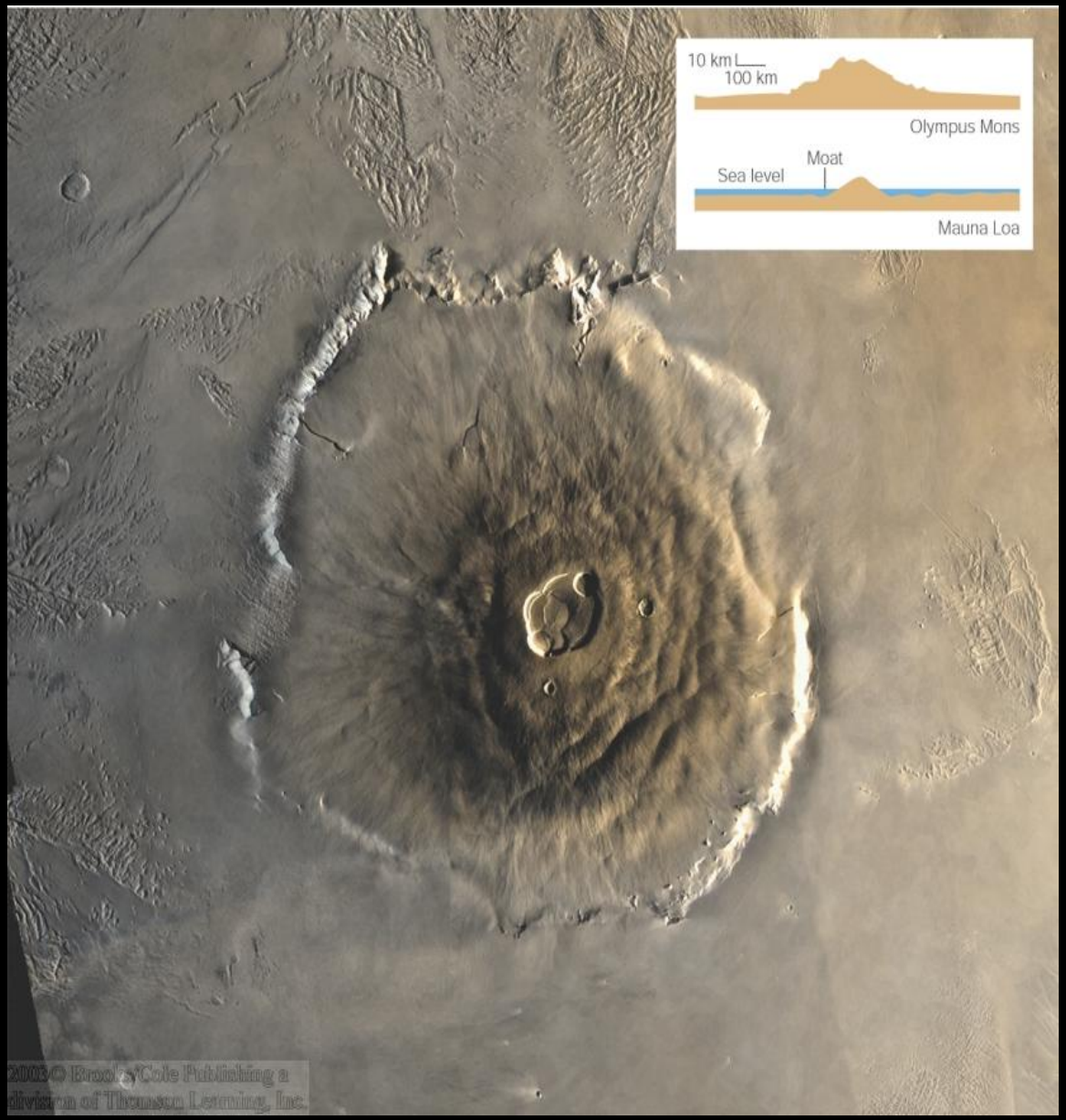
If Martians exist, they’re blonde and happy!

Volcanism on Mars

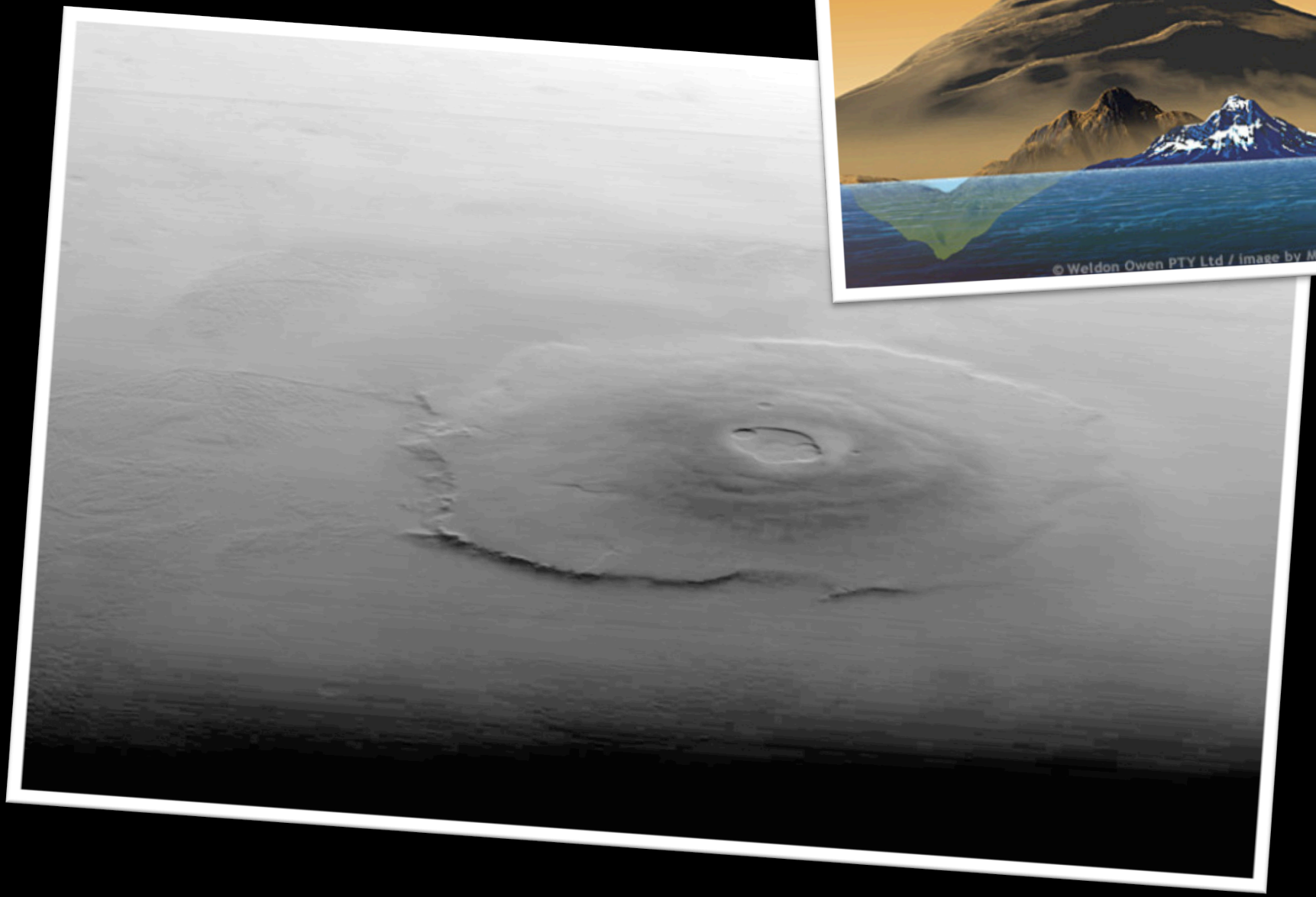
Volcanoes on Mars are shield volcanoes.

Olympus Mons:

Highest and largest shield volcano in the solar system.



