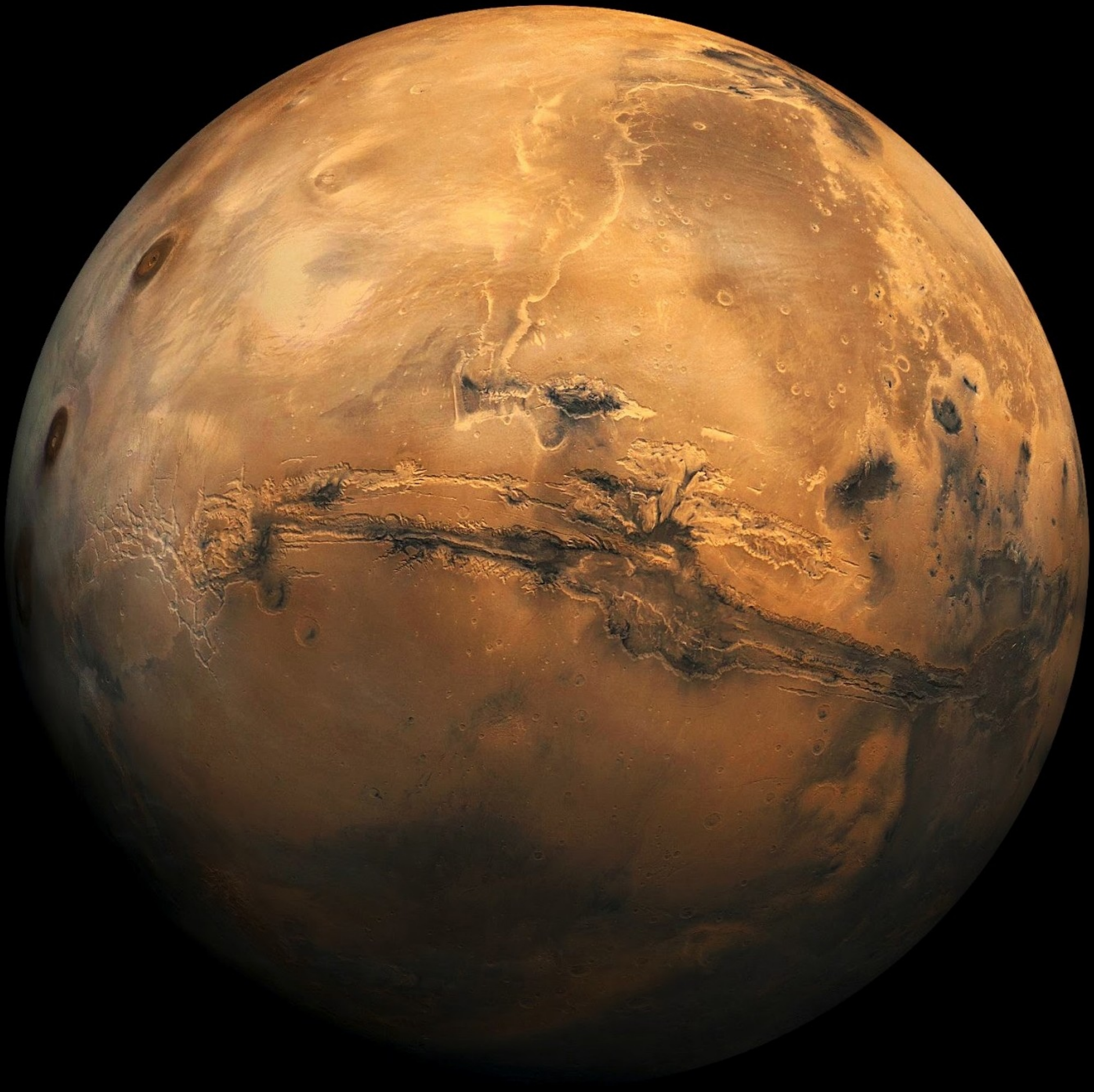
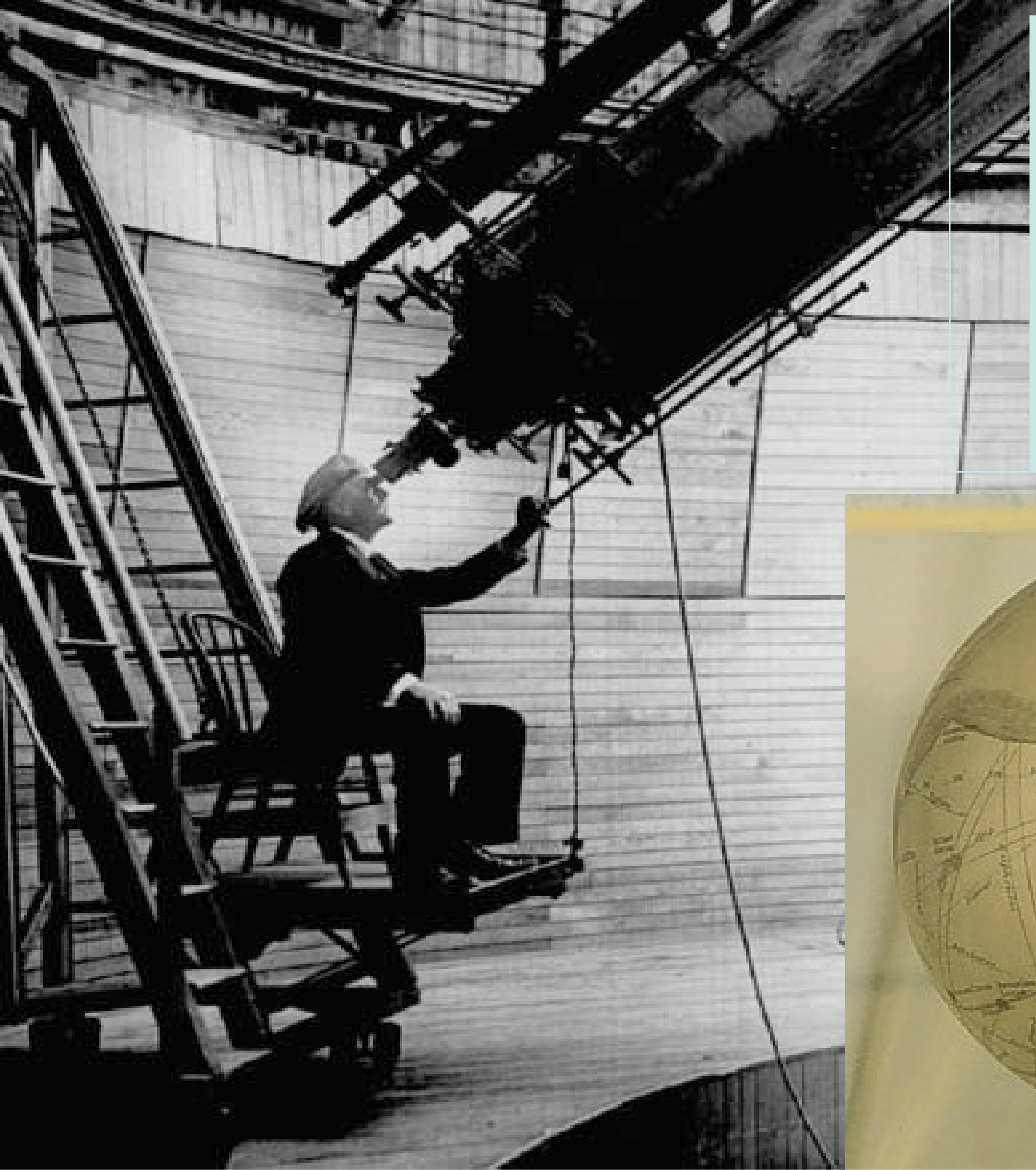


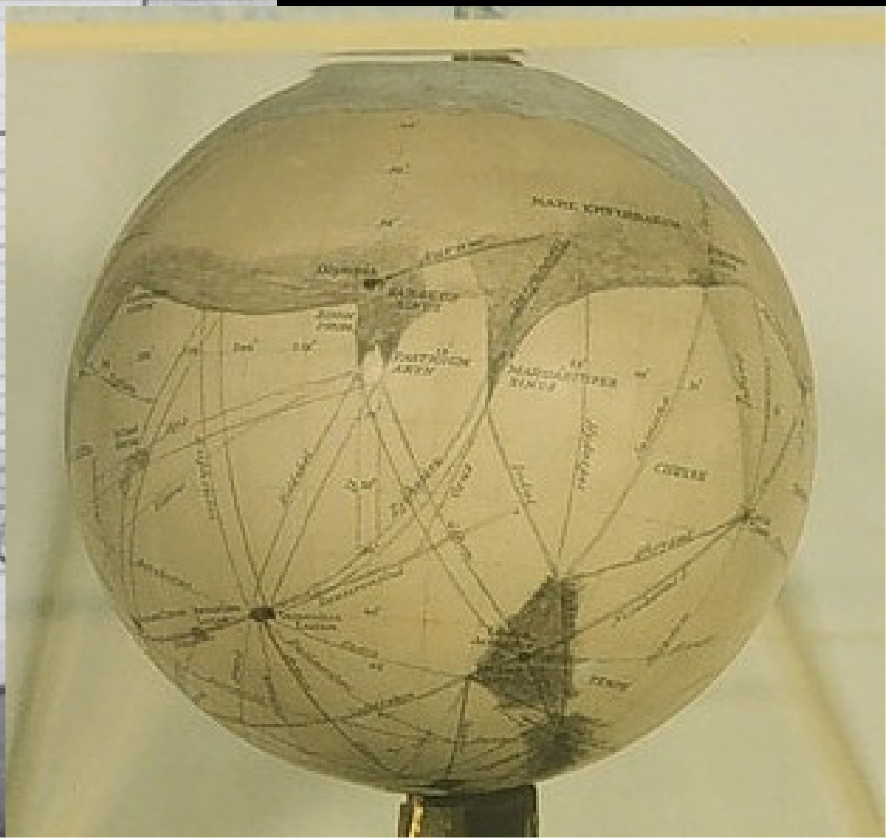
Mars Mysteries

Donna M. Jurdy
Earth & Planetary Sciences
Northwestern University



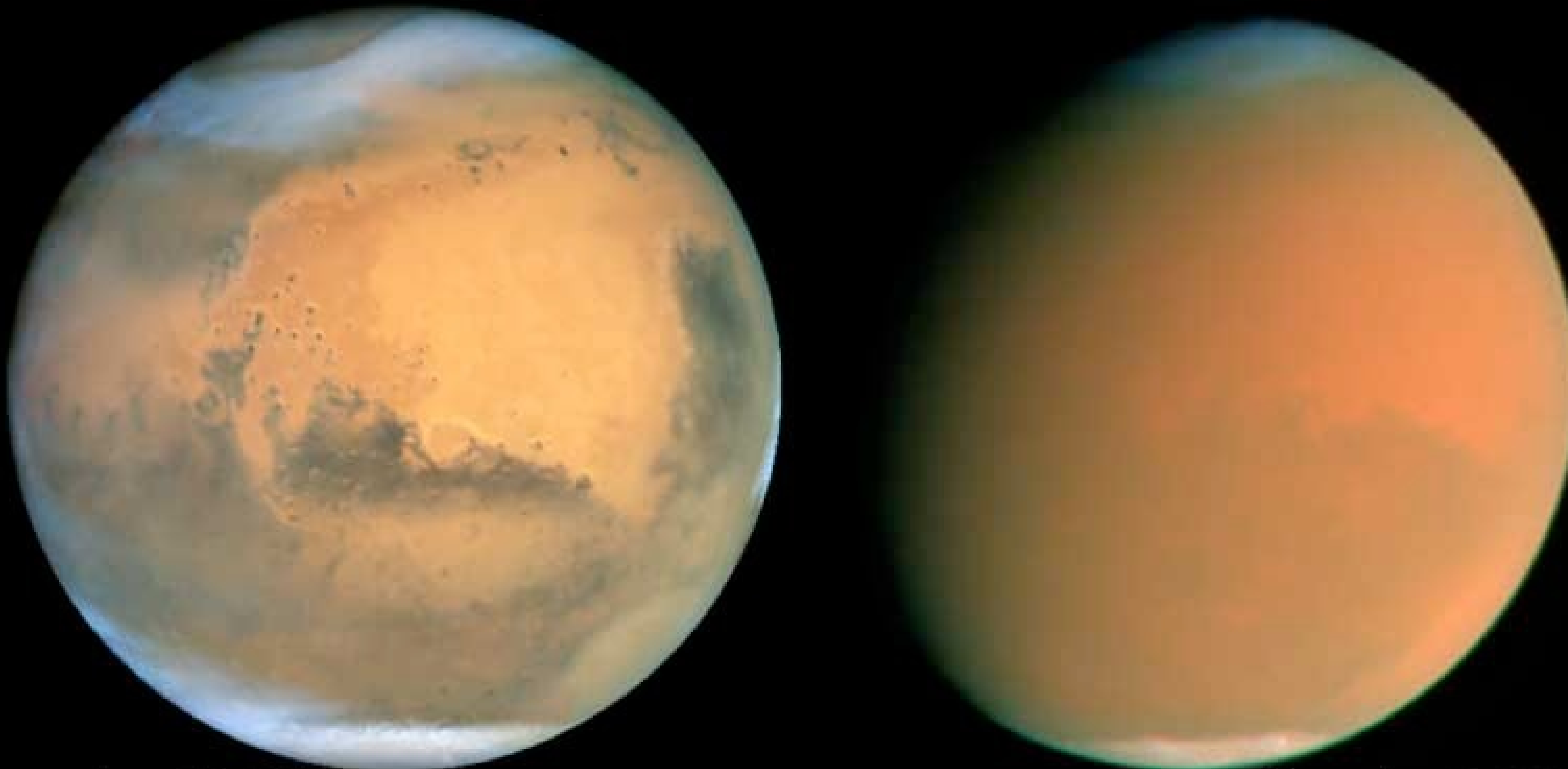
PERCIVAL LOWELL
at his 24” Refractor,
Flagstaff, Arizona observing
Mars during the favorable
perihelic opposition, 1894.

Below, a globe constructed
from his sketches.