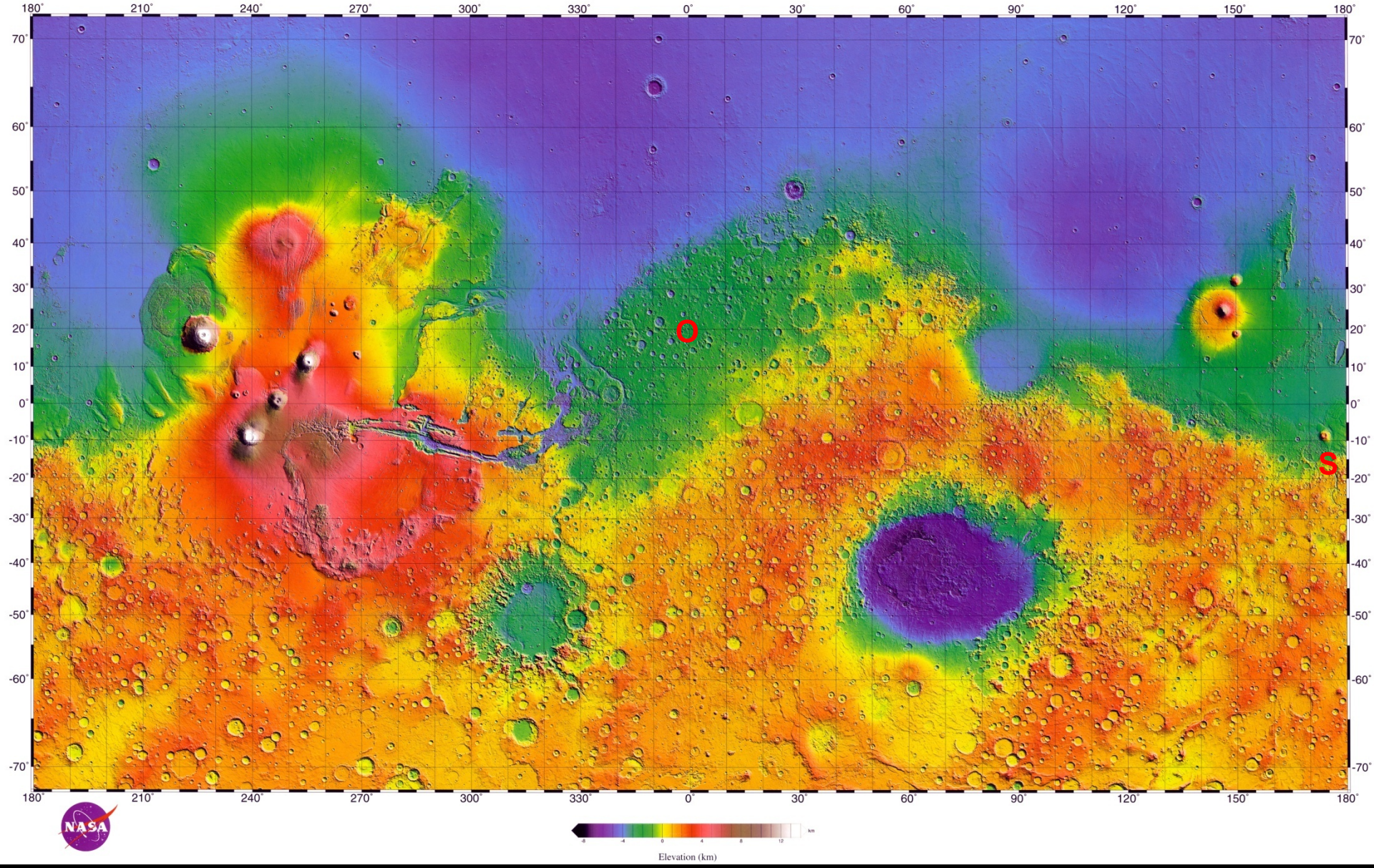
Olympus Mons

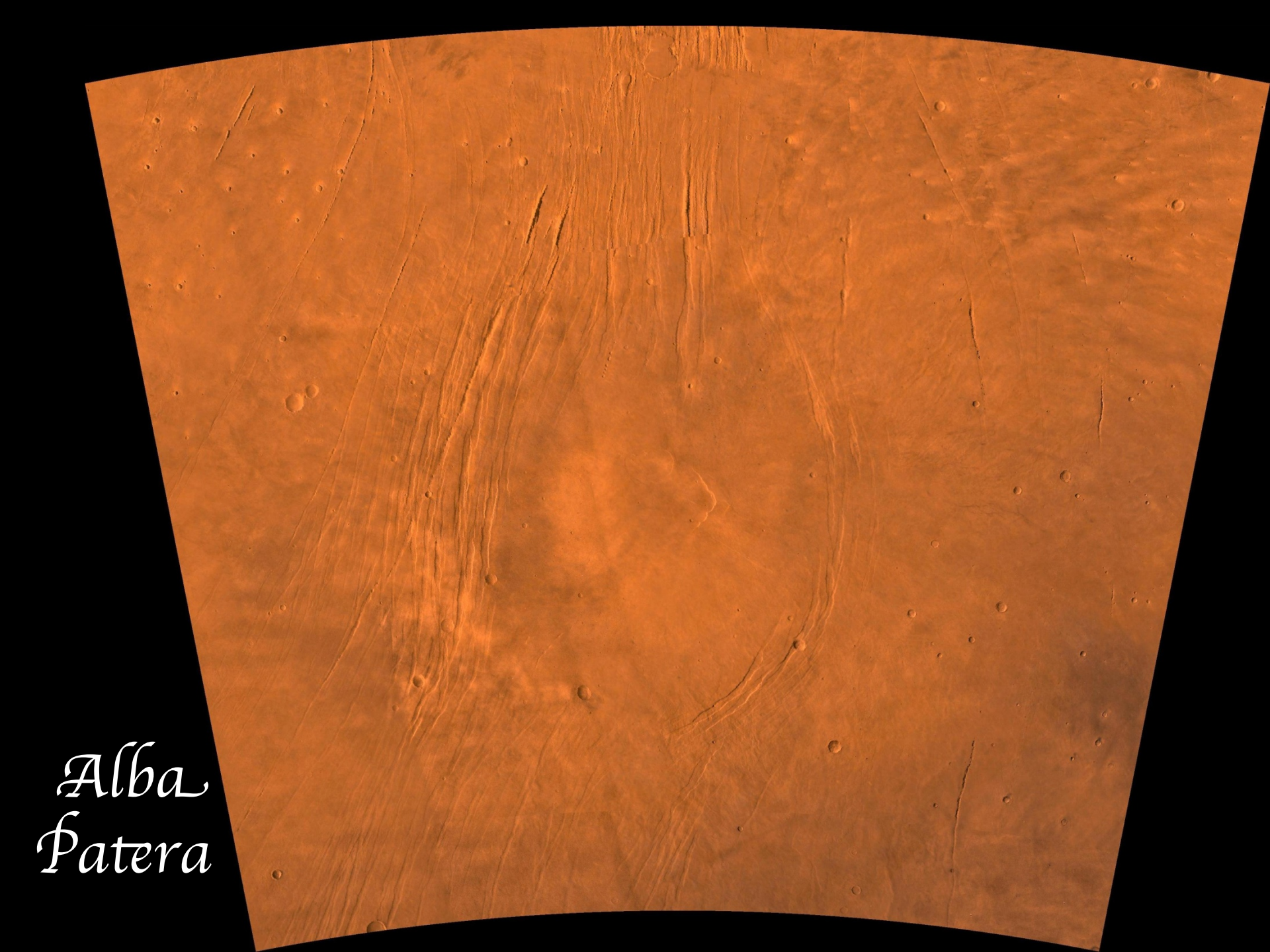


Terrestrial Shield Volcanoes

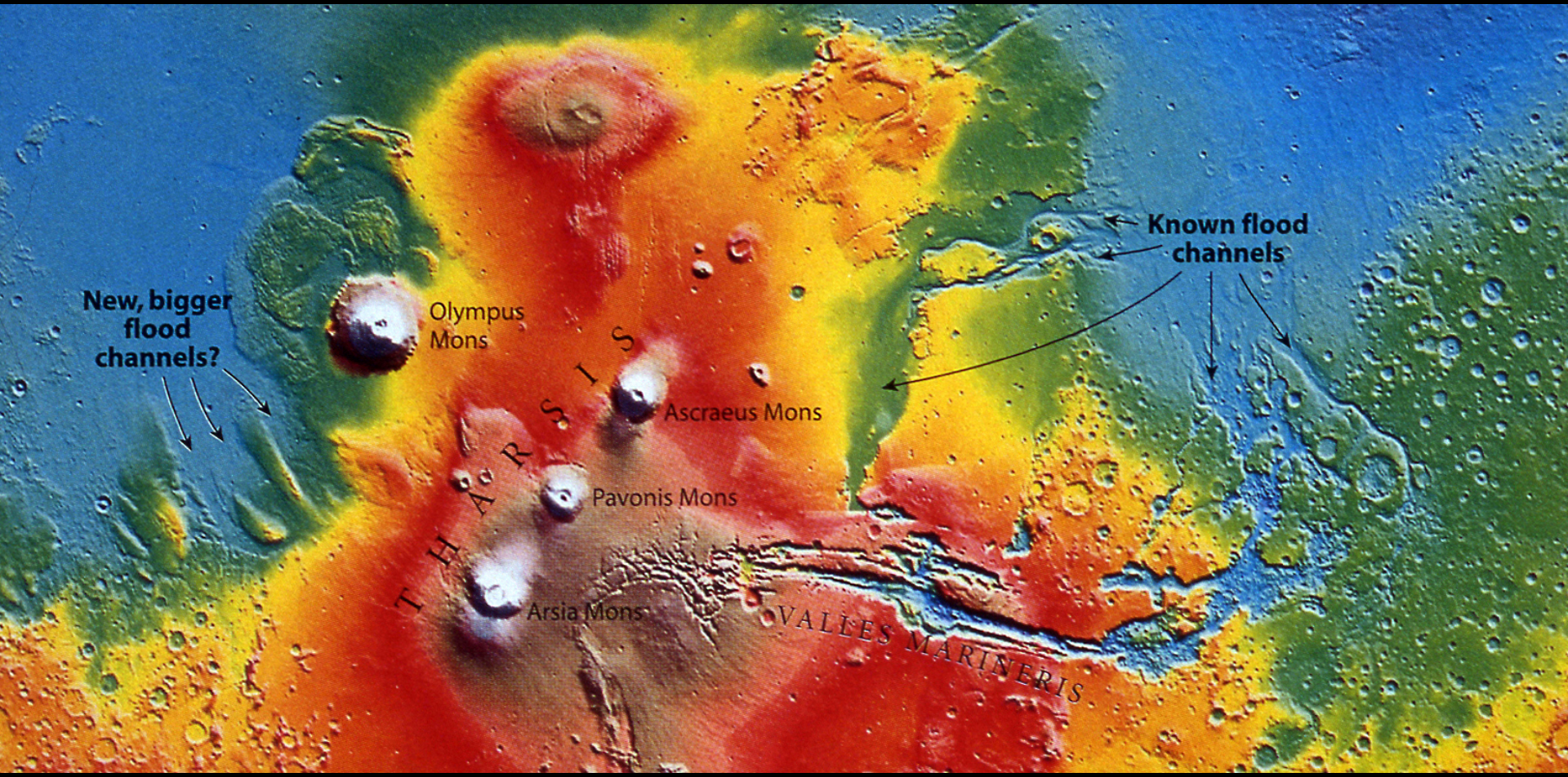
Tharsis Comparisons

The Topography of Mars

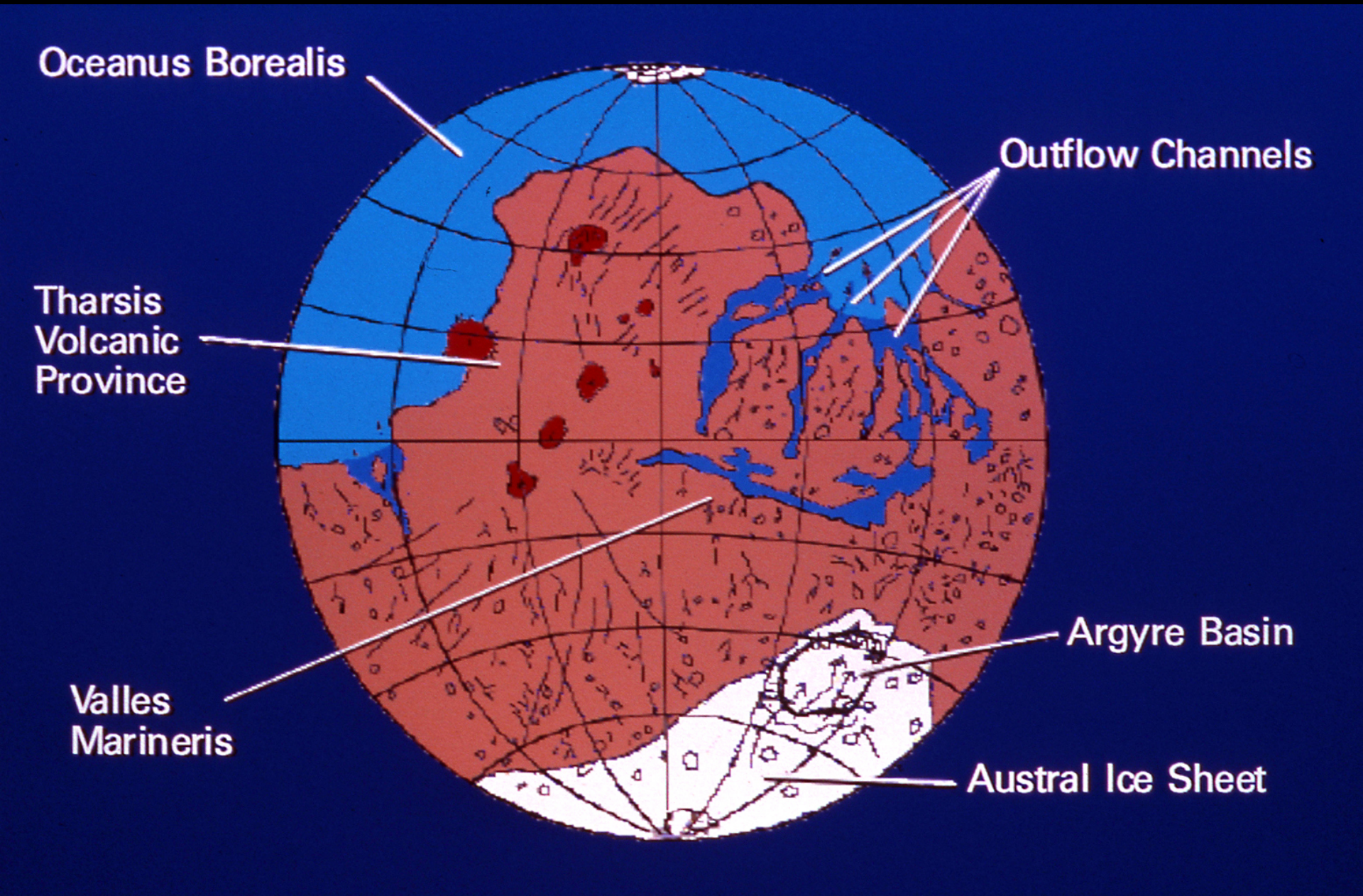



Alba
Patera

Tharsis Region Topography



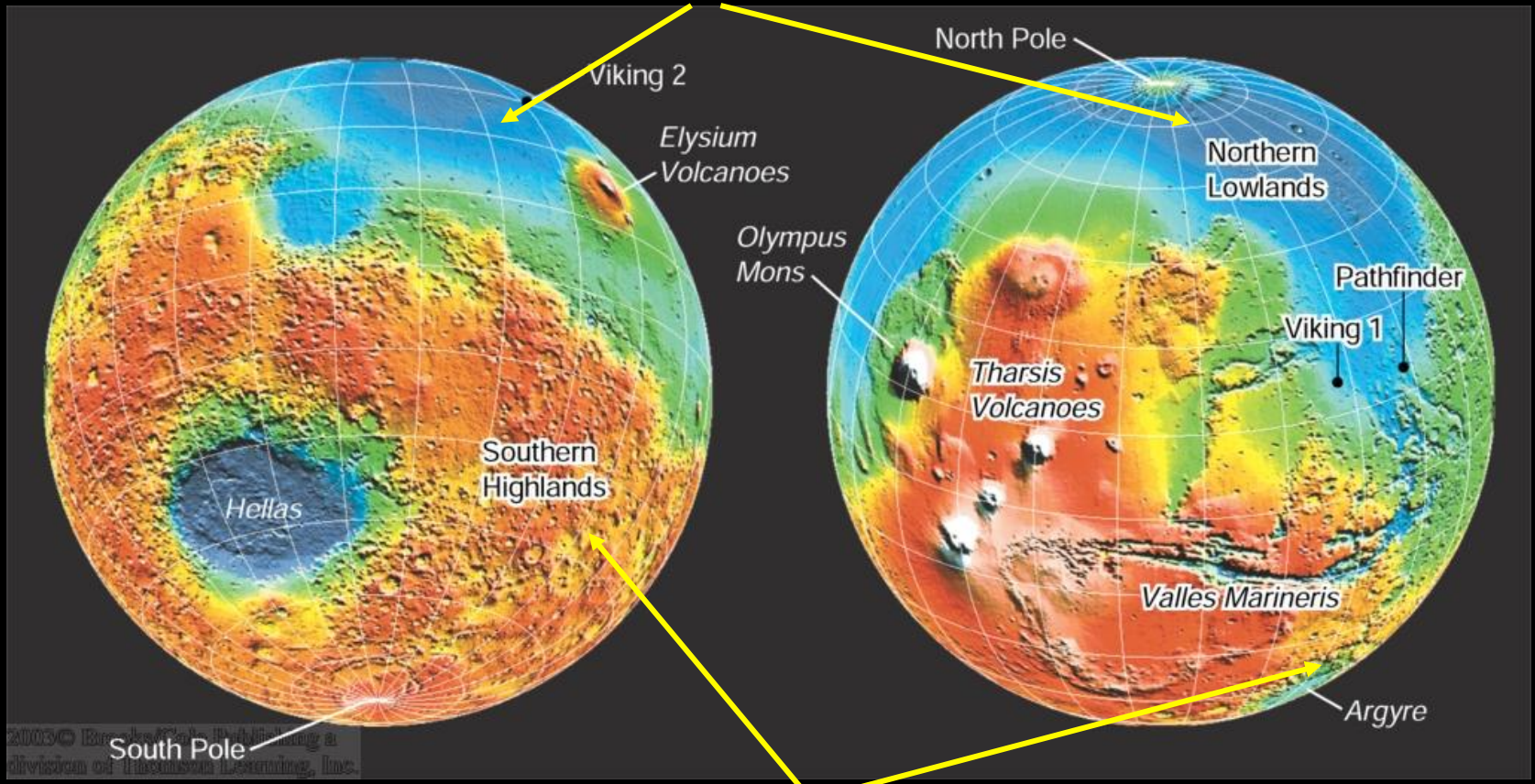
Mars Schematic



The Geology of Mars

Northern Lowlands: Free of craters; probably re-surfaced a few billion years ago.

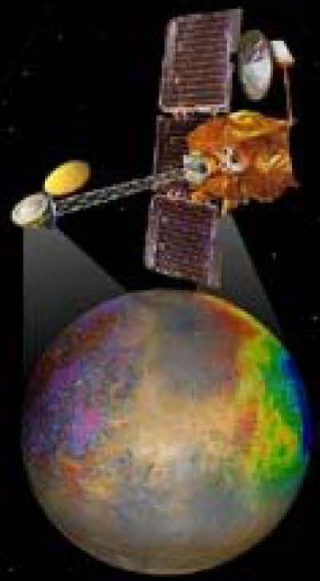
Possibly once filled with water.



Southern Highlands: Heavily cratered; probably 2 – 3 billion years old.

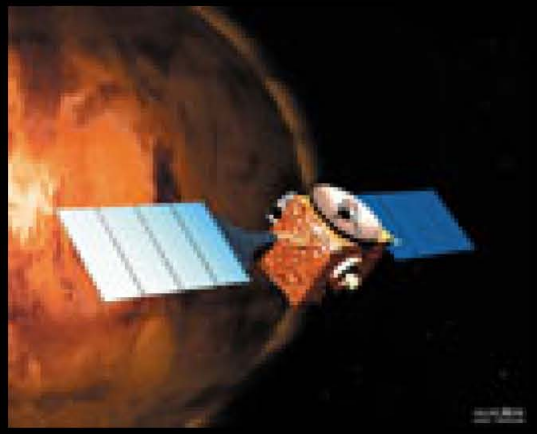
Mars Global Surveyor (MGS)

Mars Odyssey

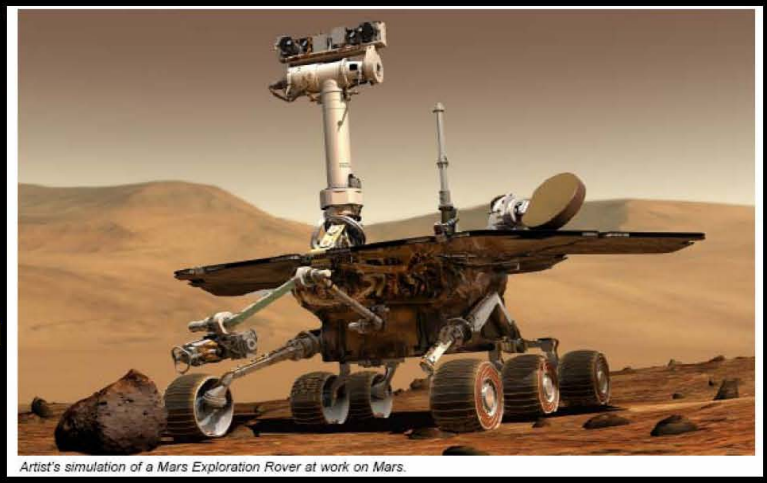


Mars Reconnaissance Orbiter

Mars Express



Mars Exploration Rovers (MERs)

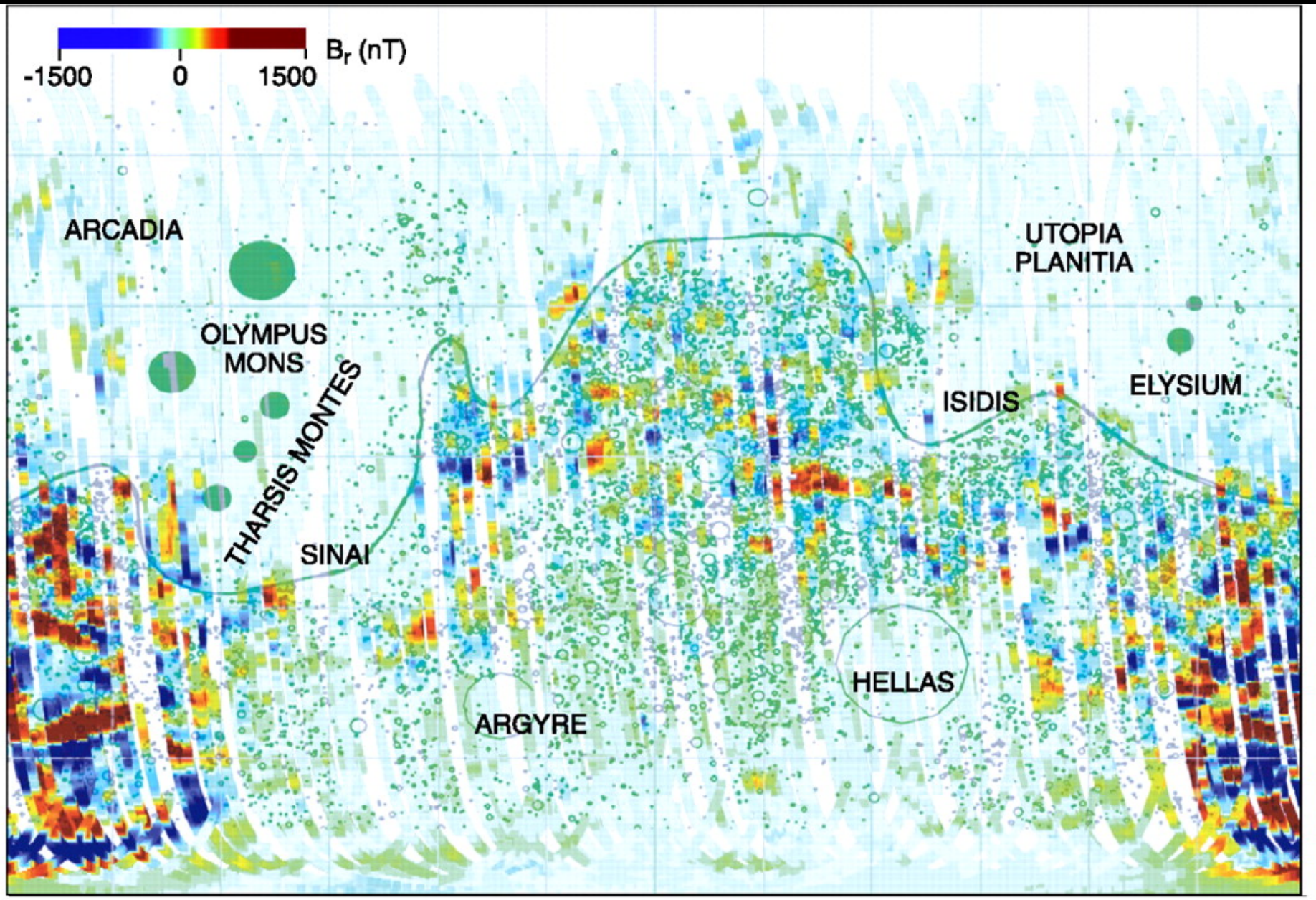


Artist's simulation of a Mars Exploration Rover at work on Mars.

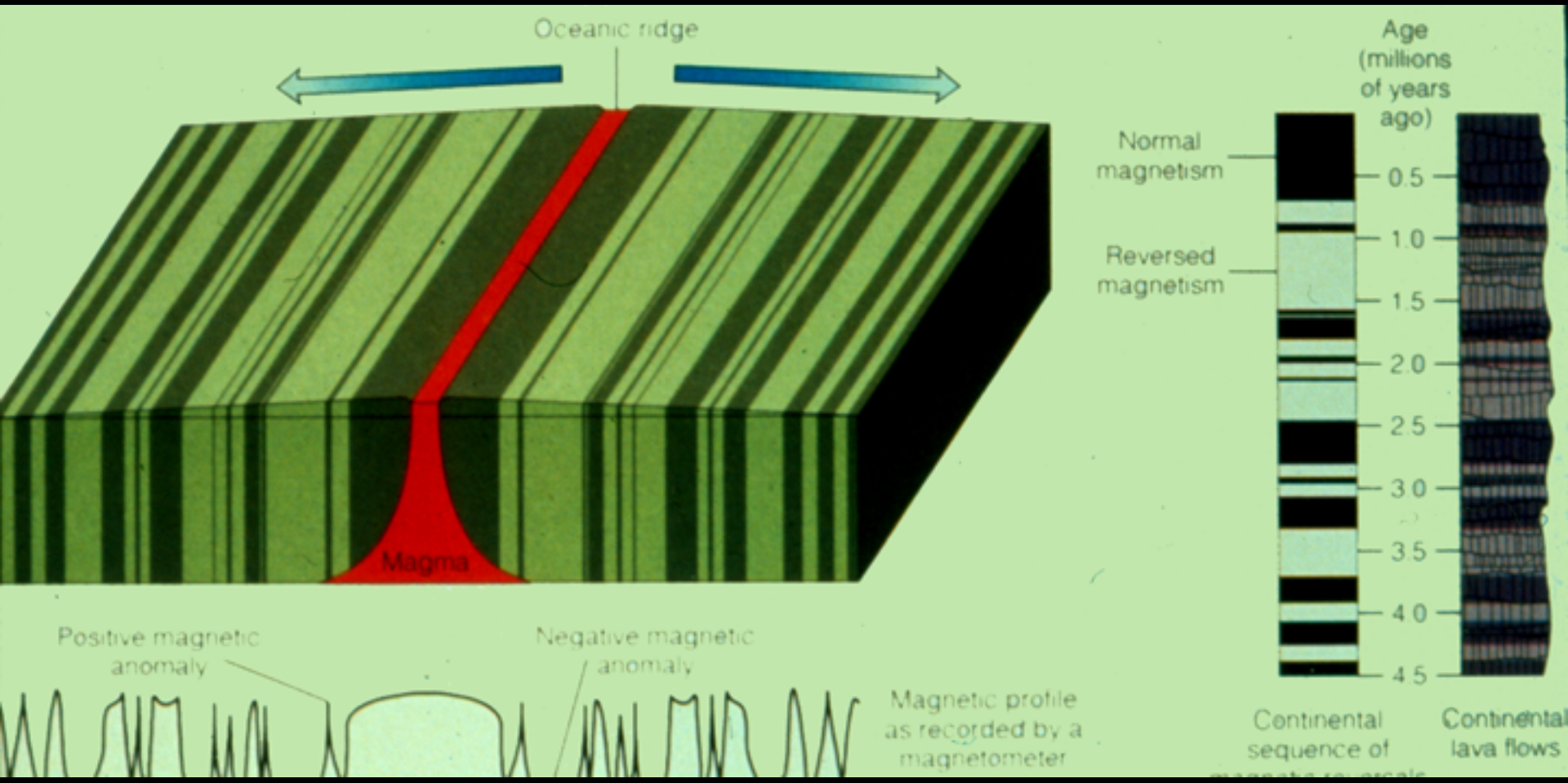
Mars Global Surveyor Liftoff

November 7, 1996

Martian Magnetics



Generation of Magnetic Lineations



Magnetization of Mars

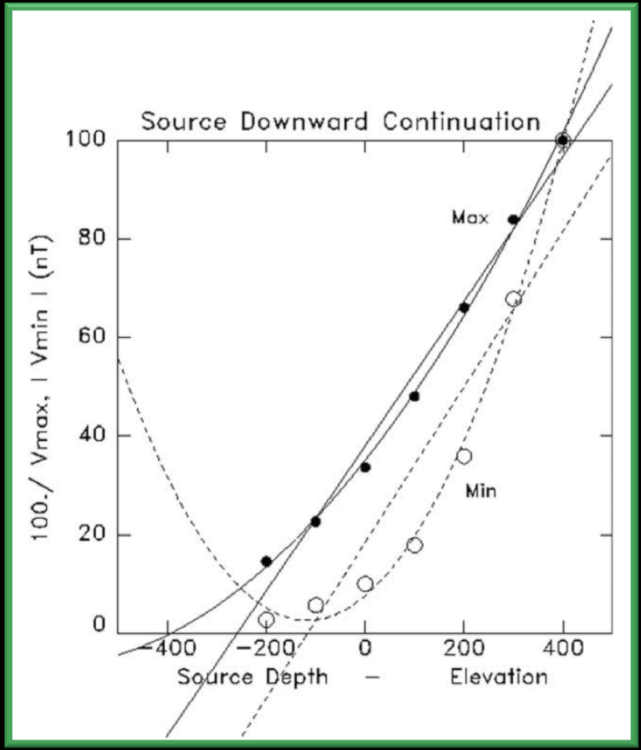


Figure: Reciprocals of maximums and minimums of sources in model shown as a function of altitude and depth of extrapolation. Linear and parabolic fits are made for maximums of the positives (solid circles) and for minimums of the negatives (open circles).

Jurdy and Stefanick (2009)

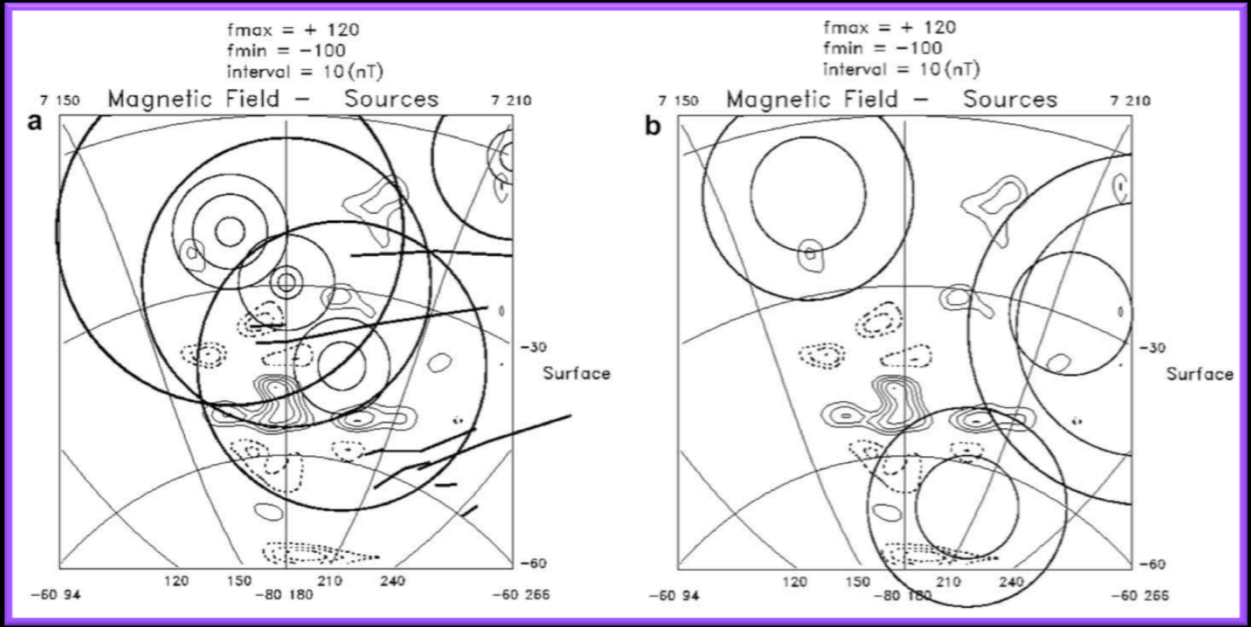


Figure: (a) Sources for magnetic field vertical component at Mars' surface. (b) Craters based on MOLA topography.

Jurdy and Stefanick (2009)

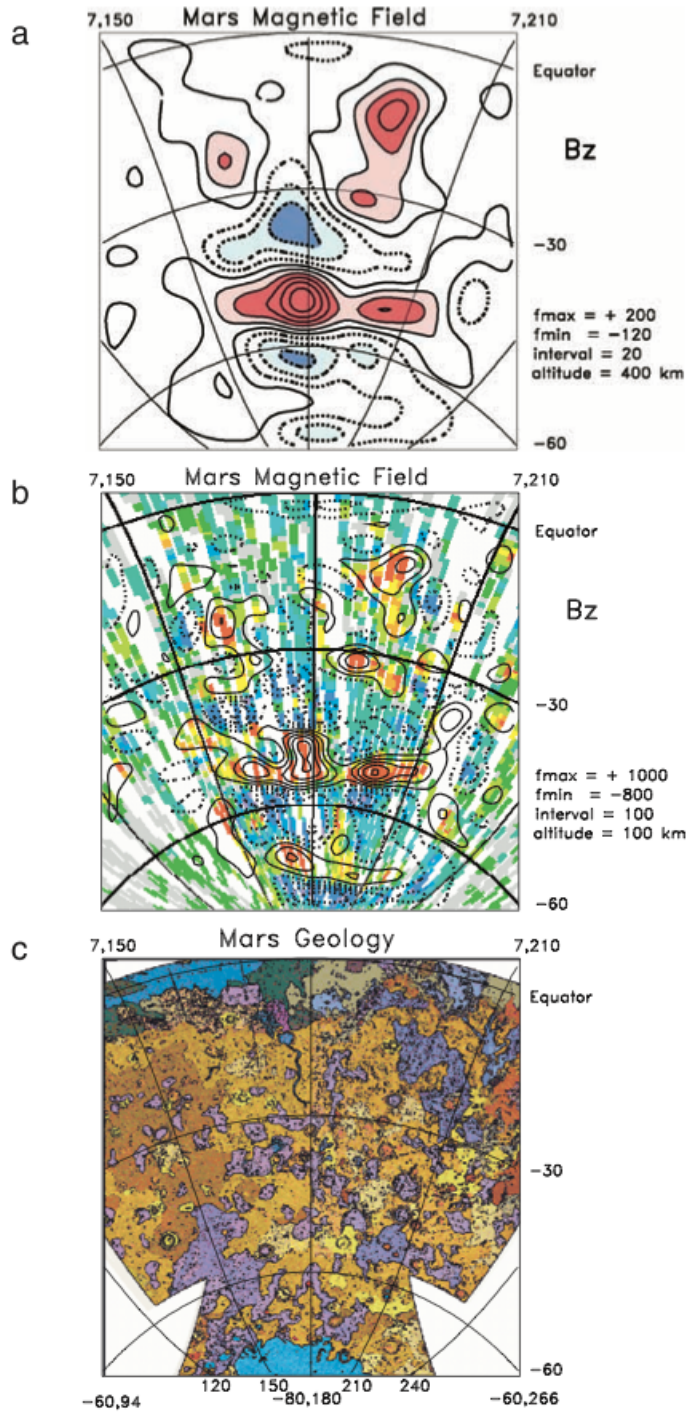
Magnetization of Mars

Figure:
(a) The vertical component of the magnetic field B_z as measured at 400 km.