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

Mars • Global Dust Storm

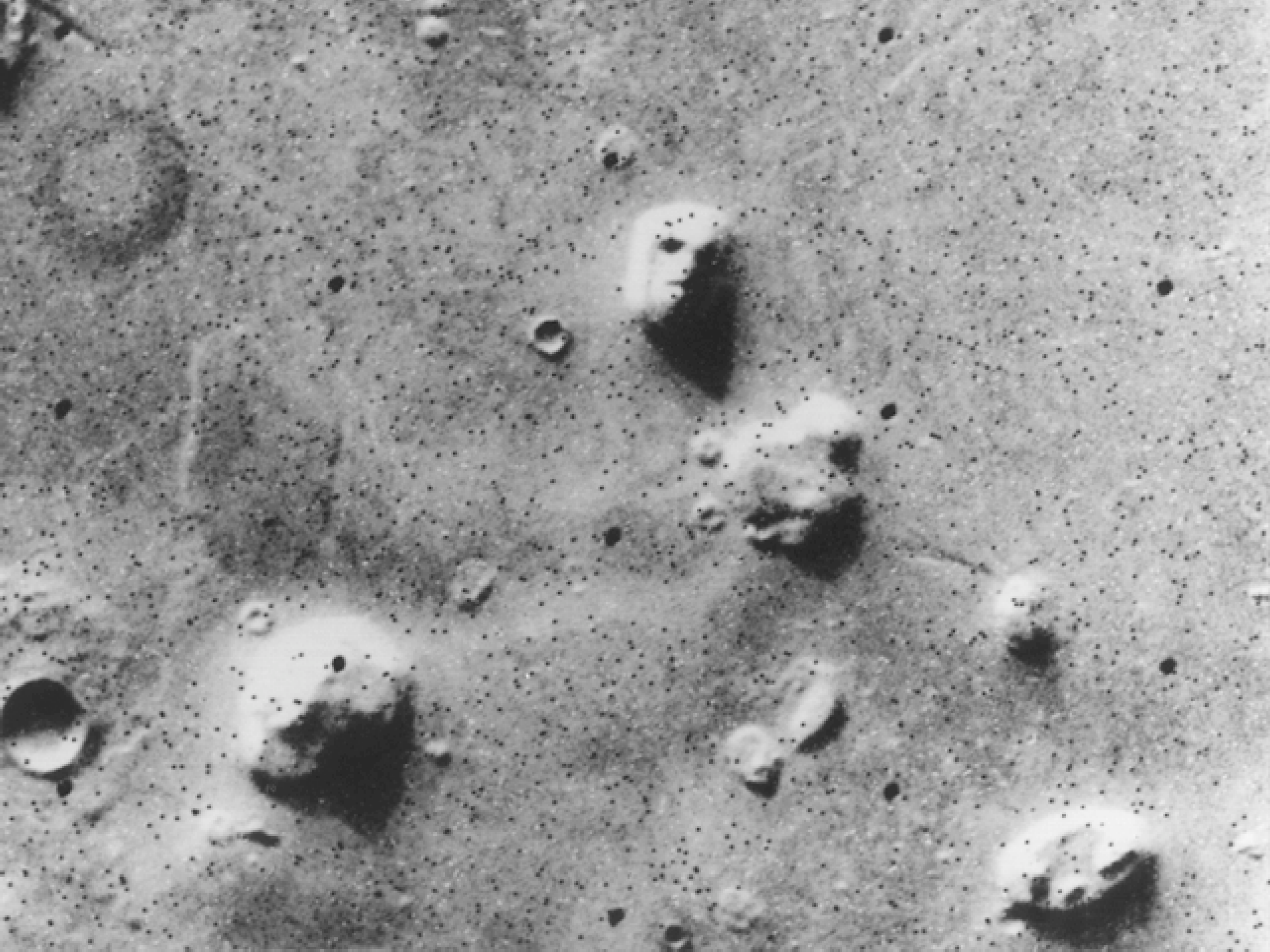


June 26, 2001

September 4, 2001

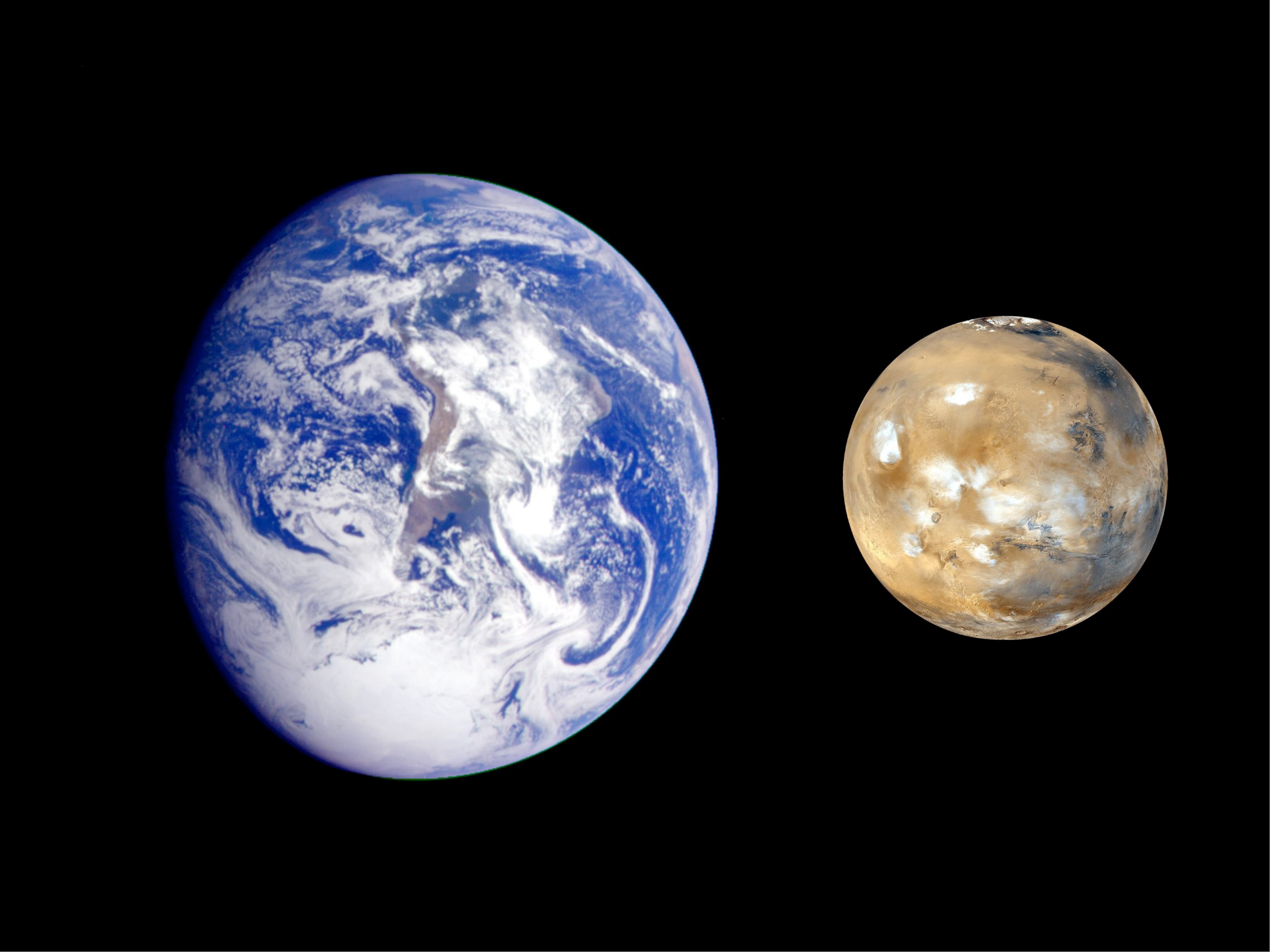
Hubble Space Telescope • WFPC2

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

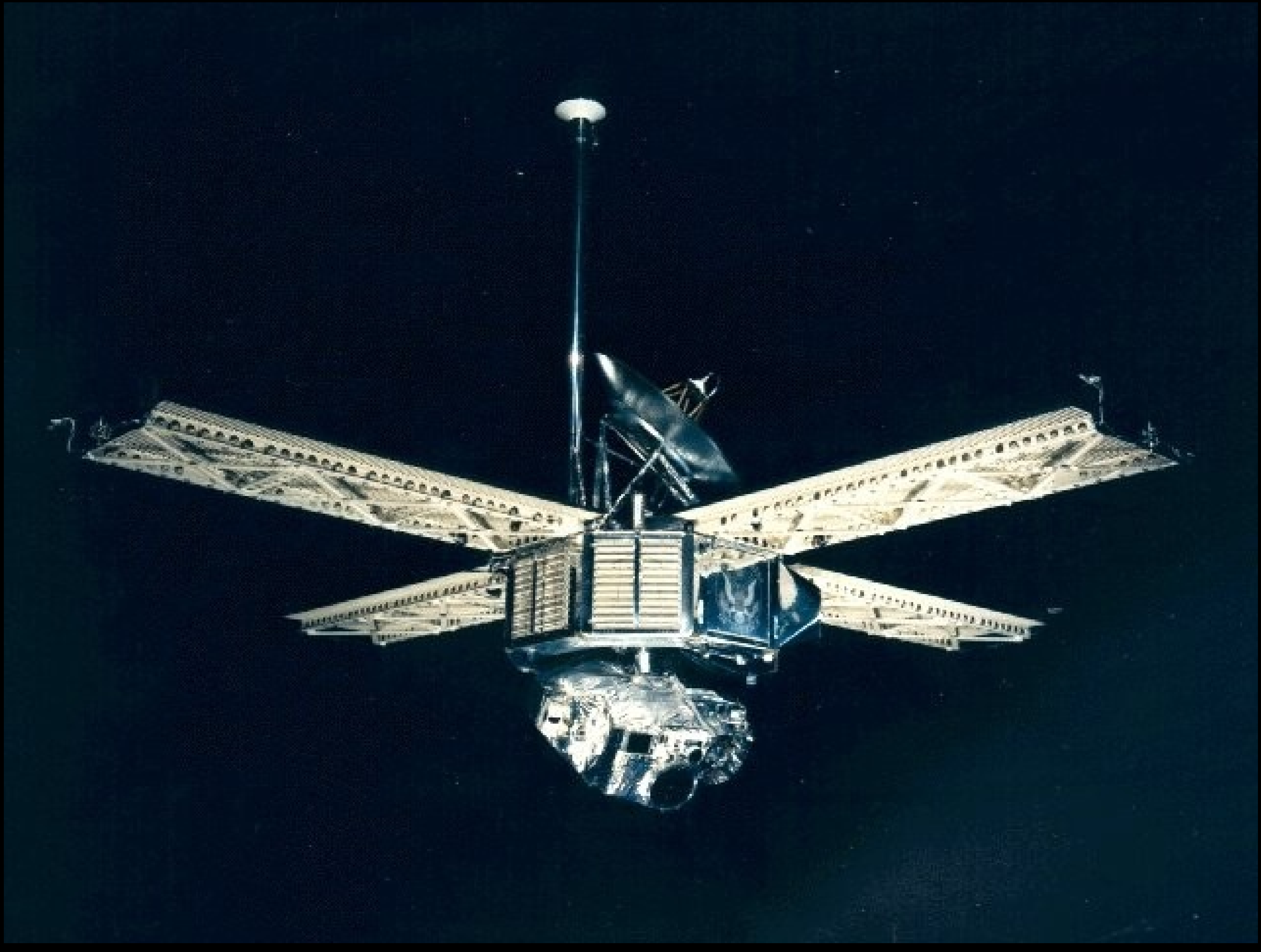


When is a face not a face?

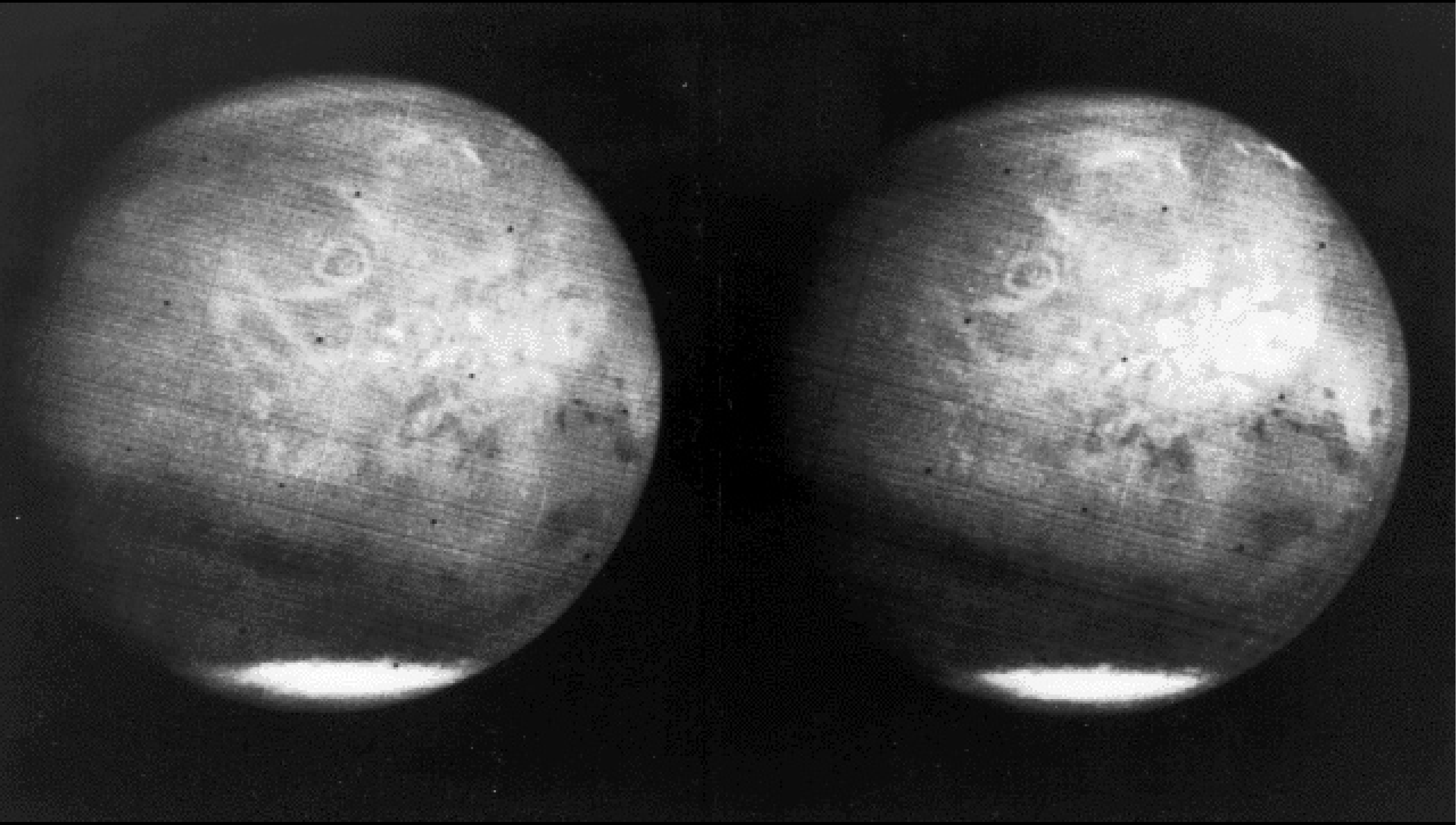
	Mercury	Venus	Earth	Moon	Mars
Radius (km)	2439	6052	6378	1738	3398
Mass (kg)	3.30×10^{23}	4.87×10^{24}	5.98×10^{24}	7.35×10^{22}	6.42×10^{23}
Density (kg/m^3)	5420	5250	5520	3340	3940
Distance from the Sun (A.U)	0.387	0.723	1.000	---	1.524
Mean Surface Pressure (bars)	---	92	1	---	0.006
Mean Surface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