(b) The vertical component of the magnetic field B_z extrapolated downward from 400 to 100 km using a Fourier transform. The result agrees very well with aerobraking data obtained at 100 km (shown in color) and fills in data gaps. Aerobraking data: red, strongly positive; blue, strongly negative.

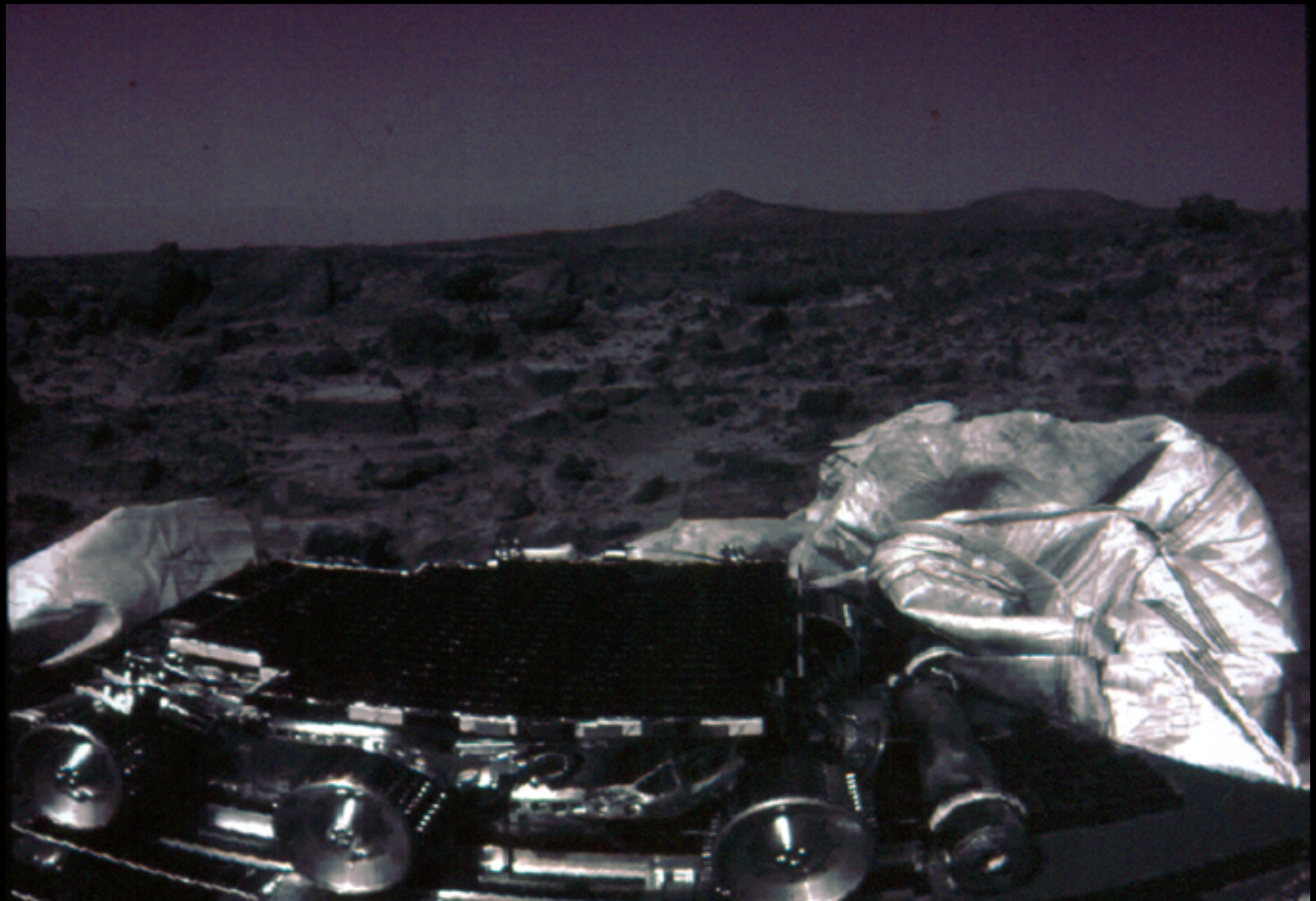
(c) Geology of Mars' highland terrain.

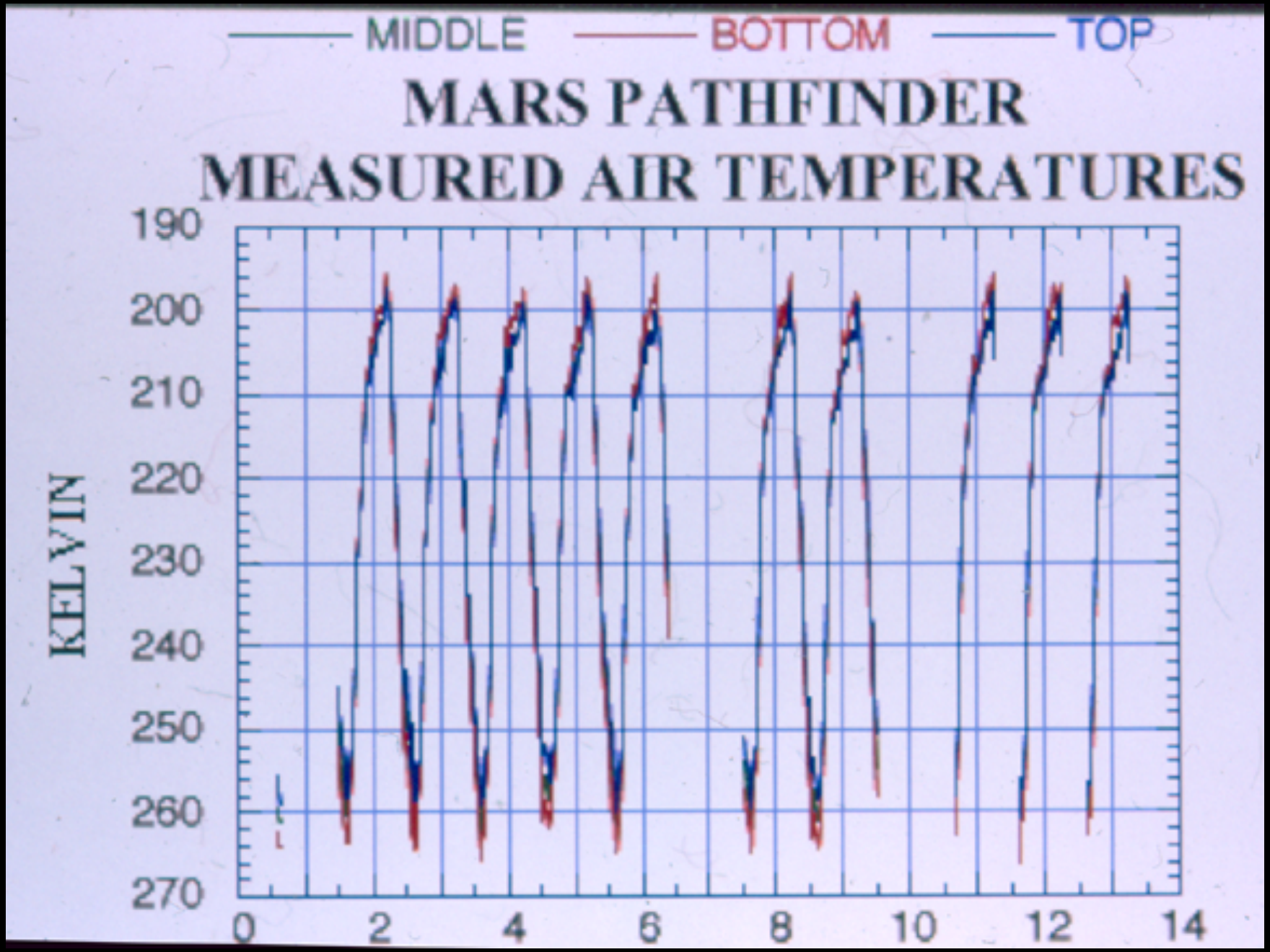
Jurdy and Stefanick (2004)

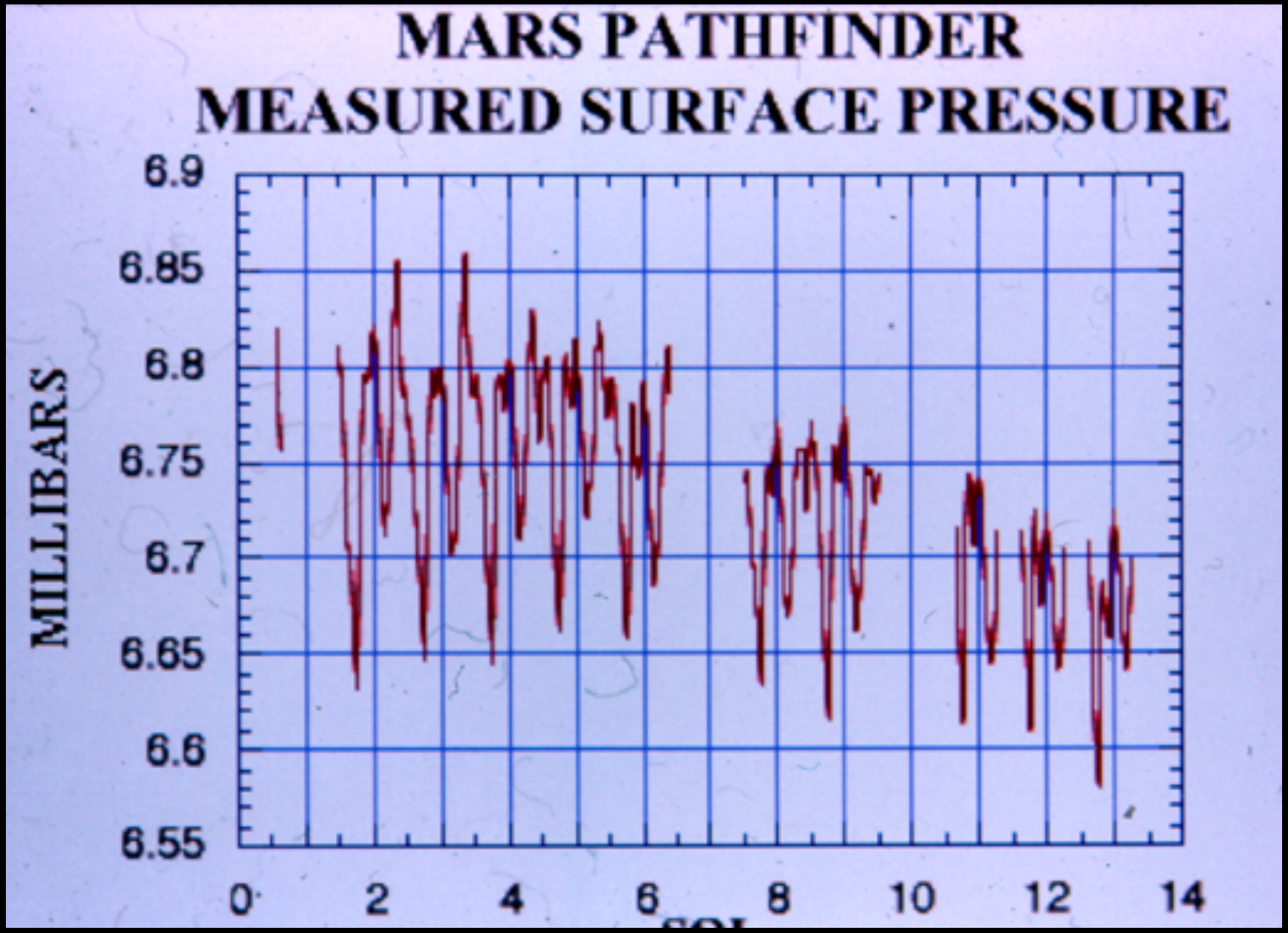


Pathfinder Landing Site (July 4, 1977)

Pathfinder/Sojourner

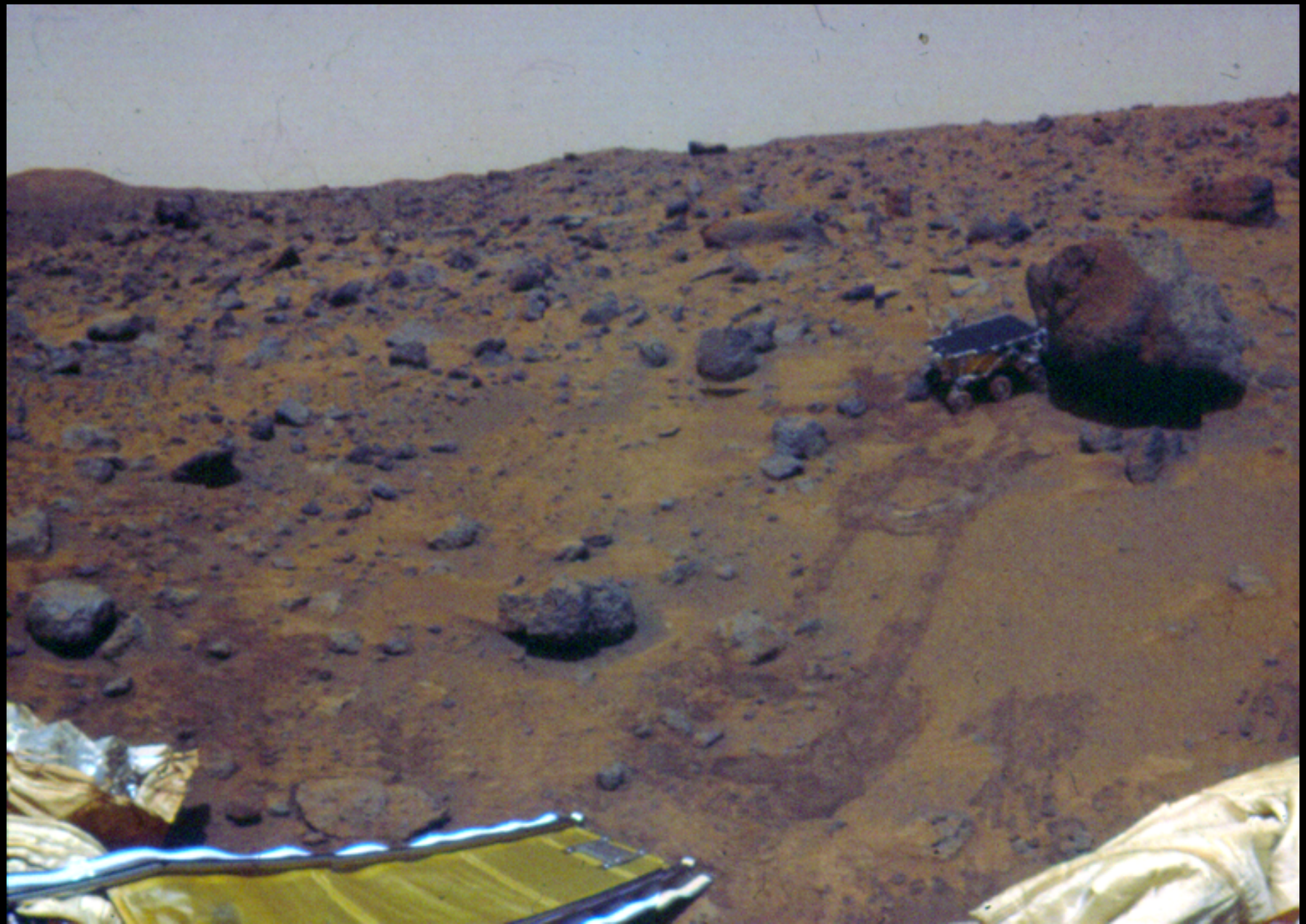



MIDDLE
BOTTOM
TOP
MARS PATHFINDER
MEASURED AIR TEMPERATURES
KELVIN
190
200
210
220
230
240
250
260
270
0
2
4
6
8
10
12
14

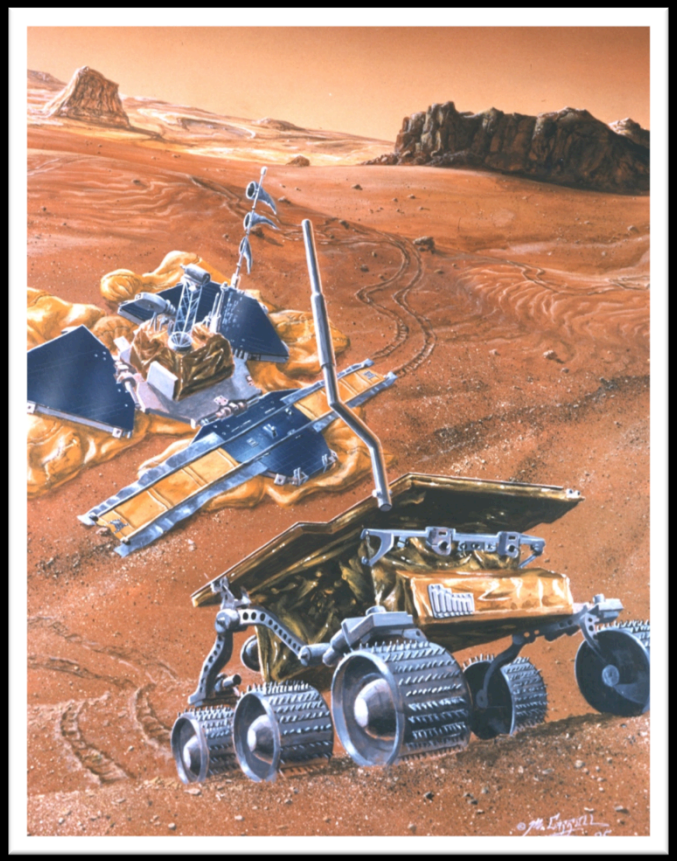

MARS PATHFINDER
MEASURED SURFACE PRESSURE
MILLIBARS
6.9
6.85
6.8
6.75
6.7
6.65
6.6
6.55
0
2
4
6
8
10
12
14

Sojourner

Sojourner at Yogi

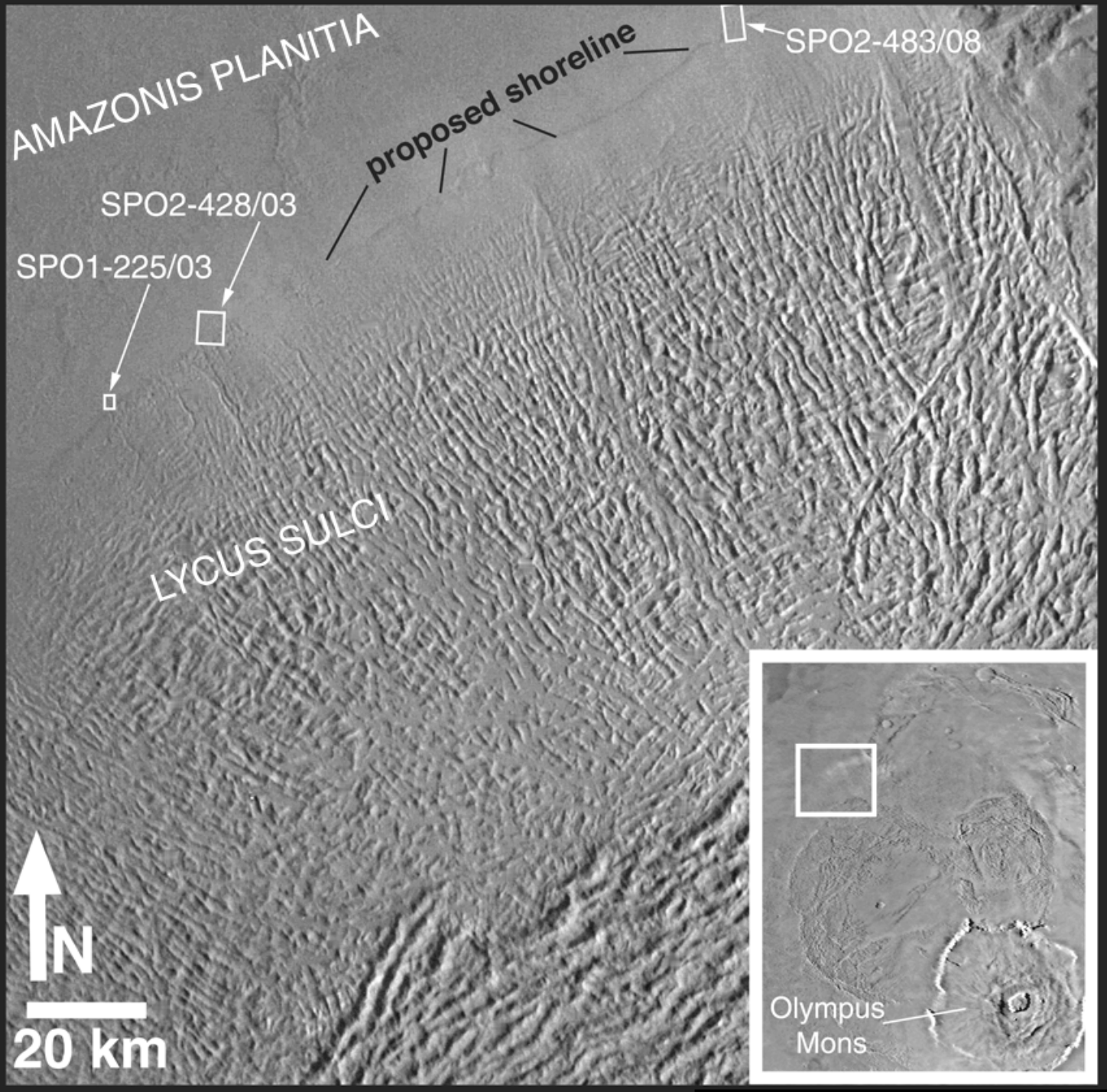


Pathfinder results

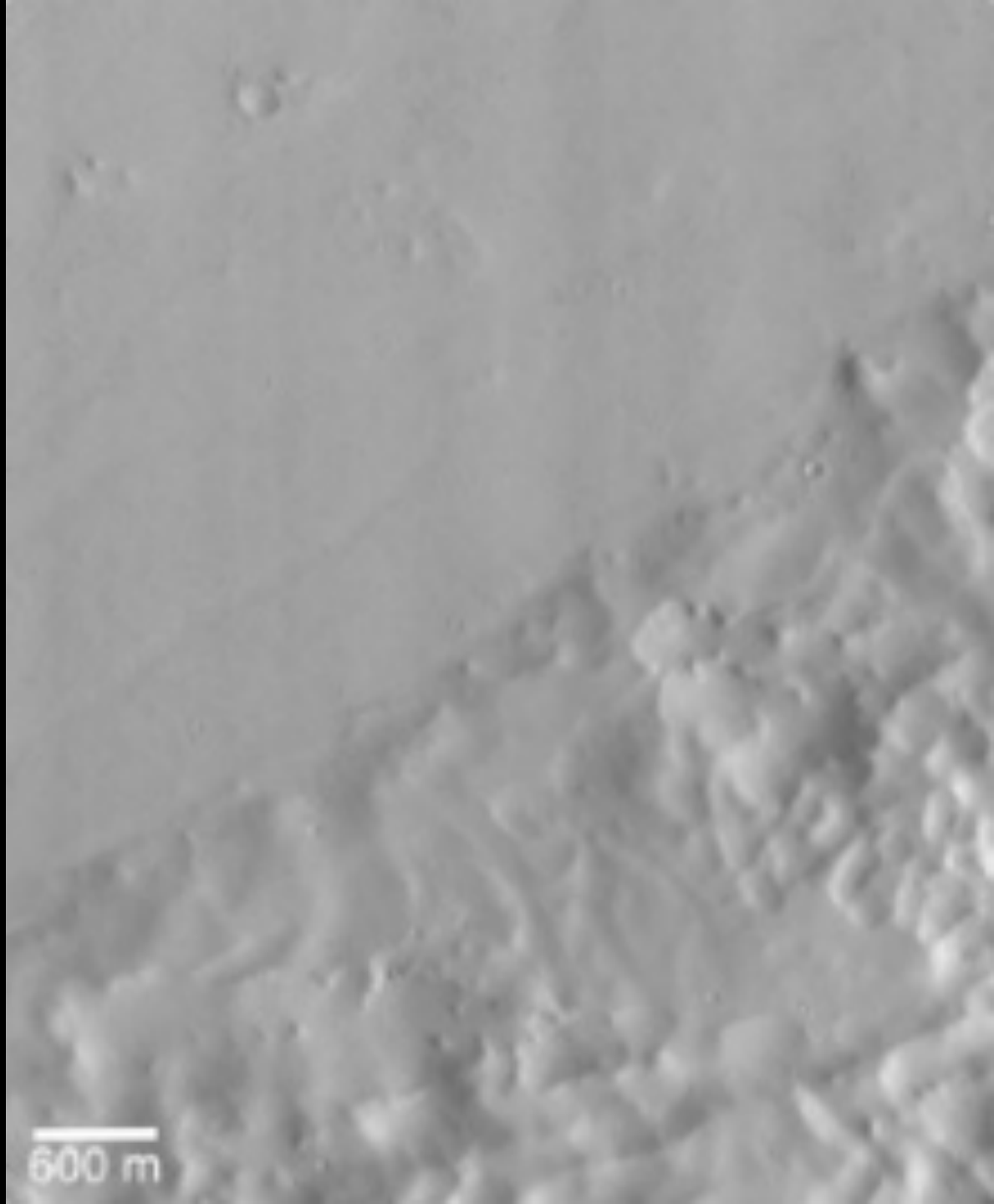


- Most rocks analyzed are basalt
- One is slightly more rich in silica
  - Could indicate tectonic activity?
  - Or could be a weathering effect

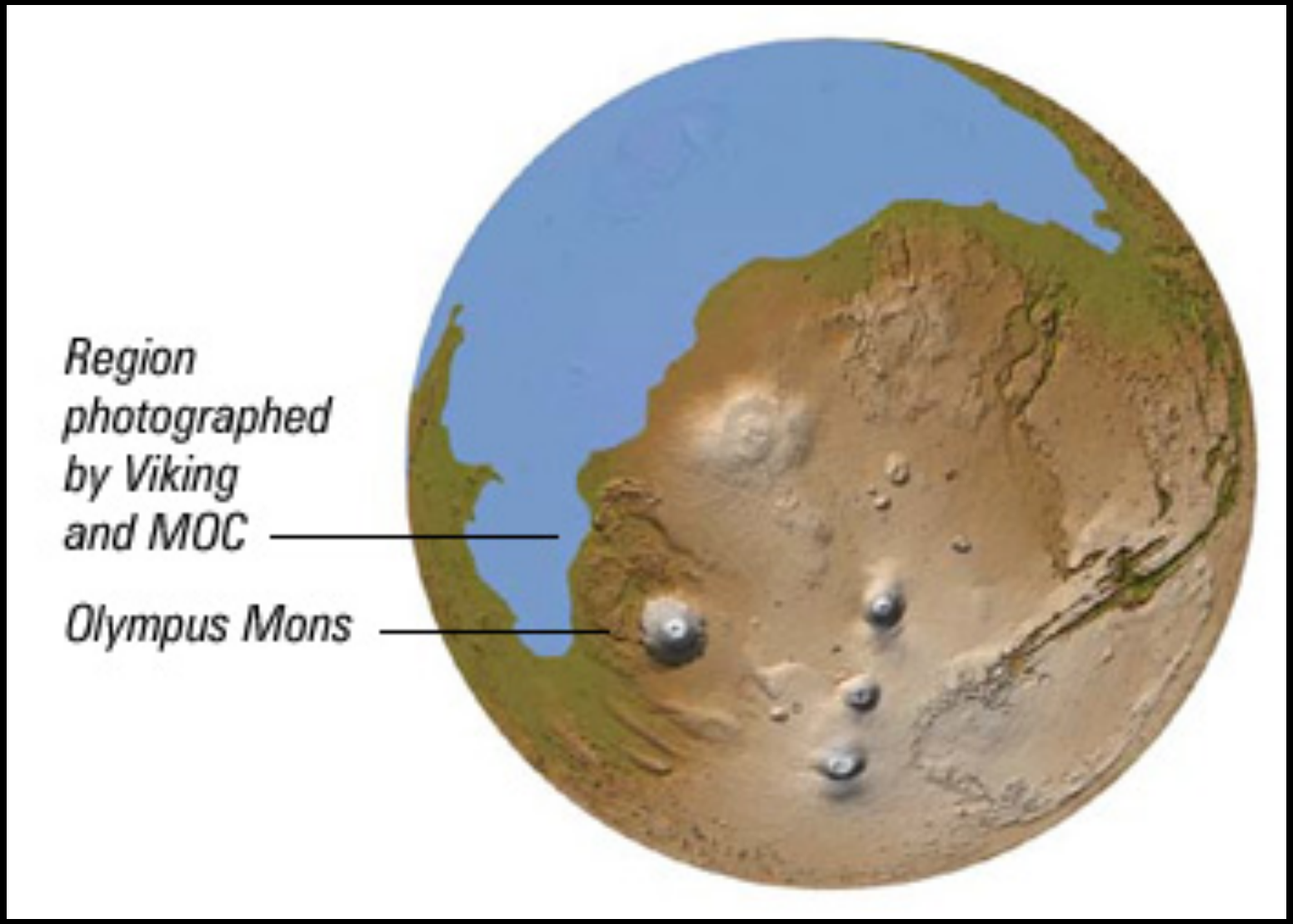
Ancient Martian Shoreline?