Mariner 7 1969



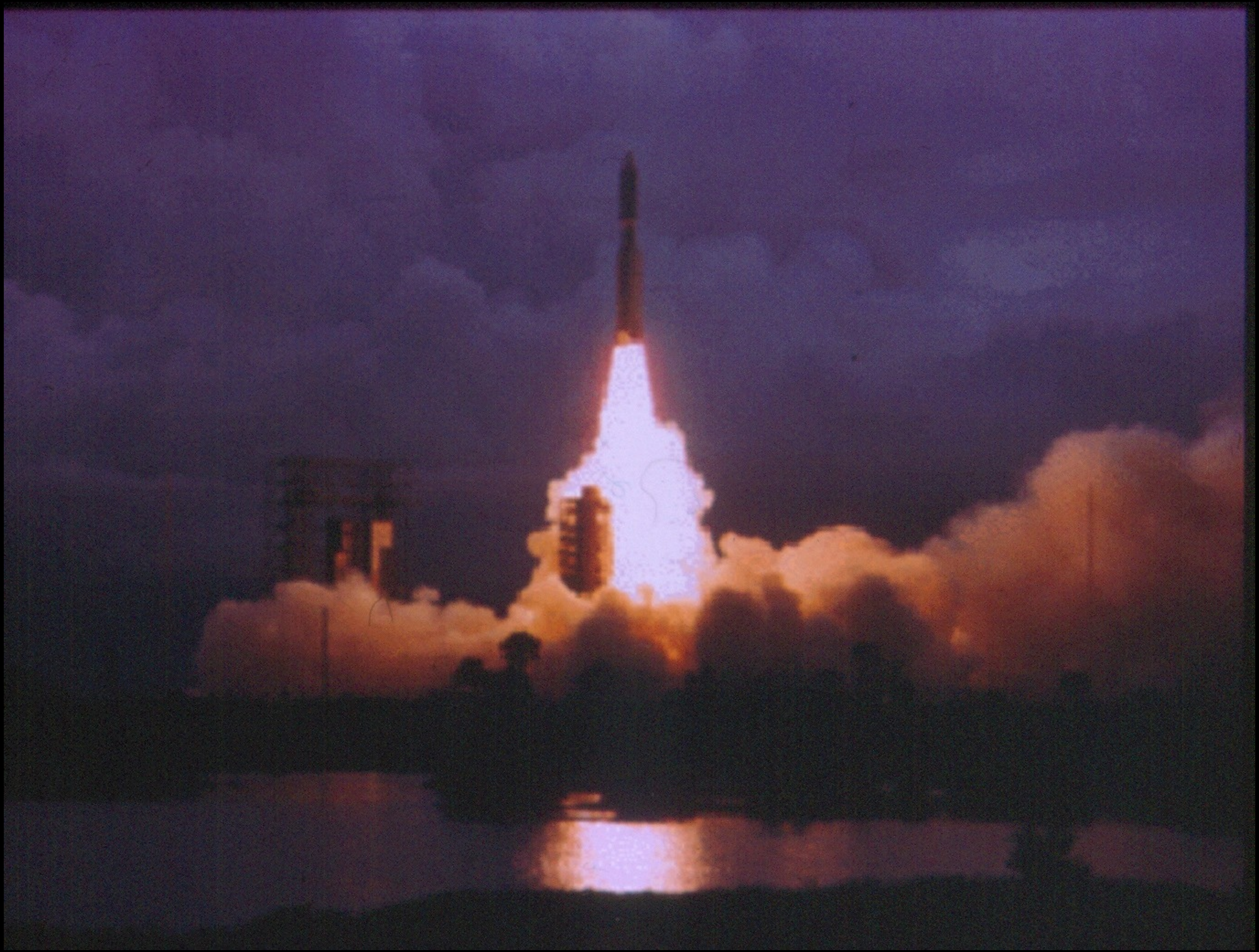
Mariner 7 Approaches Mars



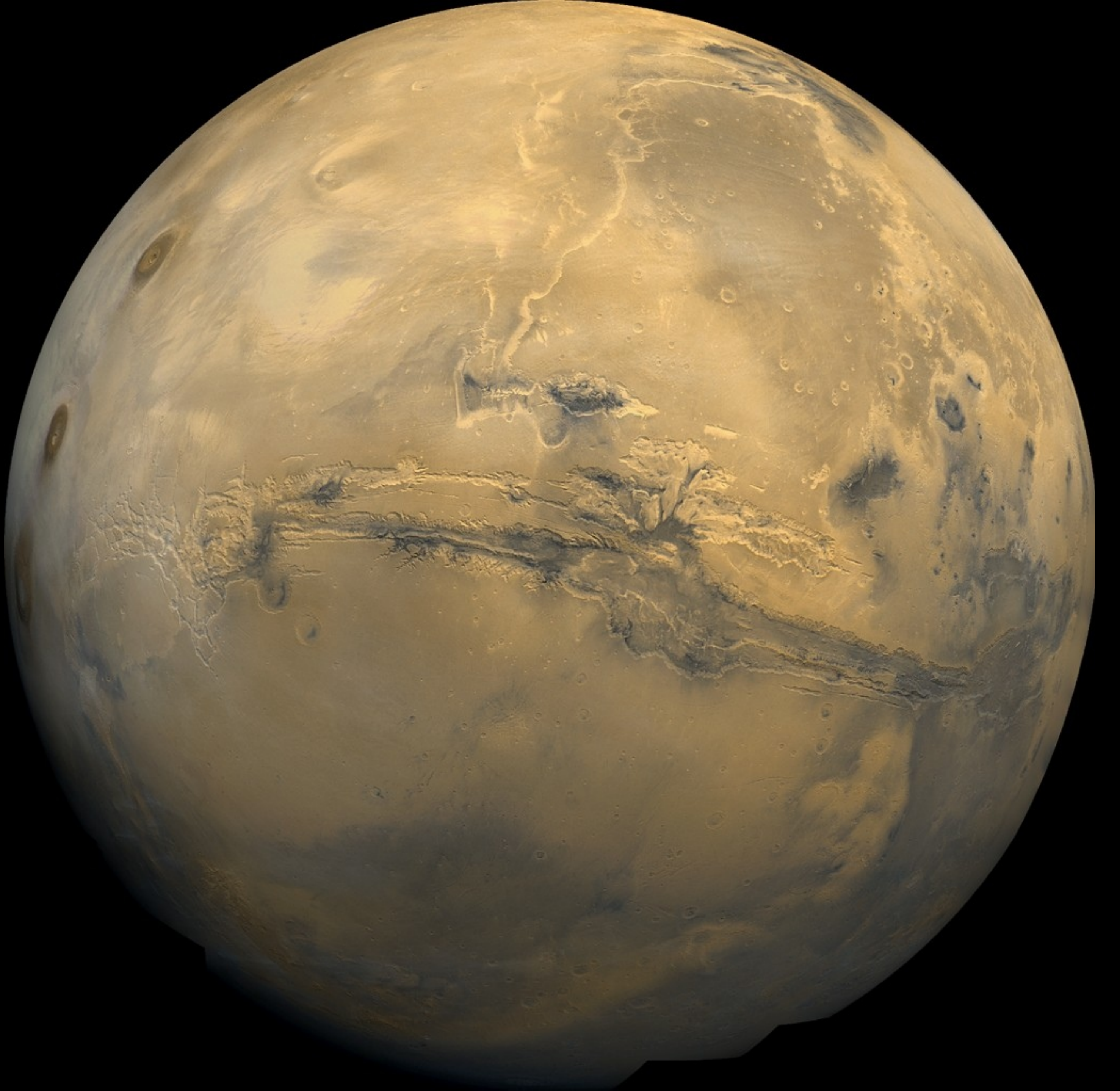
Olympus Mons, as seen from Mariner 9 (1971)

Olympus Mons Caldera

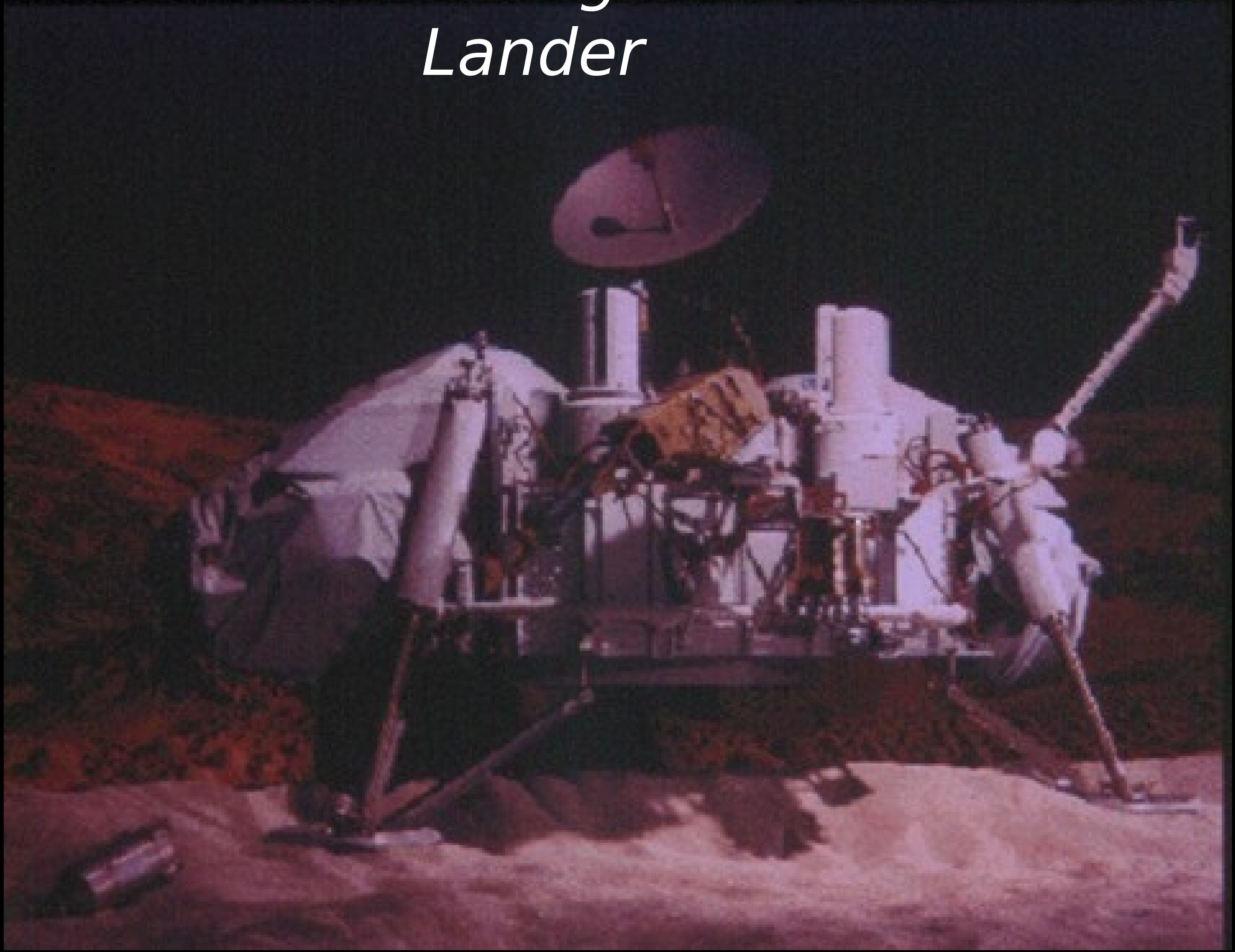
Viking 2 Liftoff - Sept 5, 1975



Composite image
of Mars
taken by small
telescopes
onboard the 2
Viking Orbiters
Mid 1970's



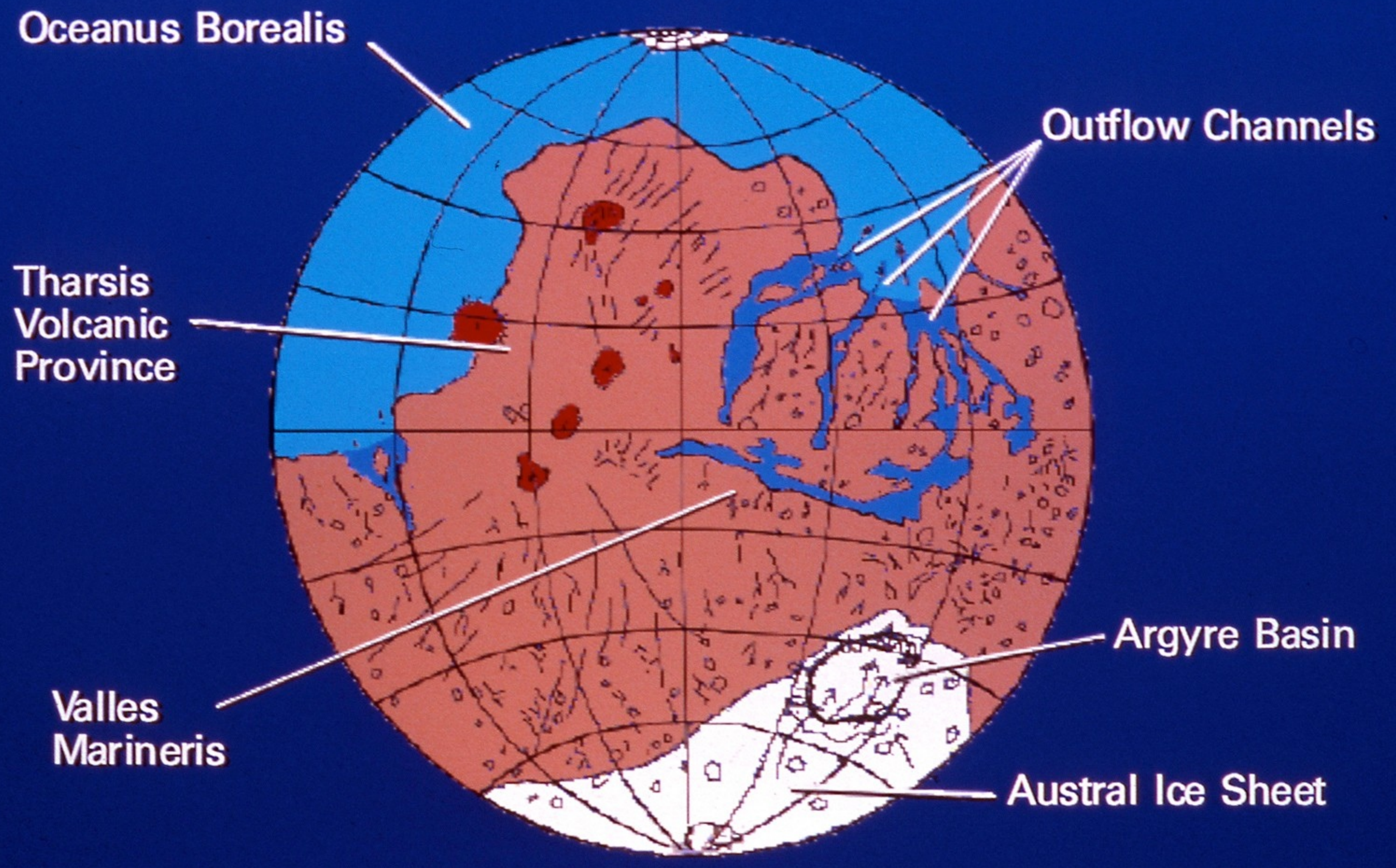
Viking Lander



Viking 2 Landing Site (Sept 1976)