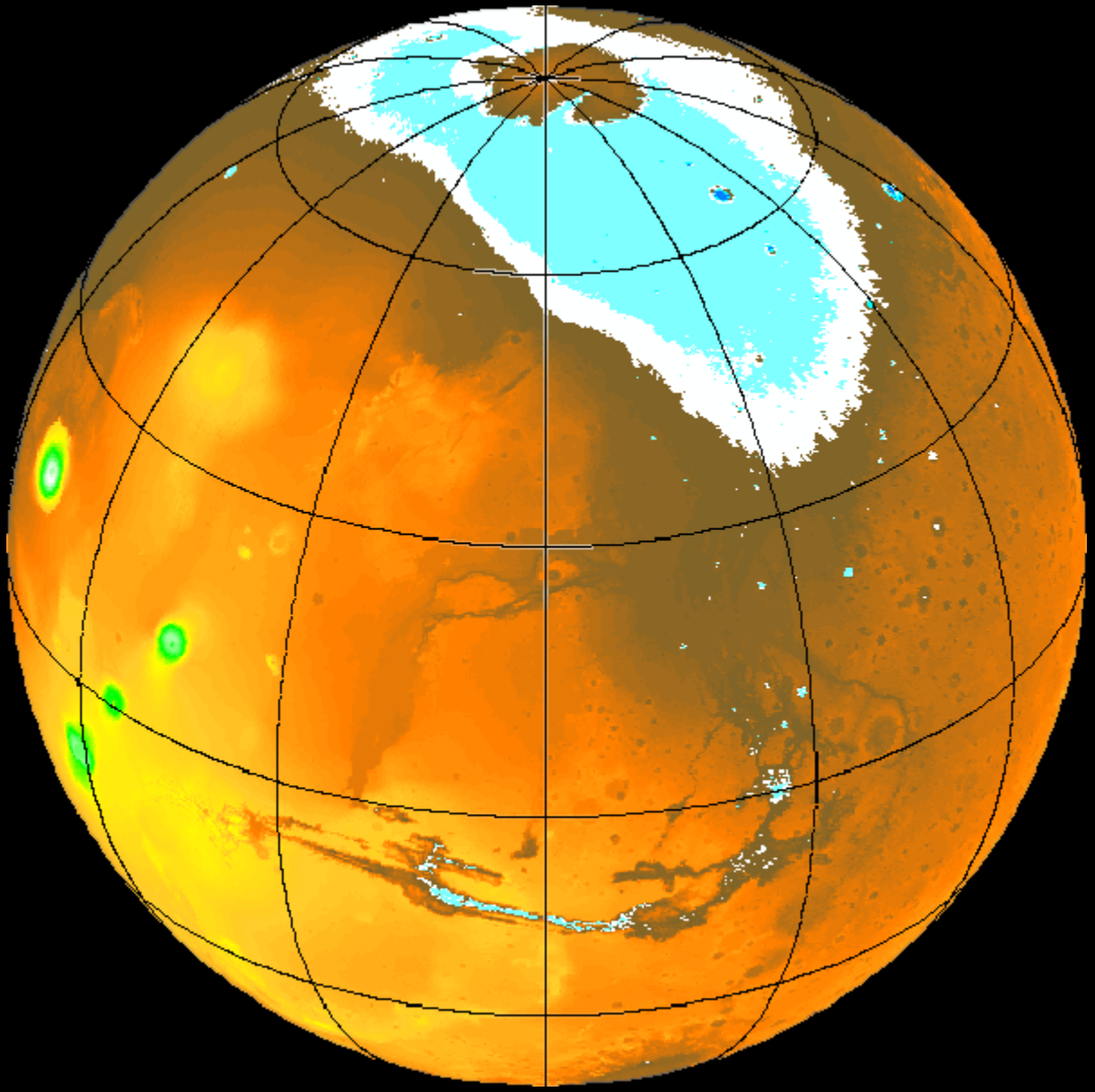
Shoreline? – Up Close and Personal



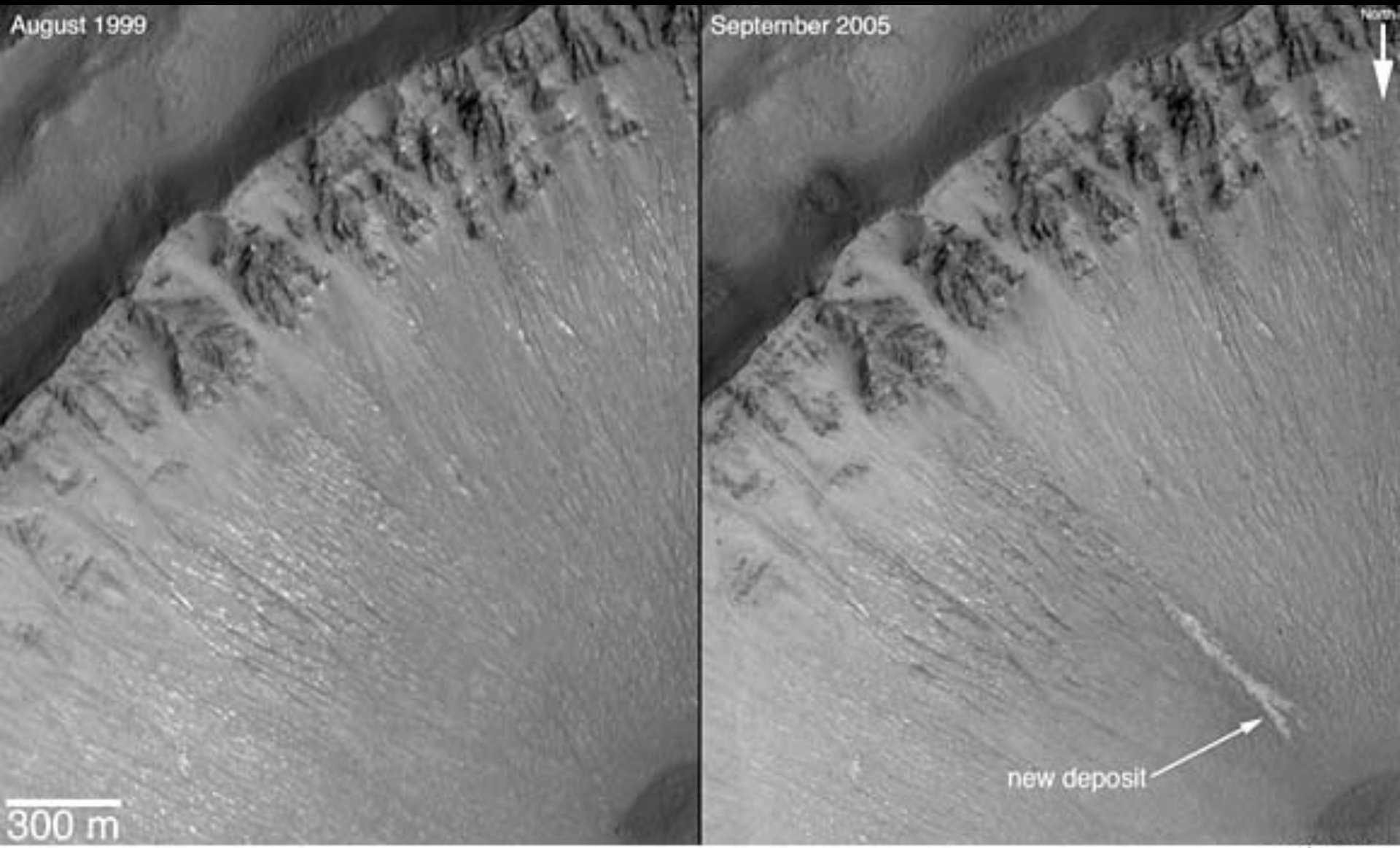
Martian Ocean?



The Drying of Mars



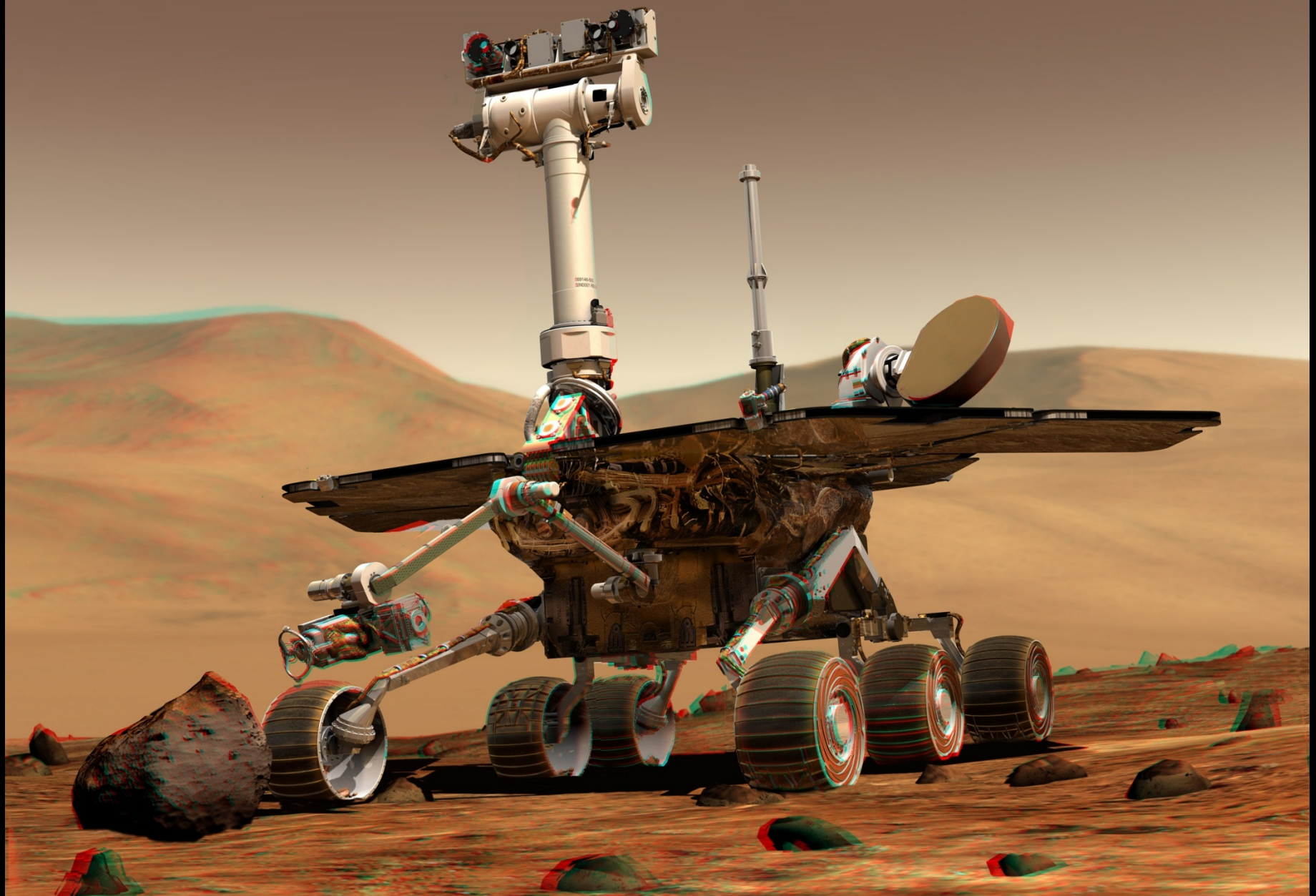
New Groundwater Flow?