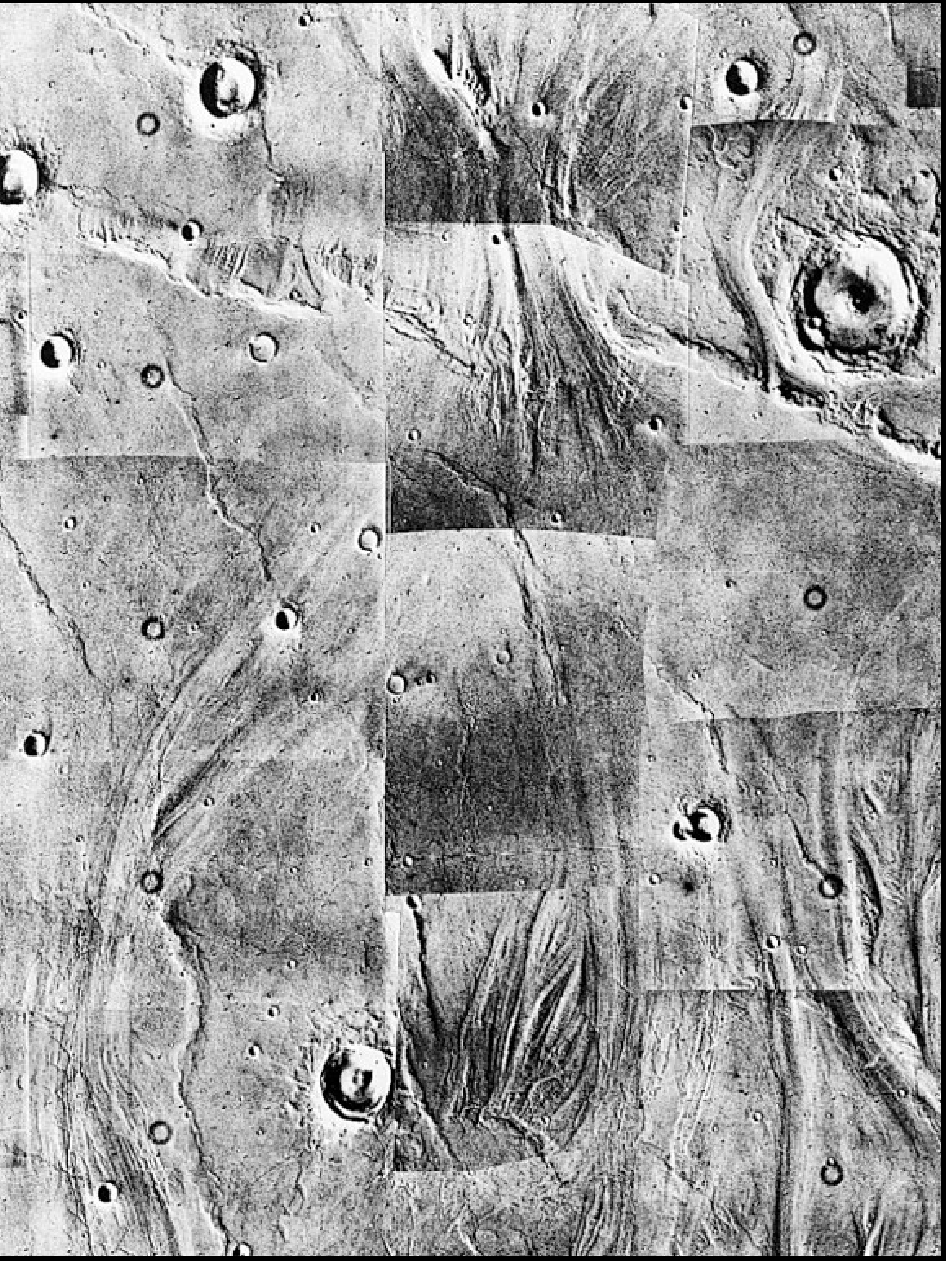
Evidence for (really old, really tiny) Martians?

Mars Oceans



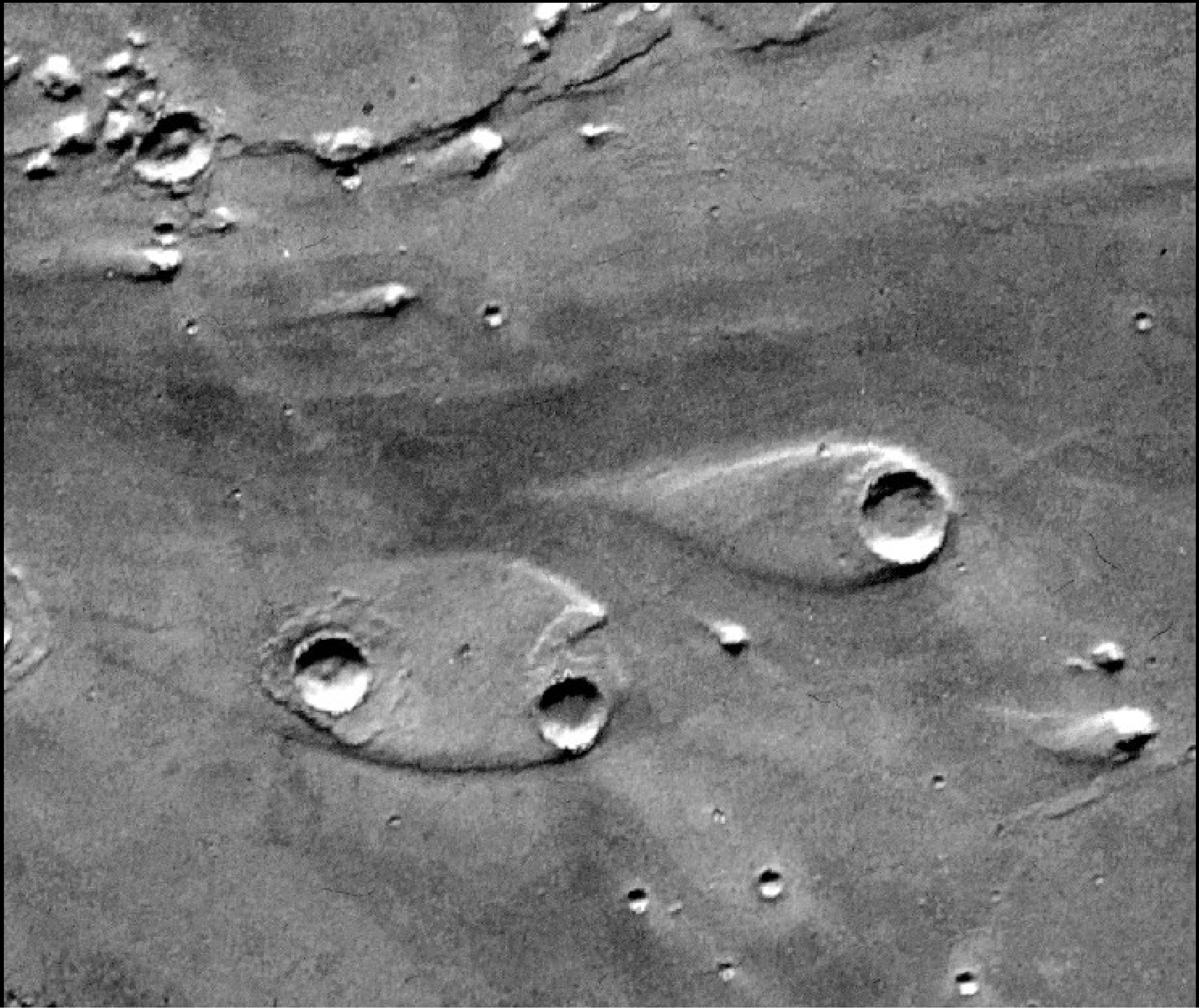
Oceanus Borealis
Outflow Channels
Tharsis Volcanic Province
Argyre Basin
Valles Marineris
Austral Ice Sheet

Water on Mars

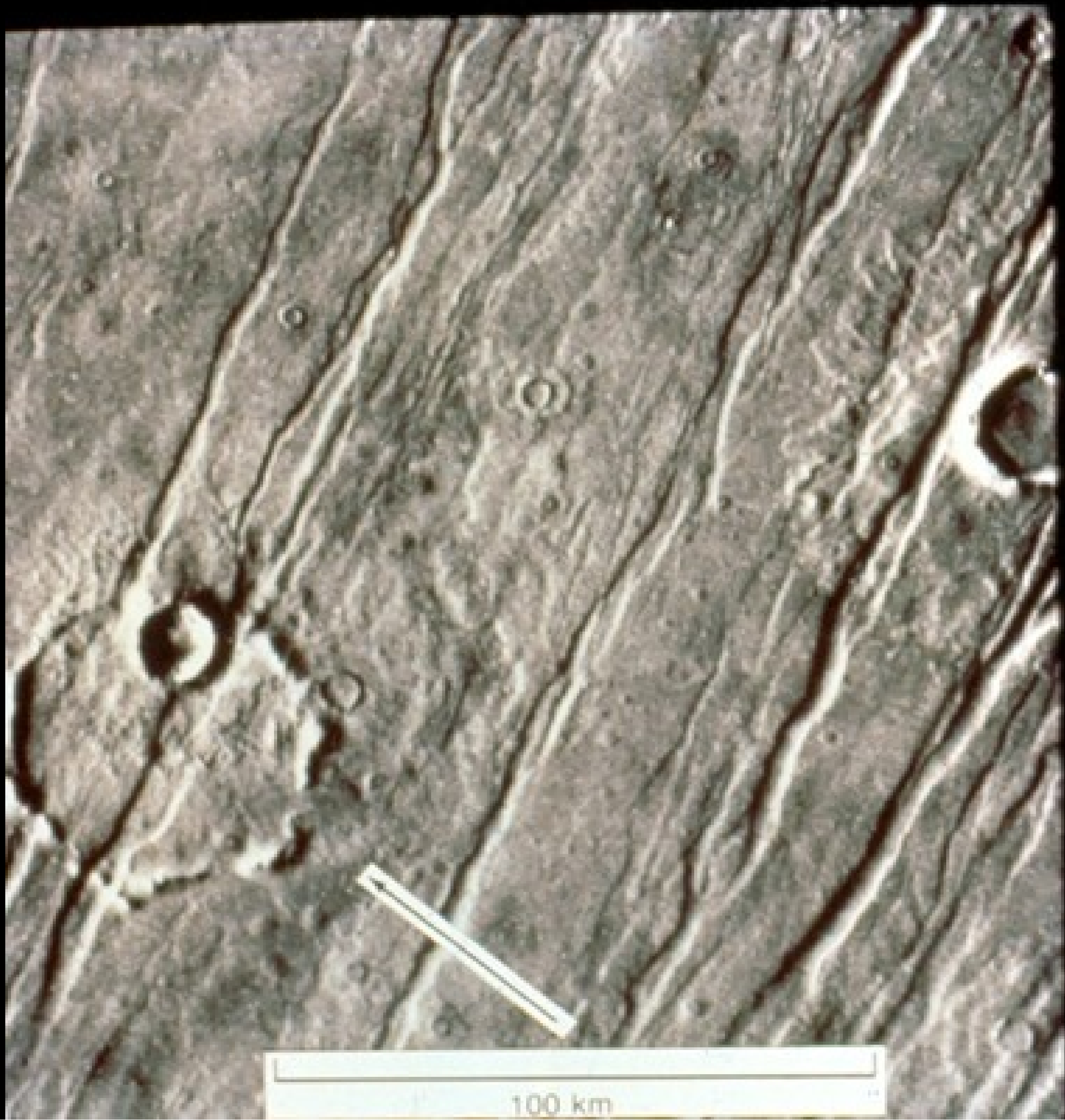


- Ancient Mars had flowing water on its surface.
- These images clearly show the results of what appears to have been flowing water.
- The Viking landers actually recorded frost forming, then evaporating.
- There does not seem to be any liquid water on Mars today.
- It is possible that there may be surface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

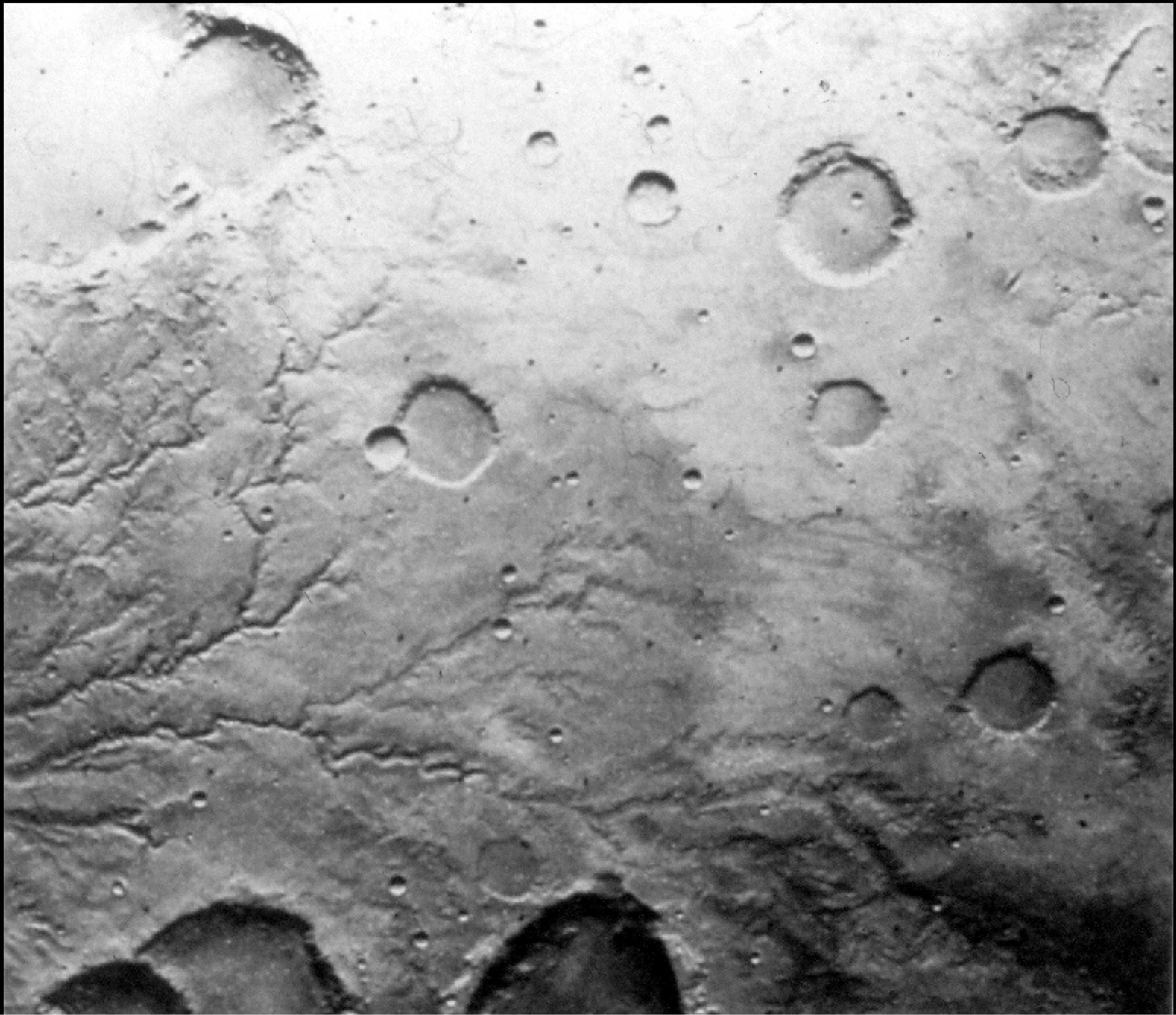
Channel Islands



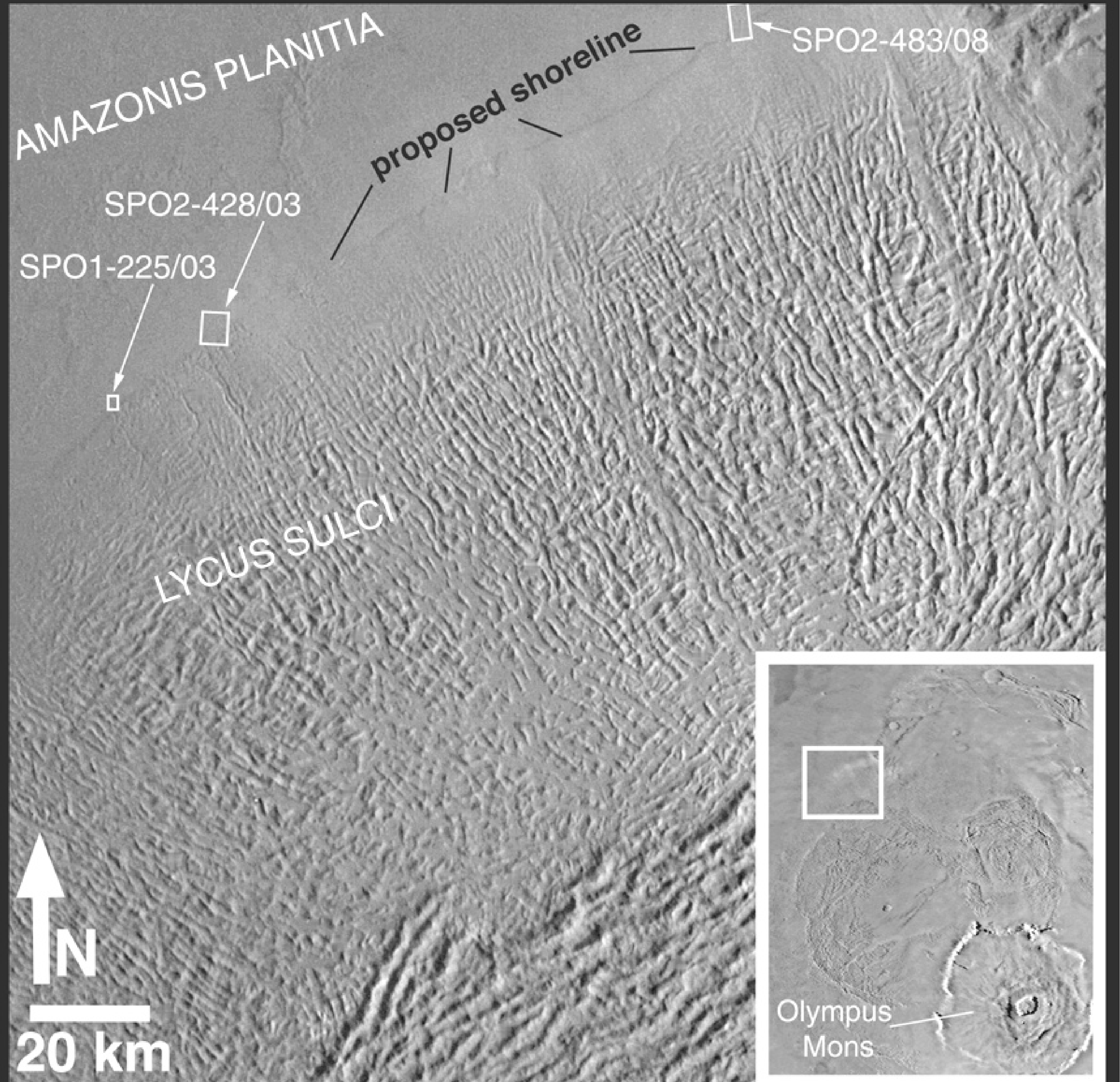
Crater Erosion, Lobate Ejecta



River Channels?

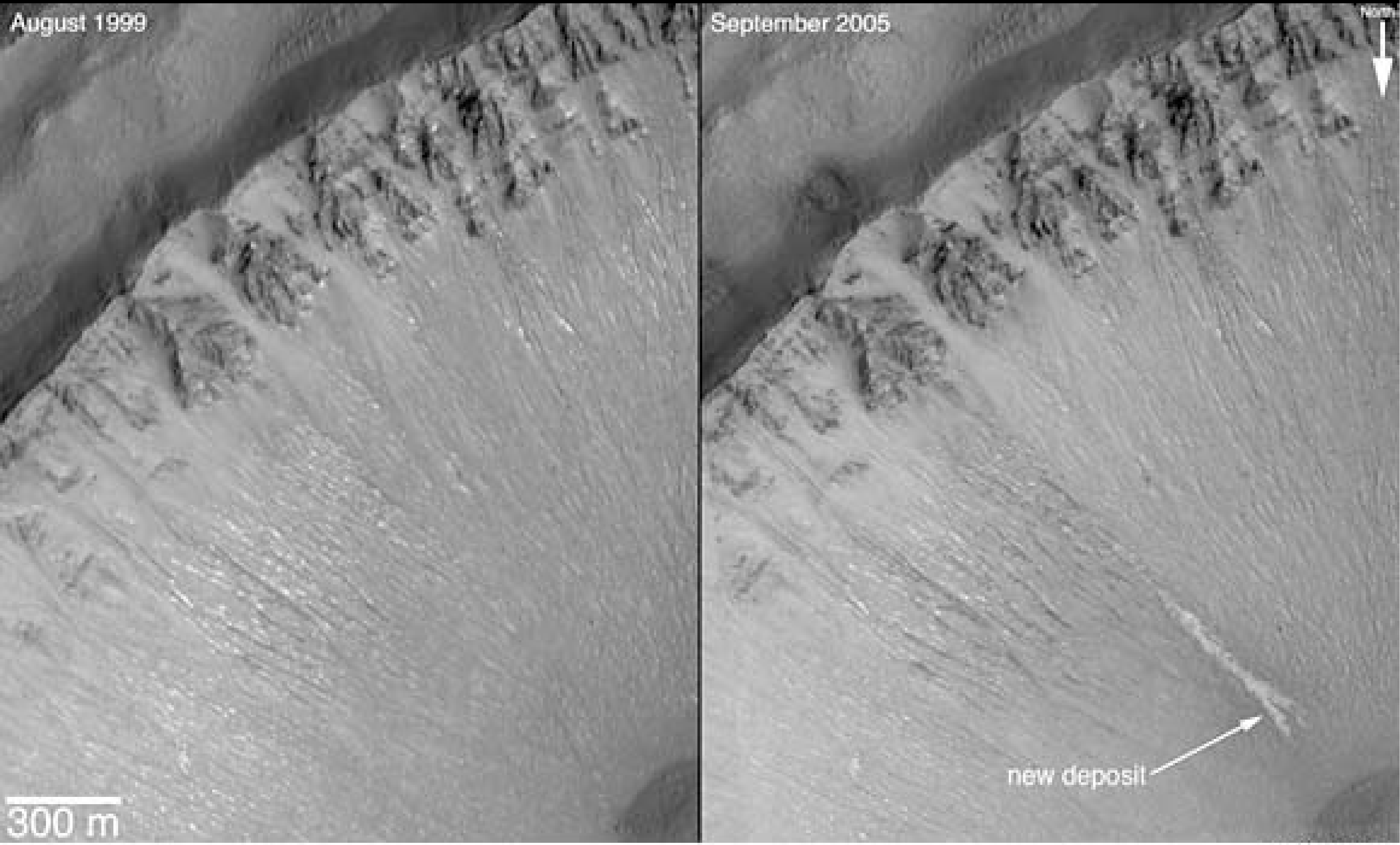


Ancient Martian Shoreline?

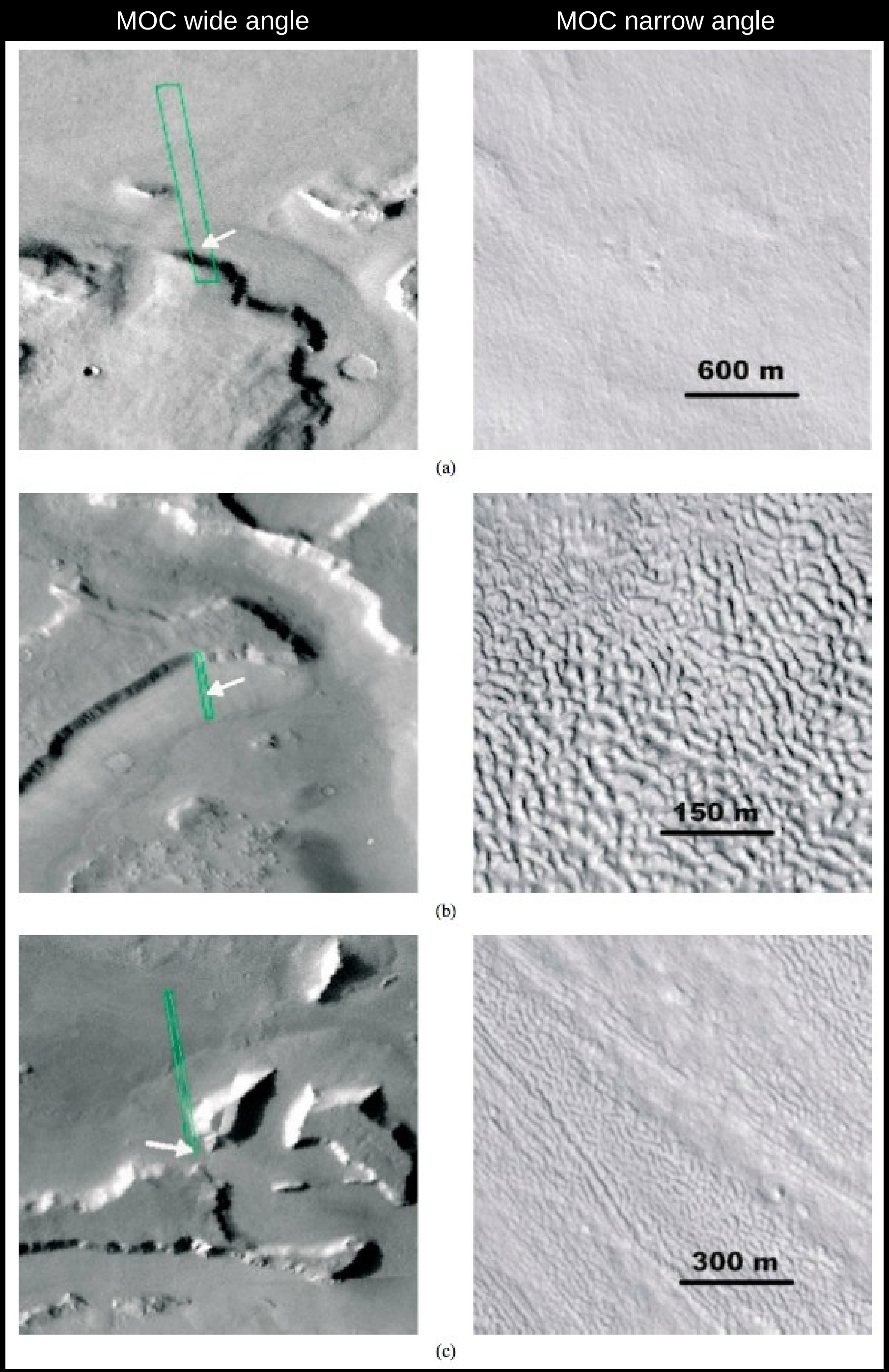


Shoreline? – Up Close and Personal

Current Groundwater Flow?