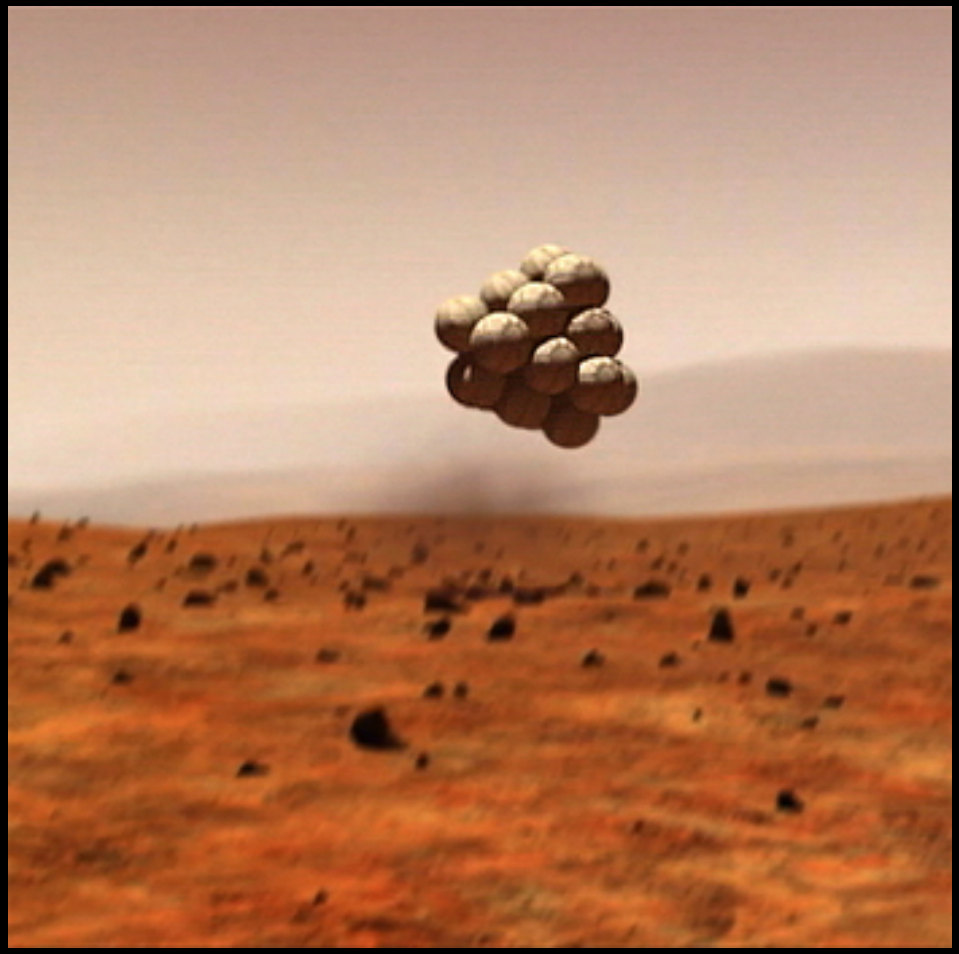
AP / NASA

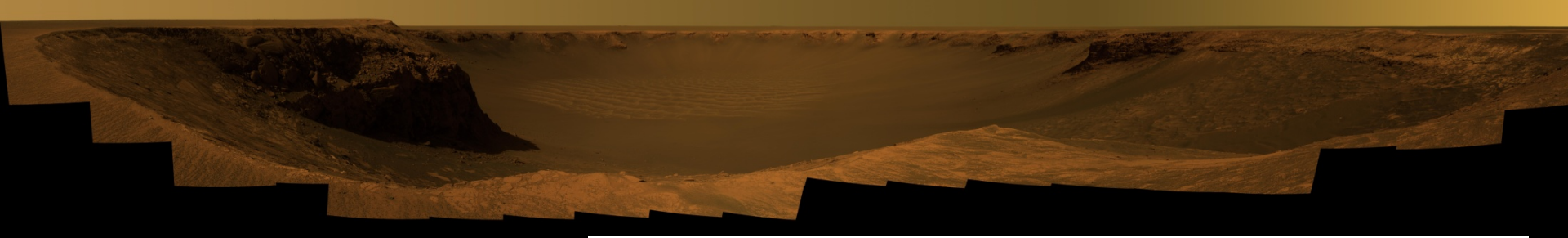
Martian Water Clouds

Mars Exploration Rover (in 3D!)



Spirit, Opportunity Landing Strategy

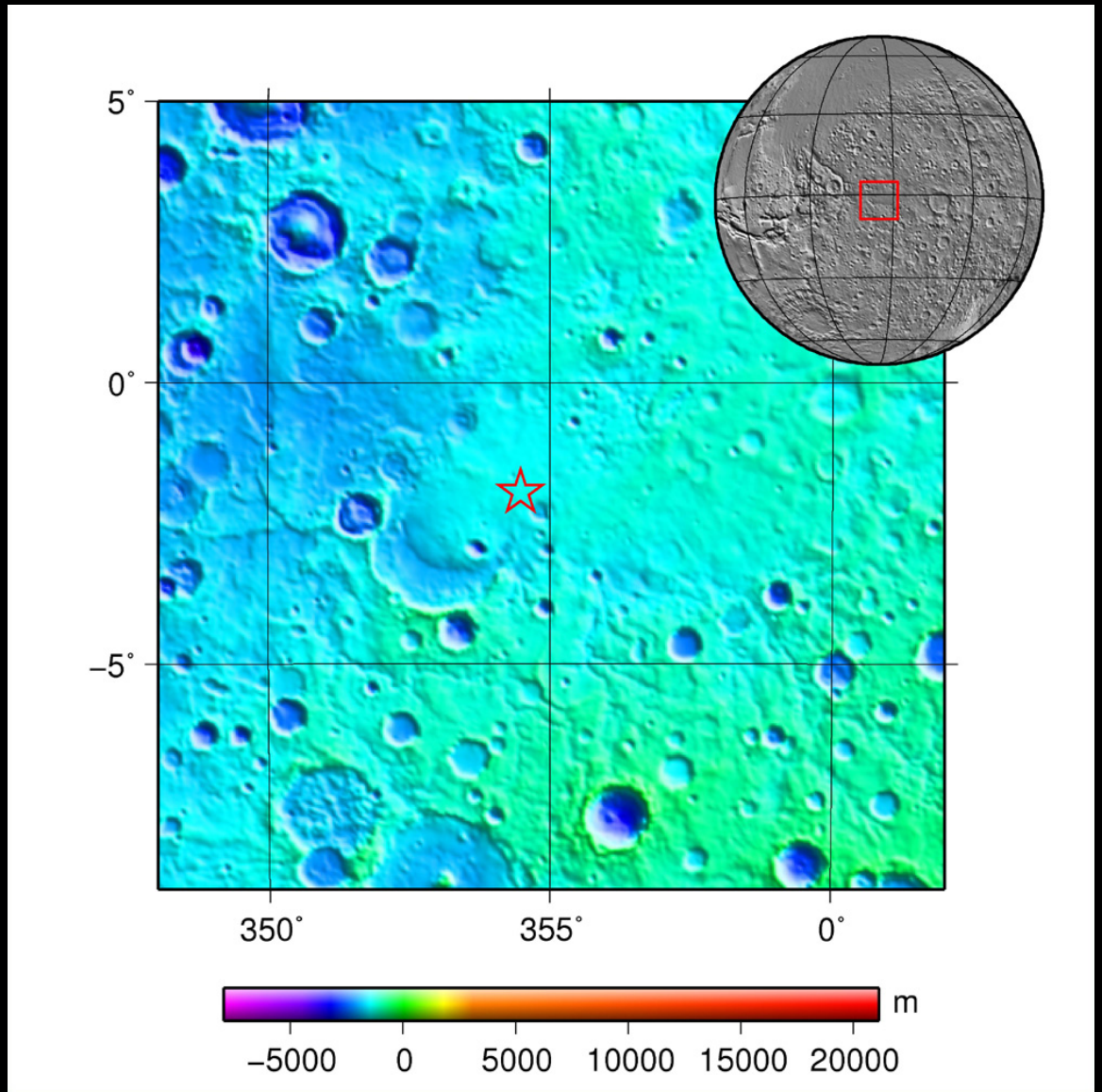




Opportunity Landing Site

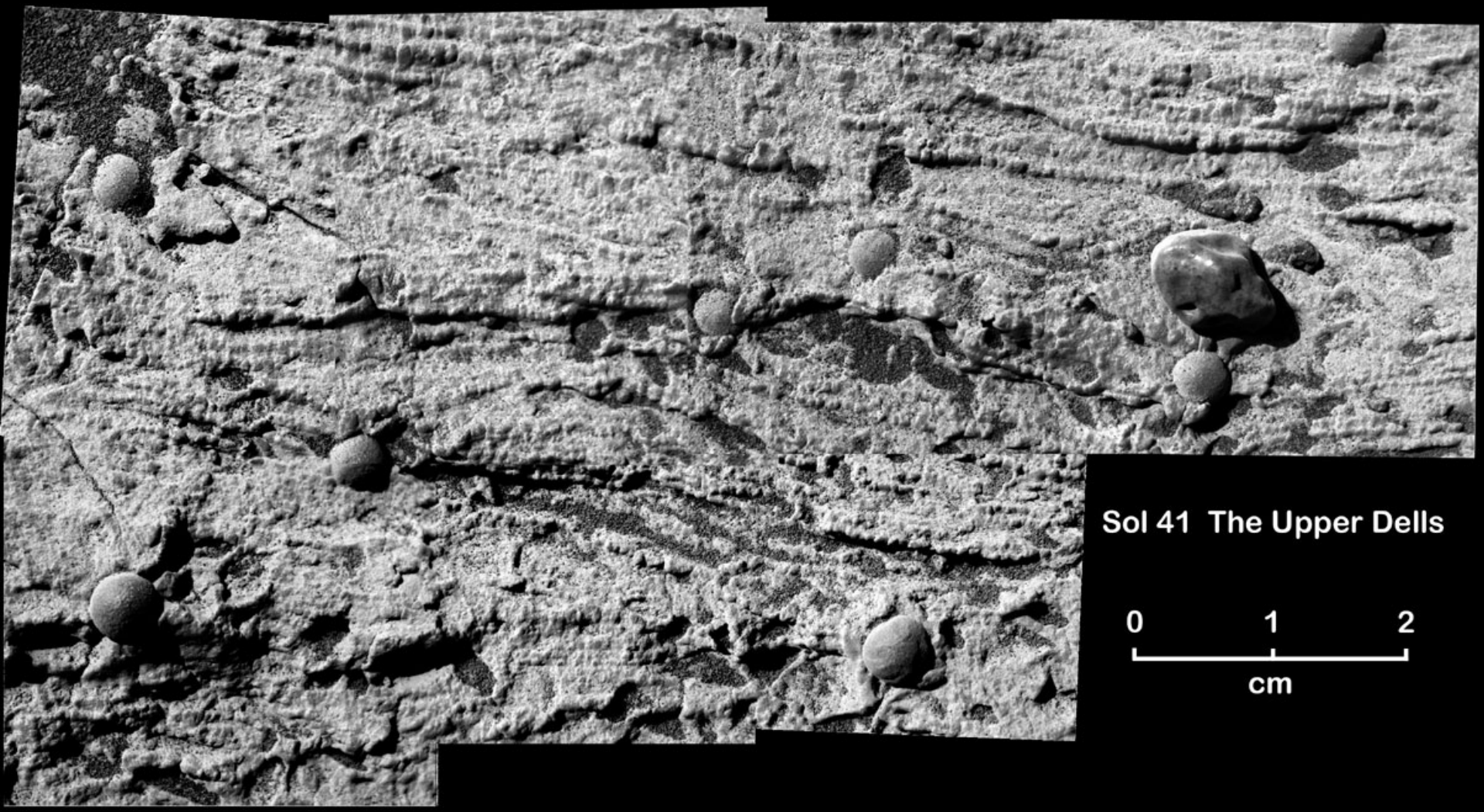
Victoria Crater Panorama

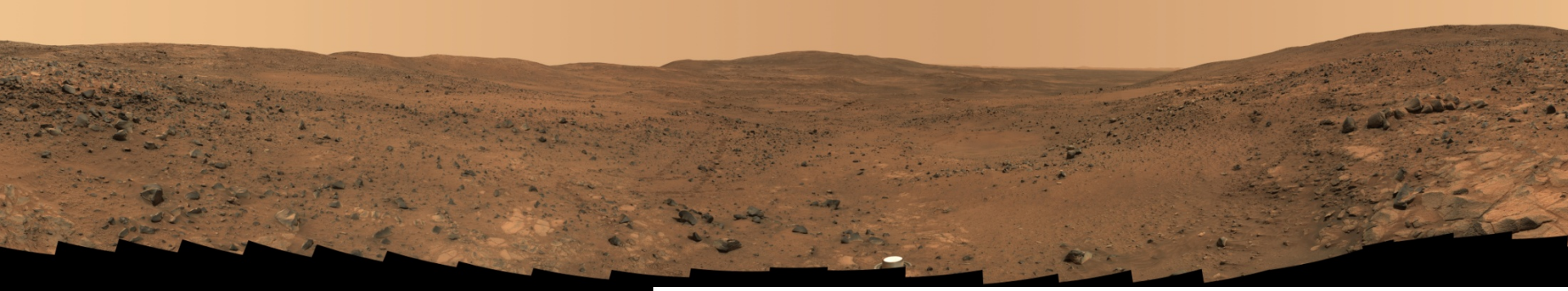
(Meridian Planum)



Erebus Crater (Opportunity)

Crossbeds and Blueberries (Opportunity)