AP / NASA



Debris Aprons

(a) Smooth surface texture may represent original apron surface

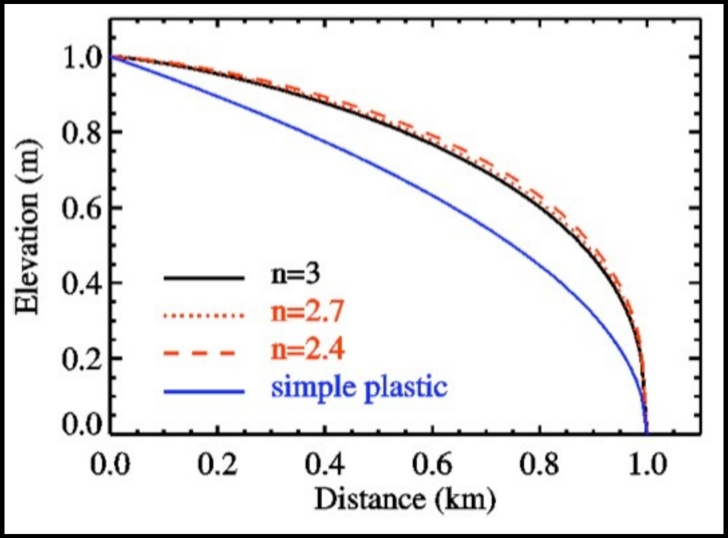
(b) Pitted surface texture may develop through ice sublimation induced collapse

(c) Ridged texture

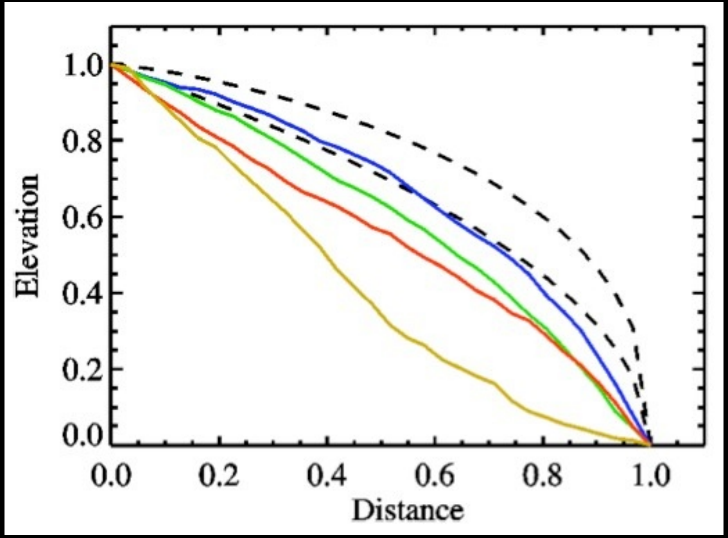
Li, Robinson, Jurdy (2005)

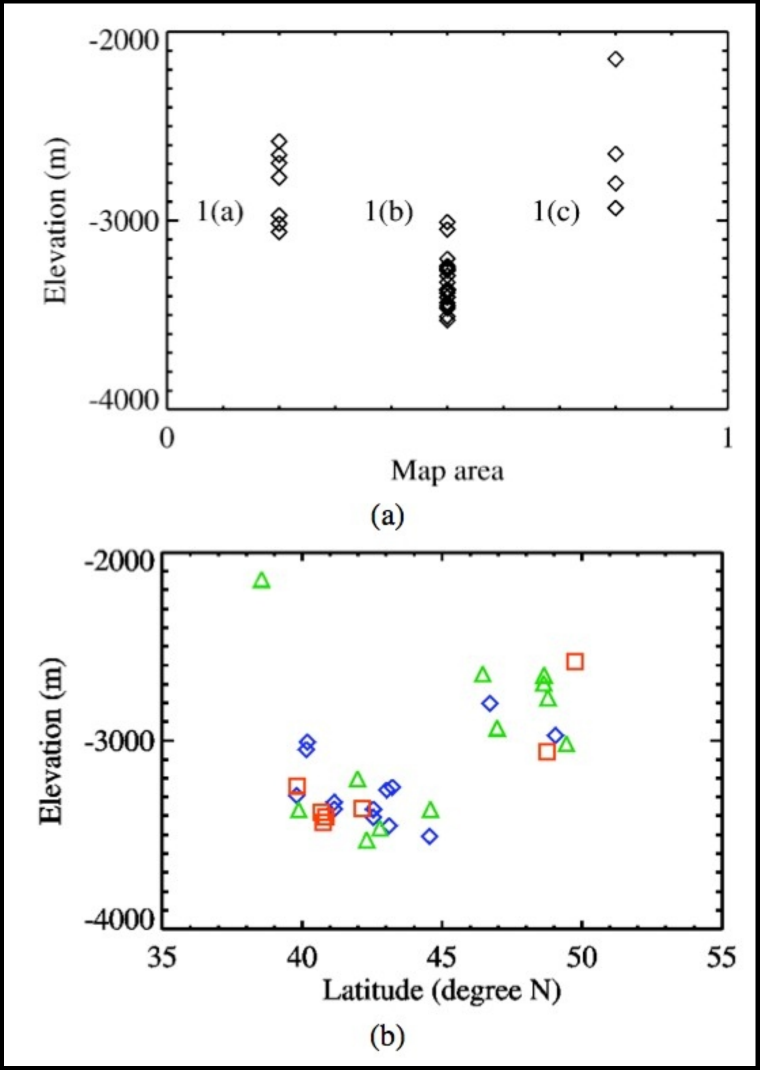
Debris Apron Models

Li, Robinson, Jurdy (2005)



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



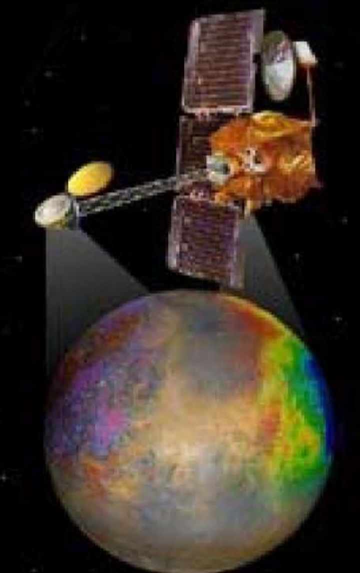


Above: Relationships between apron type and (a) elevation and (b) latitude (type I blue diamond shape, type II green triangle, type III red square).

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

Mars Global Surveyor (MGS)

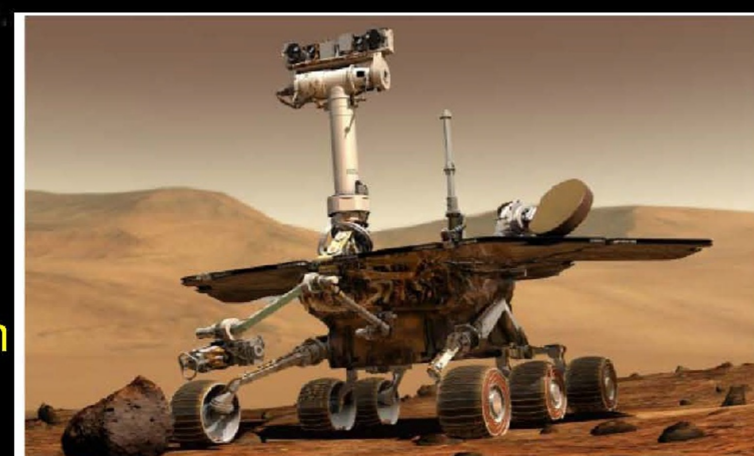
Mars Odyssey



Mars Reconnaissance Orbiter

Mars Express

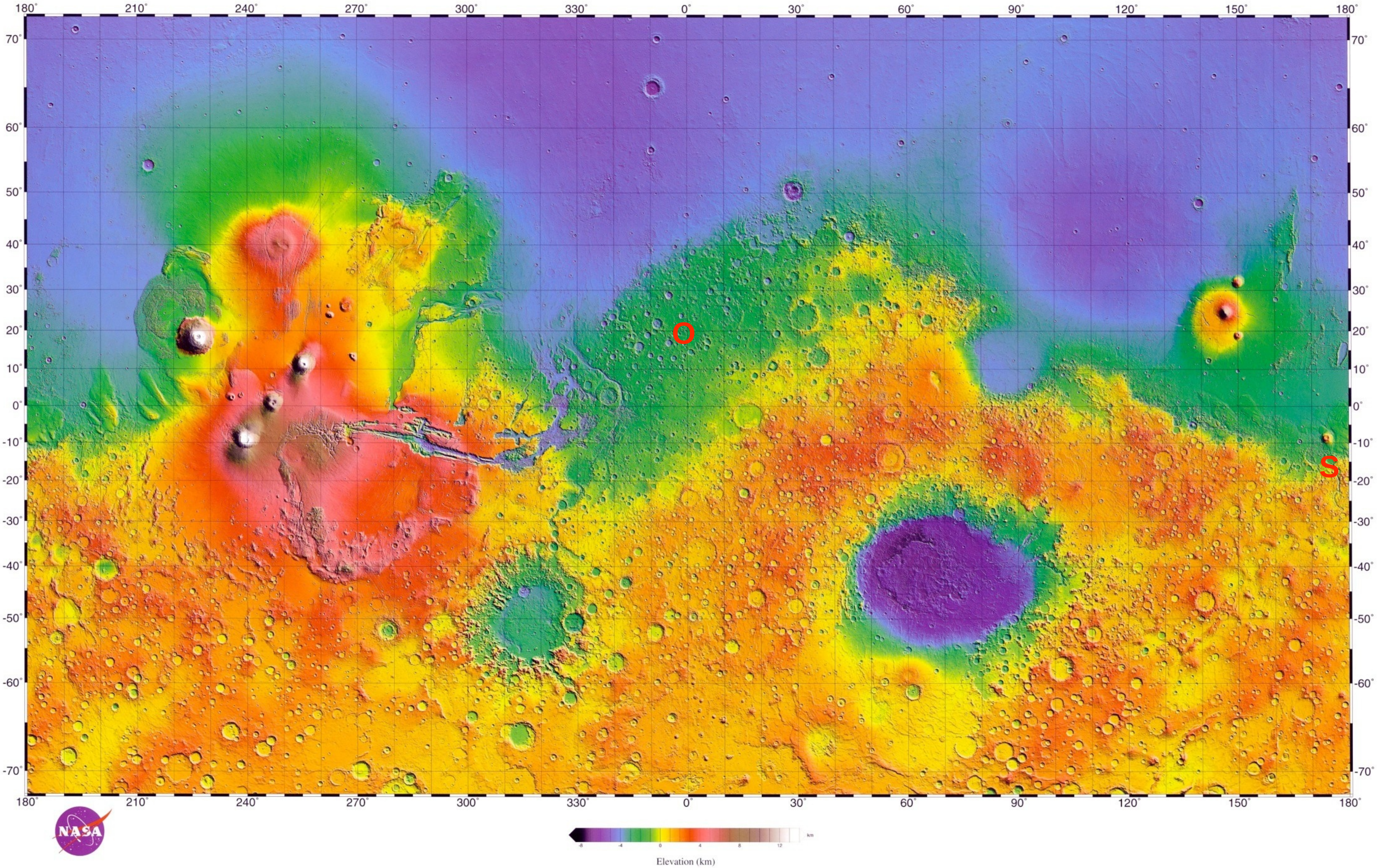
Mars Exploration Rovers (MERs)



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

Mars Global Surveyor Liftoff November 7, 1996

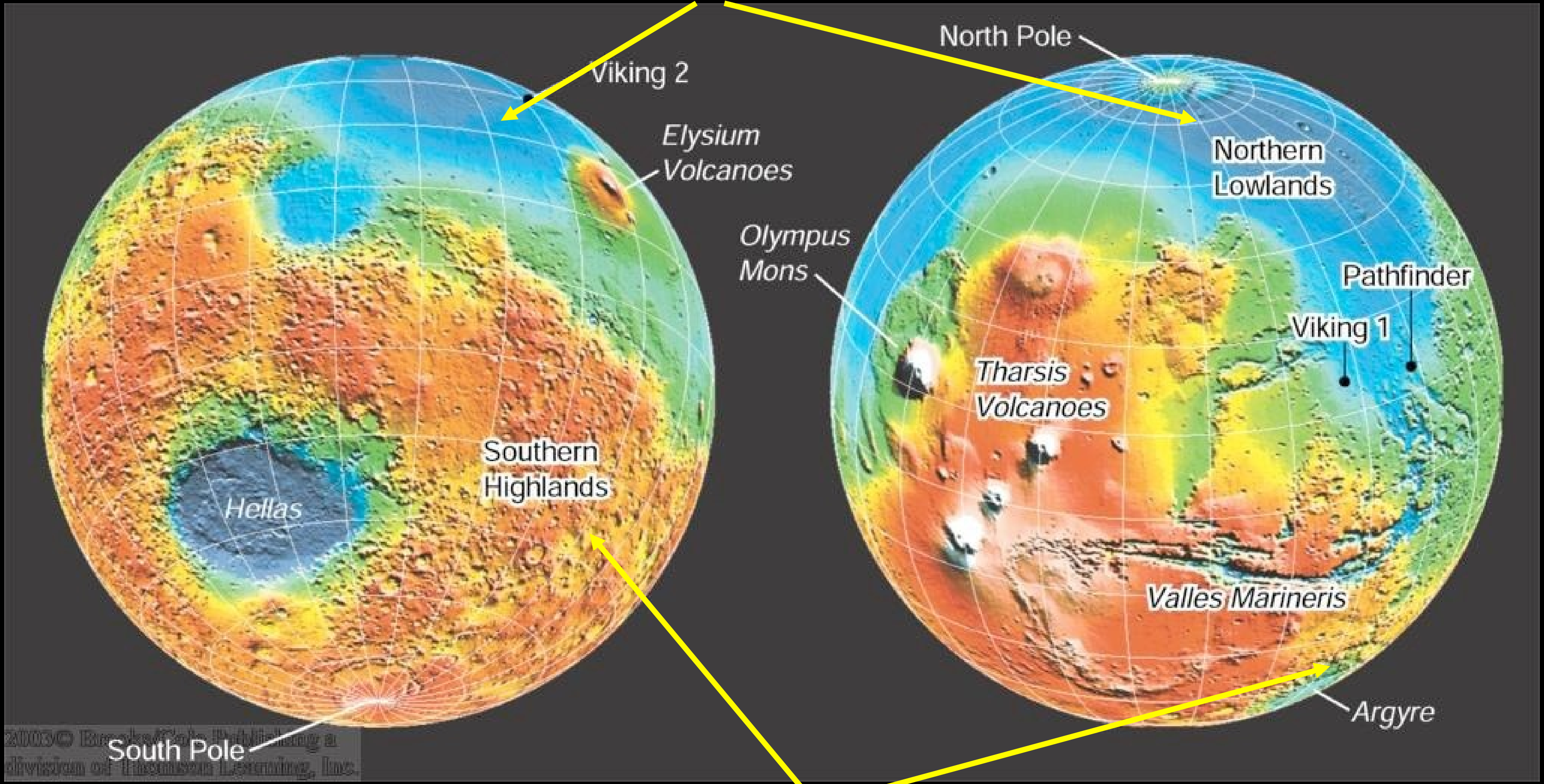
The Topography of Mars



The Geology of Mars

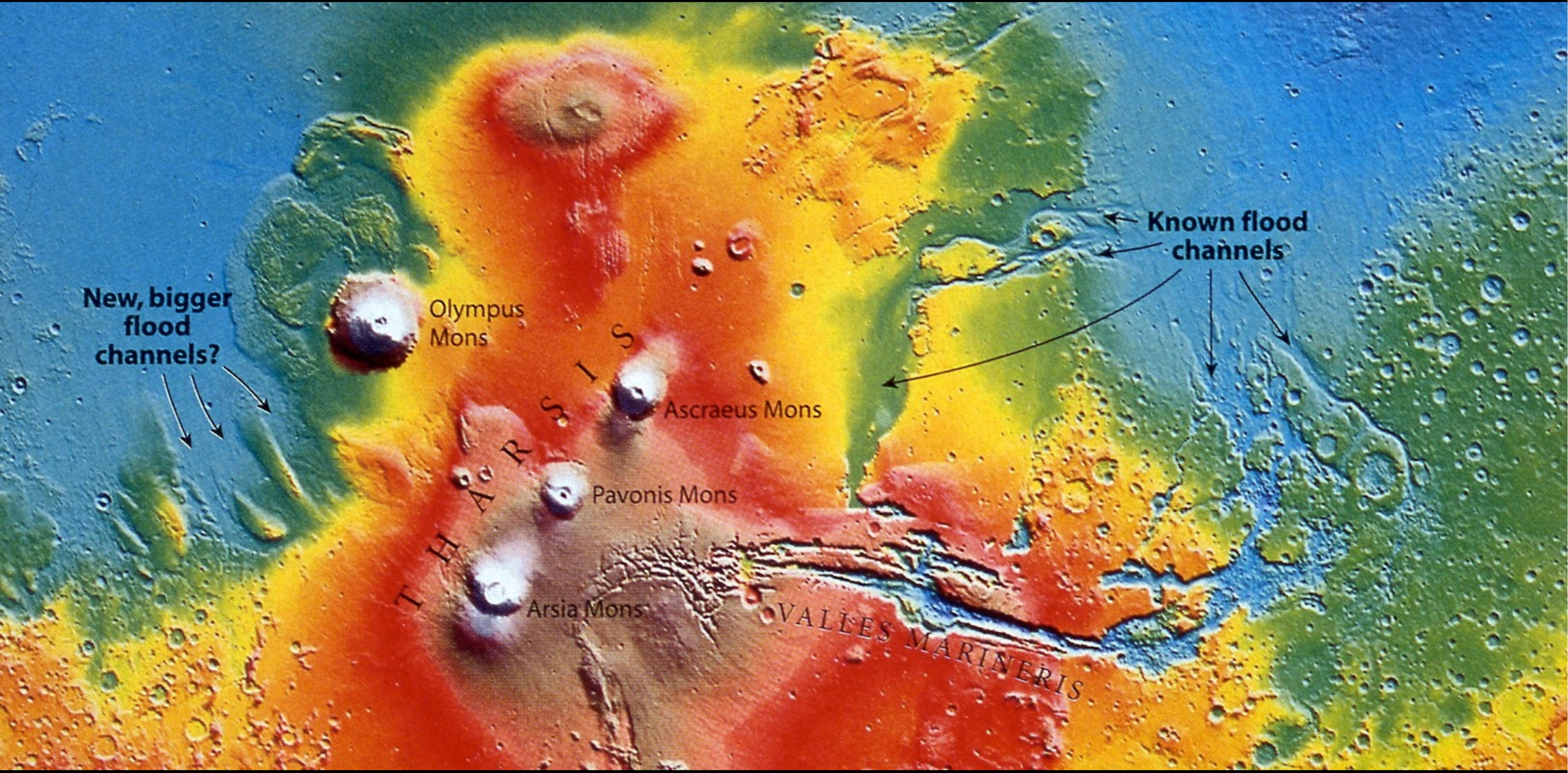
Northern Lowlands: Free of craters; probably re-surfaced a few billion years ago.

Possibly once filled with water.

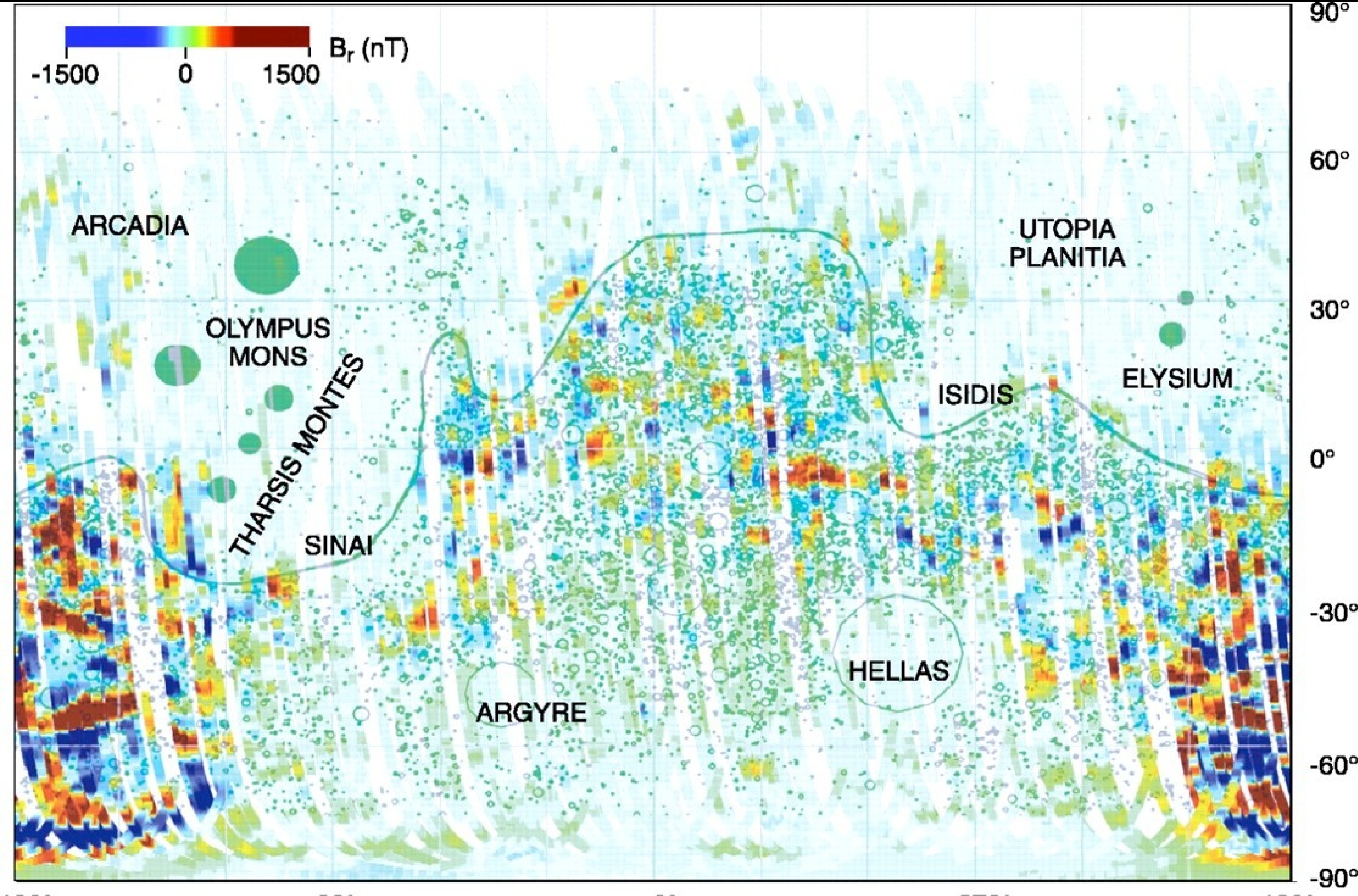


Southern Highlands: Heavily cratered; probably 2 – 3 billion years old.

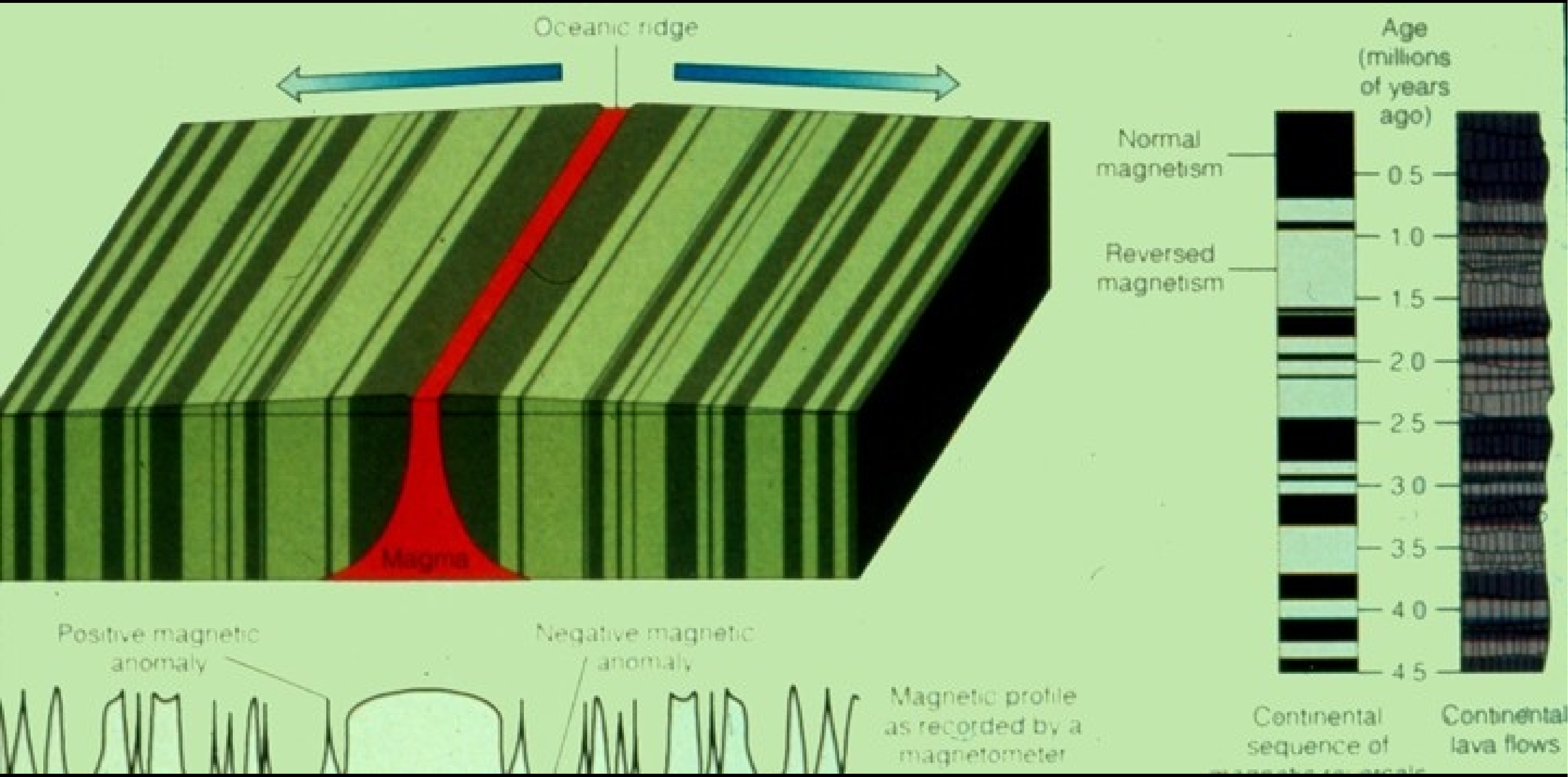
Tharsis Region Topography



Martian Magnetics



Generation of Magnetic Lineations



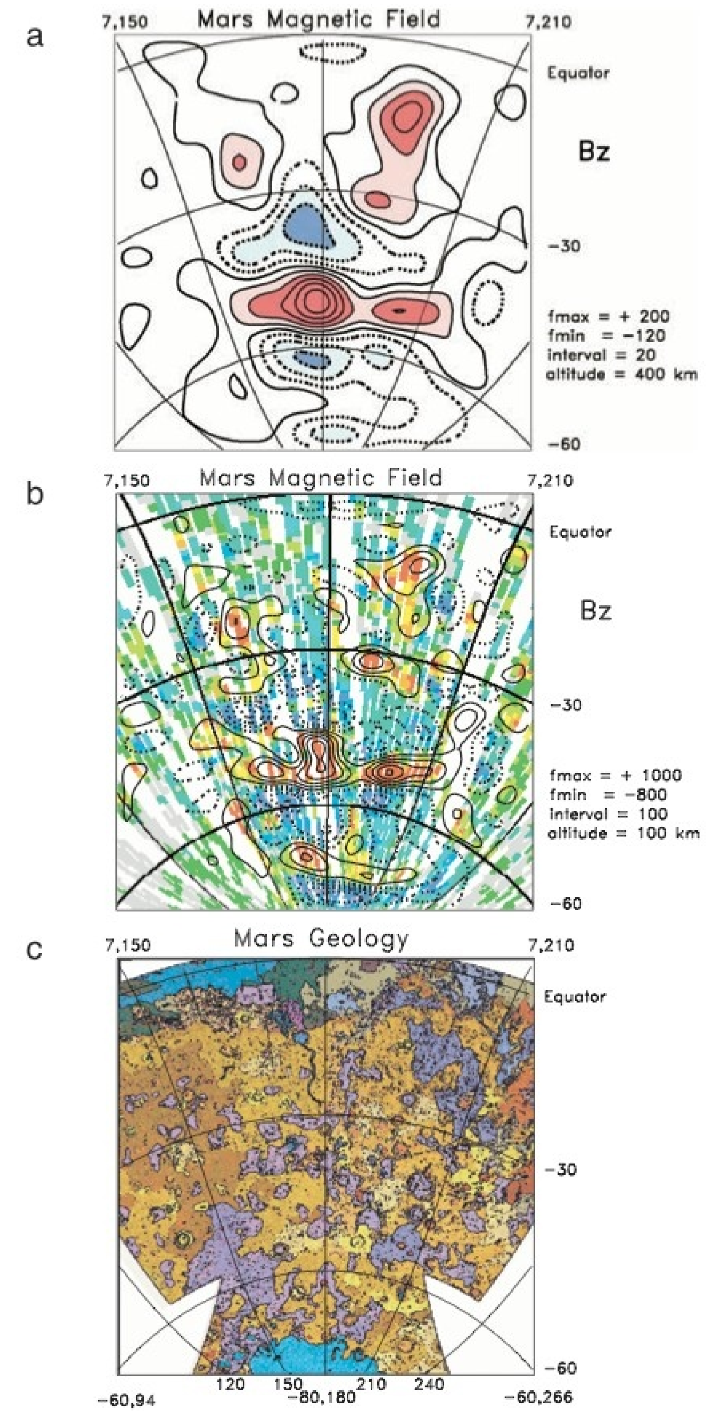
Magnetization of Mars

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)

Table 1. Possible magnetic minerals of the Martian crust, their Curie temperatures [46], and the depth at which their Curie temperature is reached for multiple estimates of Martian heat flux ~3.7 - 4.5 Ga. Magnetic minerals are considered end members if part of a series (e.g., magnetite-titanomagnetite). The magnetized depth is calculated using $(Tc - Ts)k/F$, where k is thermal conductivity (3 W/(m·K)), Tc is Curie temperature (K), Ts is surface temperature (assumed to be 230 K [33]), and F is heat flux (W/m^2).