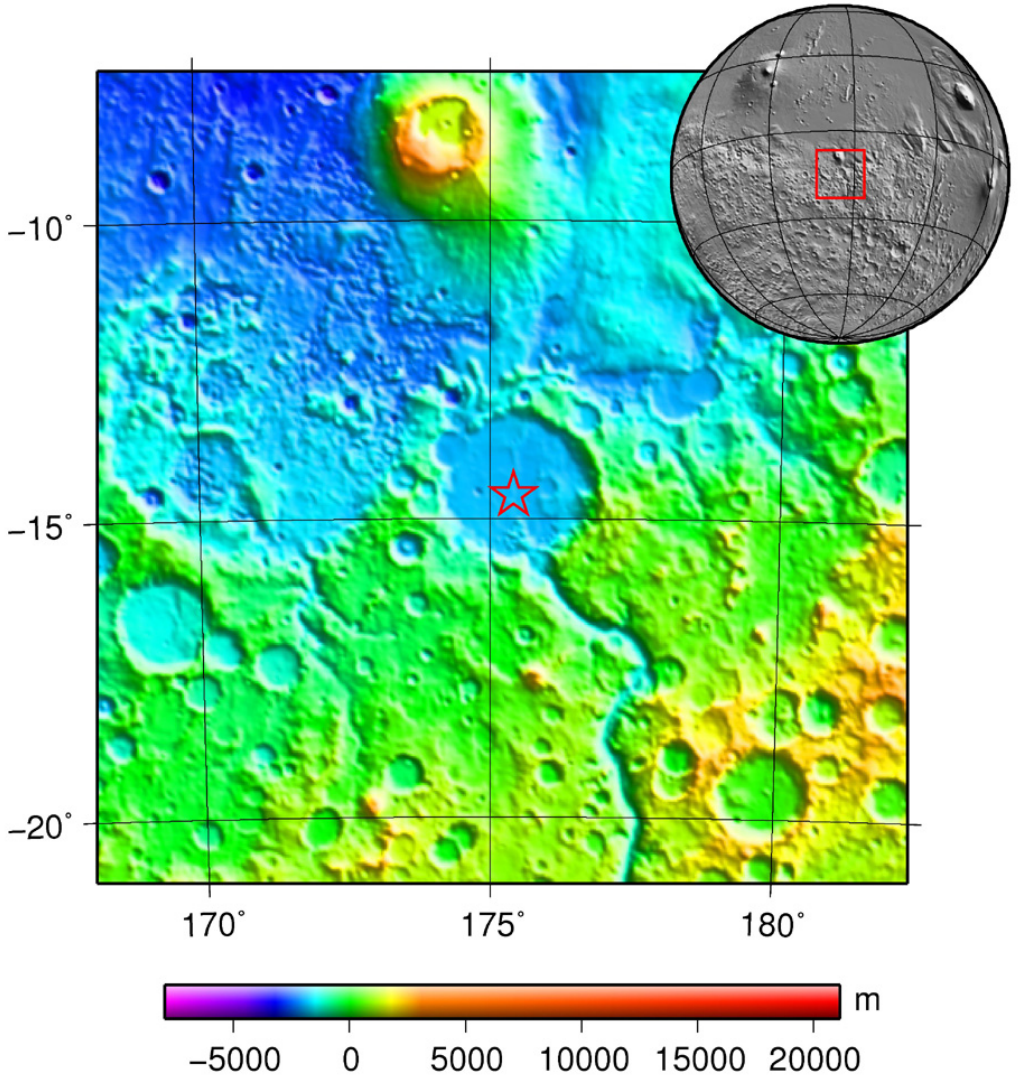




Spirit Landing Site

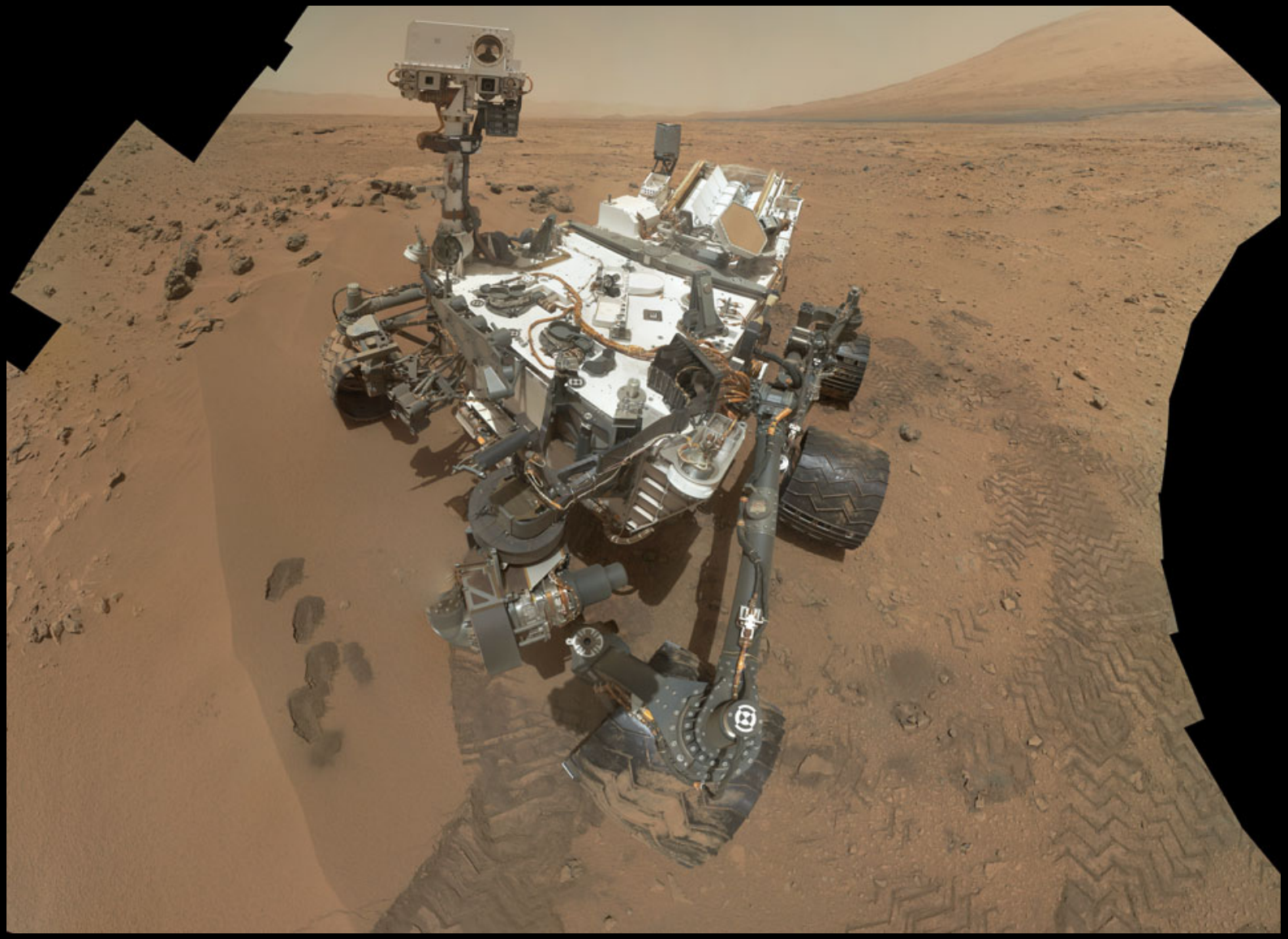
Husband Hill Panorama

(Gusev Crater)

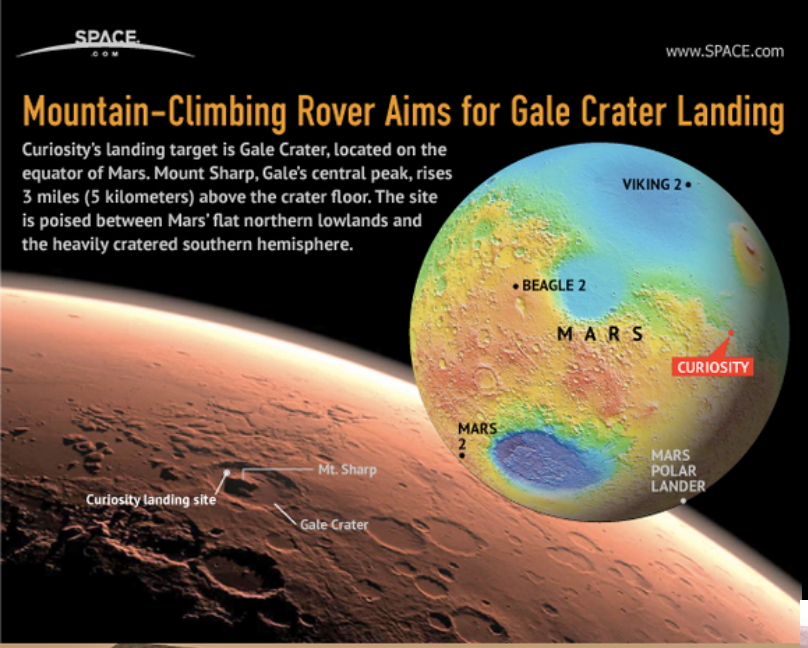


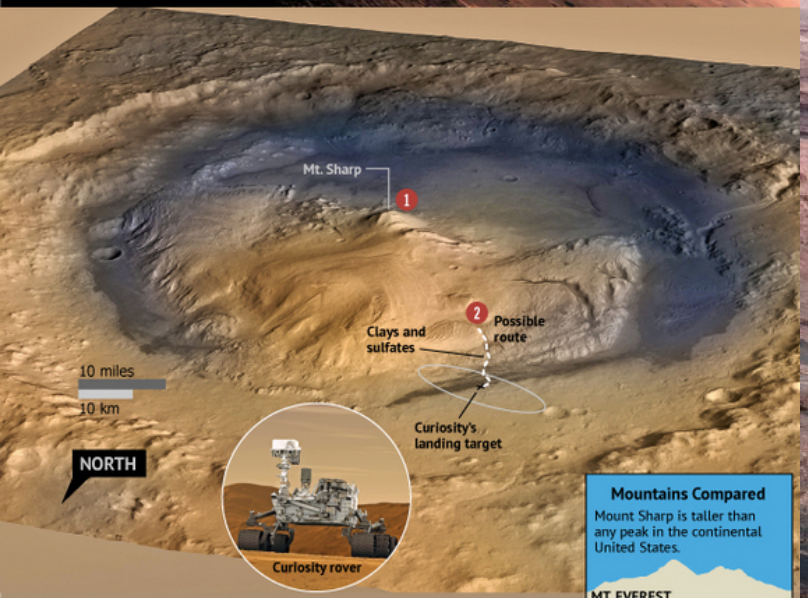

Rim of Victoria C
(S

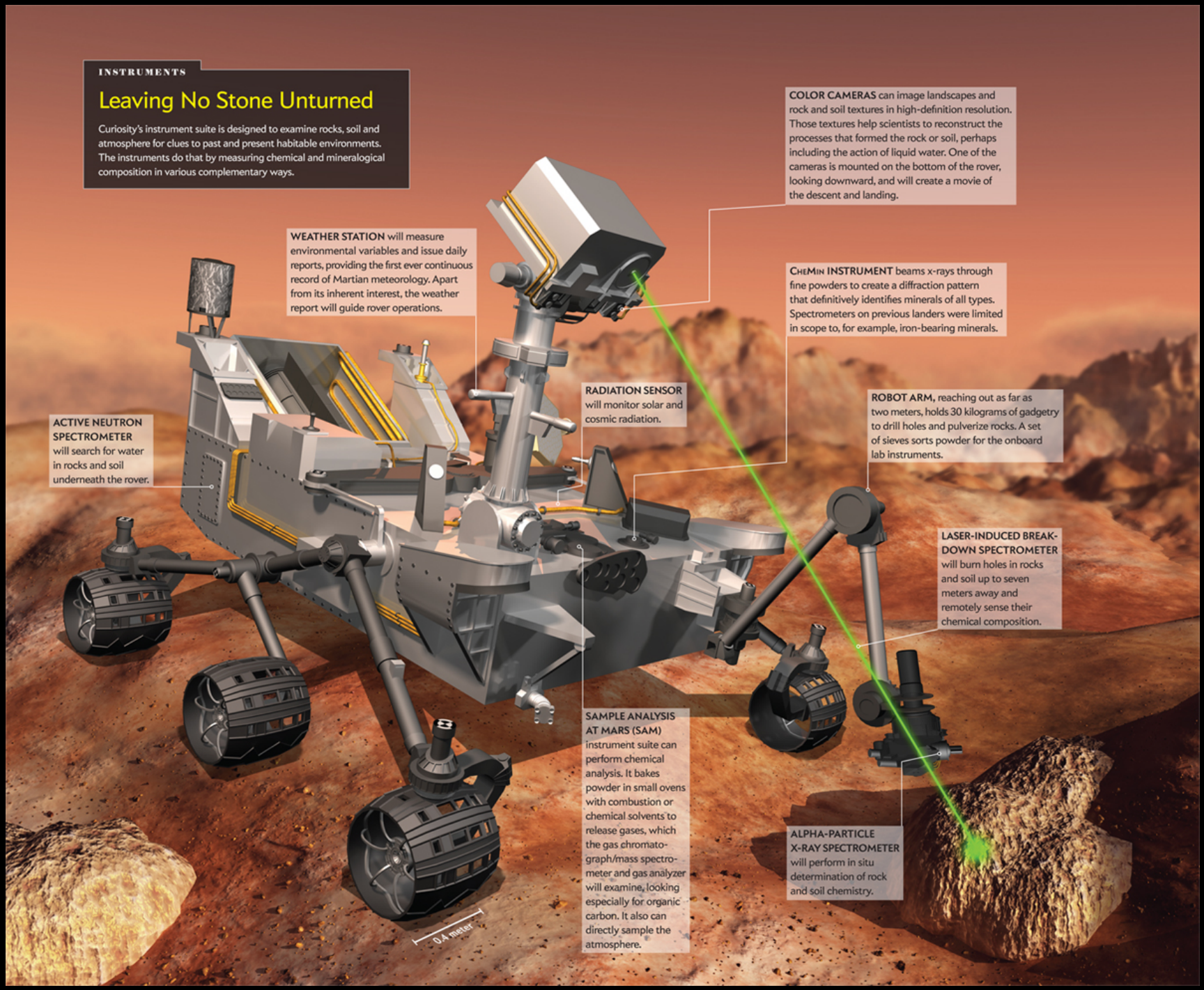
Curiosity



Curiosity Landing Site






INSTRUMENTS
Leaving No Stone Unturned
Curiosity's instrument suite is designed to examine rocks, soil and atmosphere for clues to past and present habitable environments. The instruments do that by measuring chemical and mineralogical composition in various complementary ways.
COLOR CAMERAS can image landscapes and rock and soil textures in high-definition resolution. Those textures help scientists to reconstruct the processes that formed the rock or soil, perhaps including the action of liquid water. One of the cameras is mounted on the bottom of the rover, looking downward, and will create a movie of the descent and landing.
WEATHER STATION will measure environmental variables and issue daily reports, providing the first ever continuous record of Martian meteorology. Apart from its inherent interest, the weather report will guide rover operations.
CHEMIN INSTRUMENT beams x-rays through fine powders to create a diffraction pattern that definitively identifies minerals of all types. Spectrometers on previous landers were limited in scope to, for example, iron-bearing minerals.
RADIATION SENSOR will monitor solar and cosmic radiation.
ROBOT ARM, reaching out as far as two meters, holds 30 kilograms of gadgetry to drill holes and pulverize rocks. A set of sieves sorts powder for the onboard lab instruments.
ACTIVE NEUTRON SPECTROMETER will search for water in rocks and soil underneath the rover.
LASER-INDUCED BREAK-DOWN SPECTROMETER will burn holes in rocks and soil up to seven meters away and remotely sense their chemical composition.
SAMPLE ANALYSIS AT MARS (SAM) instrument suite can perform chemical analysis. It bakes powder in small ovens with combustion or chemical solvents to release gases, which the gas chromato-graph/mass spectro-meter and gas analyzer will examine, looking especially for organic carbon. It also can directly sample the atmosphere.
ALPHA-PARTICLE X-RAY SPECTROMETER will perform in situ determination of rock and soil chemistry.
0.4 meter

Summary

- Mars may once have harbored an ocean
  - This would indicate a thicker, probably CO_2 atmosphere
- Mars used to have a magnetic field, and may have had something similar to plate tectonics
- Mars may have been very much like Earth 3.5 billion years ago, when life was beginning

Evidence for (really old, really tiny) Martians?

Conclusions

- Mars may have been very Earth-like when life was beginning on Earth
  - Could life have begun on Mars?
- There is still H_2O (as ice and vapor) on Mars, and may still exist (albeit briefly, perhaps) today
  - Could there be Martians living today?

Sunset over Mars (Spirit)

MAVEN Launch – November 18, 2013

Mars Atmosphere and Volatile EvolutioN