Likely Magnetic Minerals	Curie Temp (K)	Magnetized depth 1a (km)	Magnetized depth 2b (km)	Magnetized depth 3c (km)	Magnetized depth 4d (km)	Magnetized depth 5e (km)	Magnetized depth 6f (km)	Magnetized depth 7g (km)
titanomagnetite	123	-	-	-	-	-	-	-
magnetite	853	6.2	18.7 - 934.5	27.9 - 35.3	28.3	58.4 - 109.9	37.4 - 93.5	32.8 - 50.5
titanohematite	73	-	-	-	-	-	-	-
hematite	953	7.2	21.7 - 1084.5	32.4 - 40.9	32.9	67.8 - 127.6	43.4 - 108.5	38.1 - 58.6
pyrrhotite	598	3.7	11 - 552	16.5 - 20.8	16.7	34.5 - 64.9	22.1 - 55.2	19.4 - 29.8

a Using a 4.5 Ga heat flux of 300 mW/m^2 [42]. b Using a 4 Ga heat flux range of ~2 - 100 mW/m^2 [41]. c Using a 4 Ga heat flux range of 53 - 67 mW/m^2 [29]. d Using a 4 Ga heat flux of 66 mW/m^2 [22]. e Using a 4.0 - 3.7 Ga global mean heat flux range of 17 - 32 mW/m^2 [45], with the true value likely closer to the lower heat flux bound. f Using a >3.7 Ga heat flux range of 20 - 50+ mW/m^2 [44]. g Using an "early" Mars heat flux range of 37 - 57 mW/m^2 for Terra Cimmeria, Arabia Terra, and Noachis Terra [28].

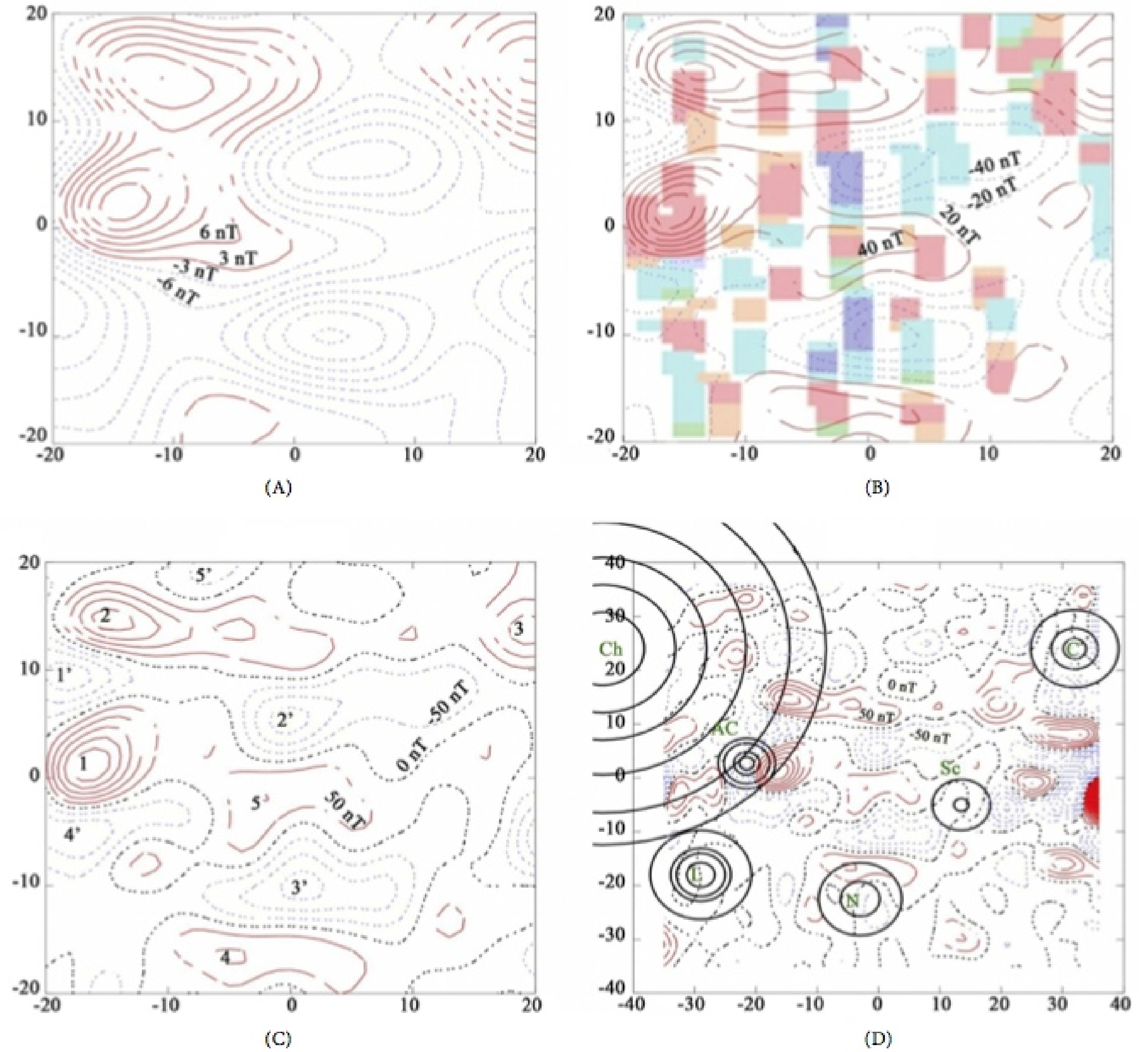


Figure 1. Magnetization in Terra Meridiani. Each base map uses MGS MAG Br data, where red contours represent positive anomalies and blue contours represent negative anomalies (black lines are 0 nT). (A) Data collected at 400 km (mapping) altitude (contour interval of 3 nT); (B) 400 km data downward continued to 110 km (contour interval of 20 nT) and correlated with aerobraking data (swaths) collected at the same altitude. In the swaths, red represents Br > 150 nT, orange is 150 > Br > 50, green represents −50 < Br < −150, light blue represents −150 < Br < −250, and dark blue represents Br < −250 nT; (C) 400 km data downward continued to the surface (contour interval is 50 nT). The numbers correspond to possible sources of magnetization; (D) Surface magnetization (contour interval is 50 nT) expanded to ~35° × 35° with regional multi-ringed basins [49] (Ch = Chryse, L = Ladon, AC = Aram Chaos, N = overlapped by Newcomb, Sc = overlapped by Schiaparelli, C = Cassini).

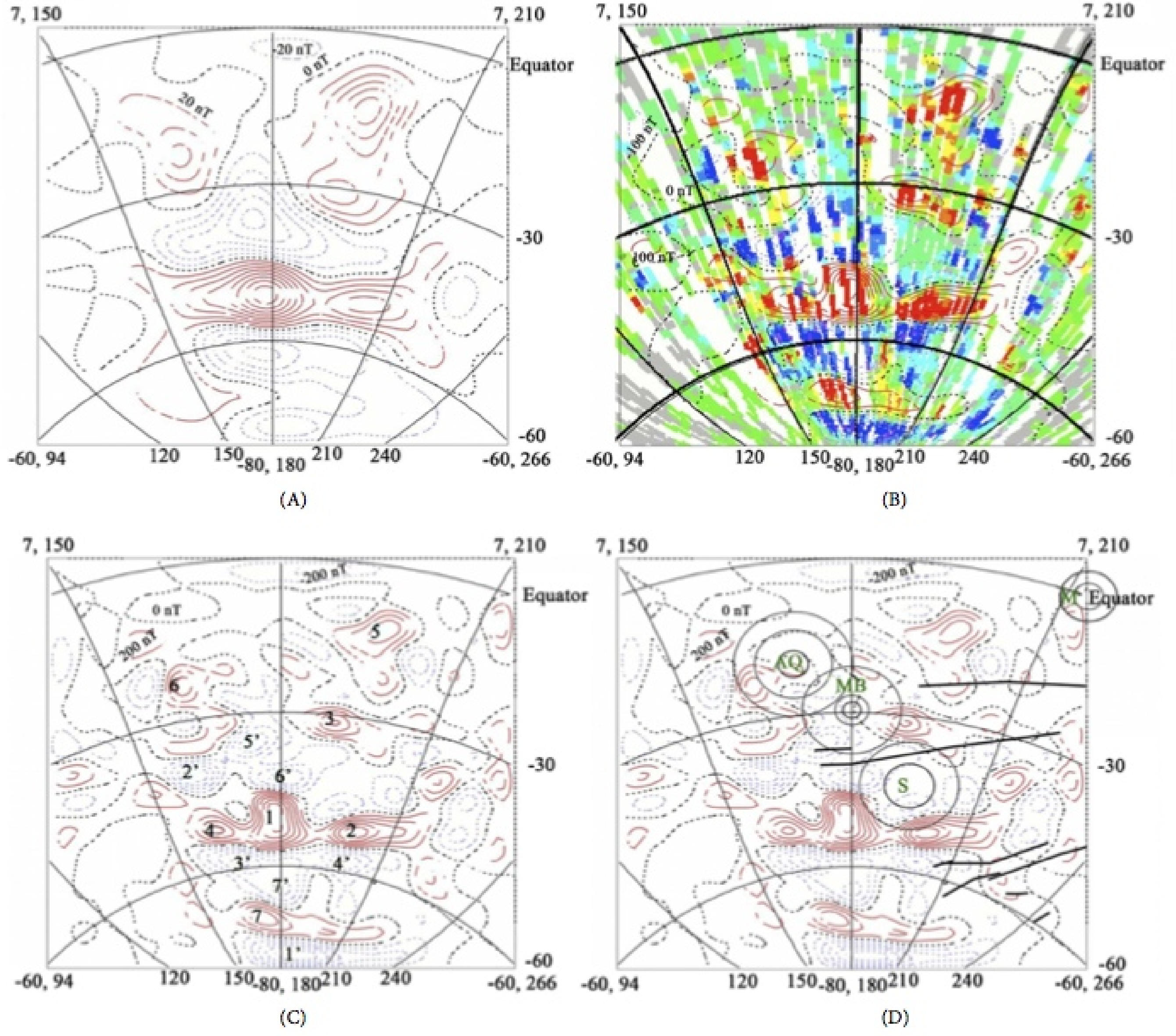
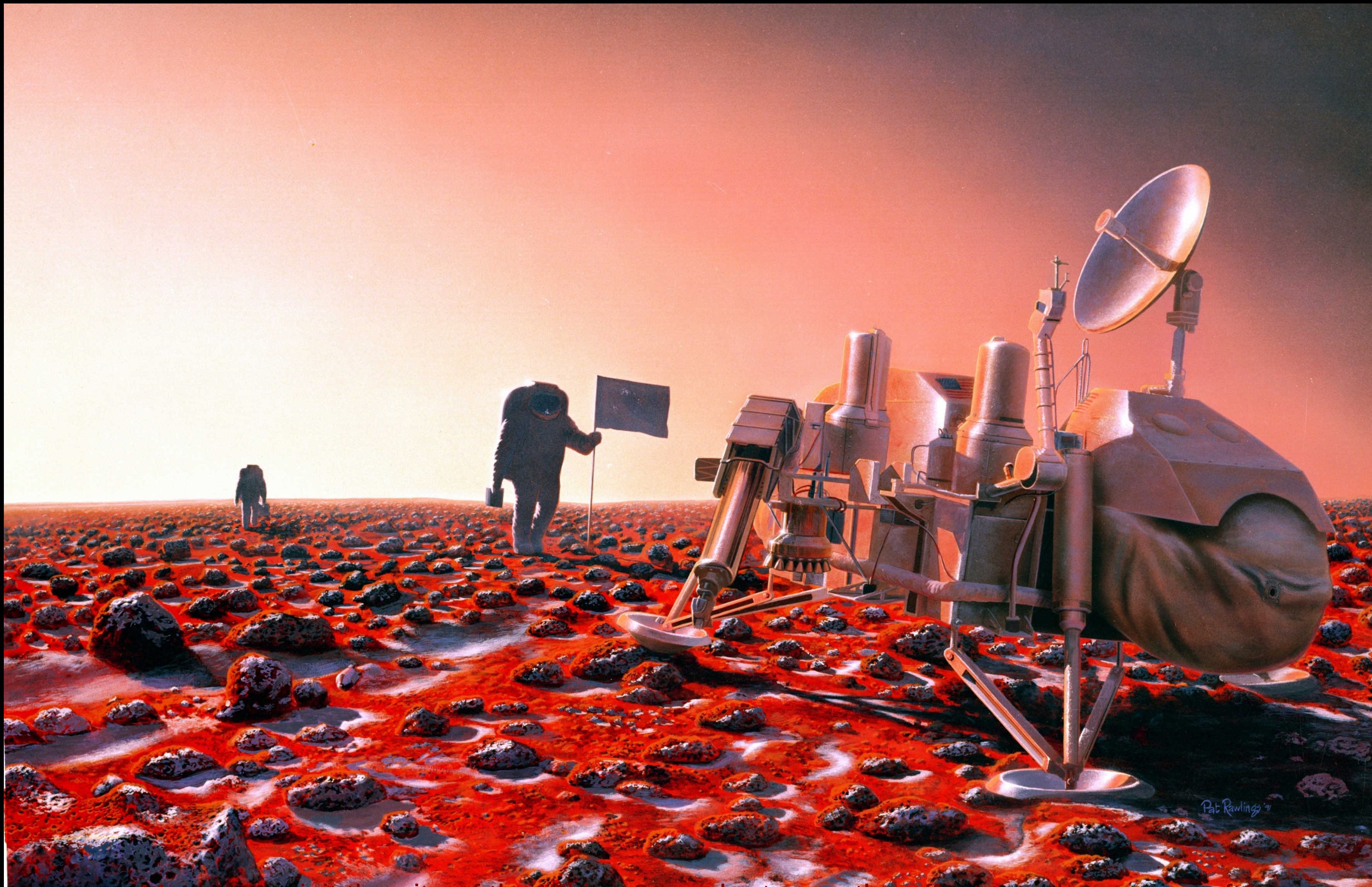


Figure 2. Magnetization in Terra Sirenum. Each base map uses MGS MAG Br data. (A) Data collected at 400 km (mapping) altitude (contour interval is 20 nT); (B) 400 km data downward continued to 100 km (contour interval is 100 nT) and correlated with aerobraking data (swaths) collected at the same altitude. Dark red represent strongly positive while dark blue represents strongly negative; (C) 400 km data downward continued to the surface (contour interval 200 nT). The numbers correspond to depth estimates; (D) Surface magnetization (contour interval 200 nT) with mapped faults [14] [15] and mapped regional multi-ringed basins [49] [50] (AQ = Al Qahira, MB = Memnonia-B, S = Sirenum, M = Mangala).

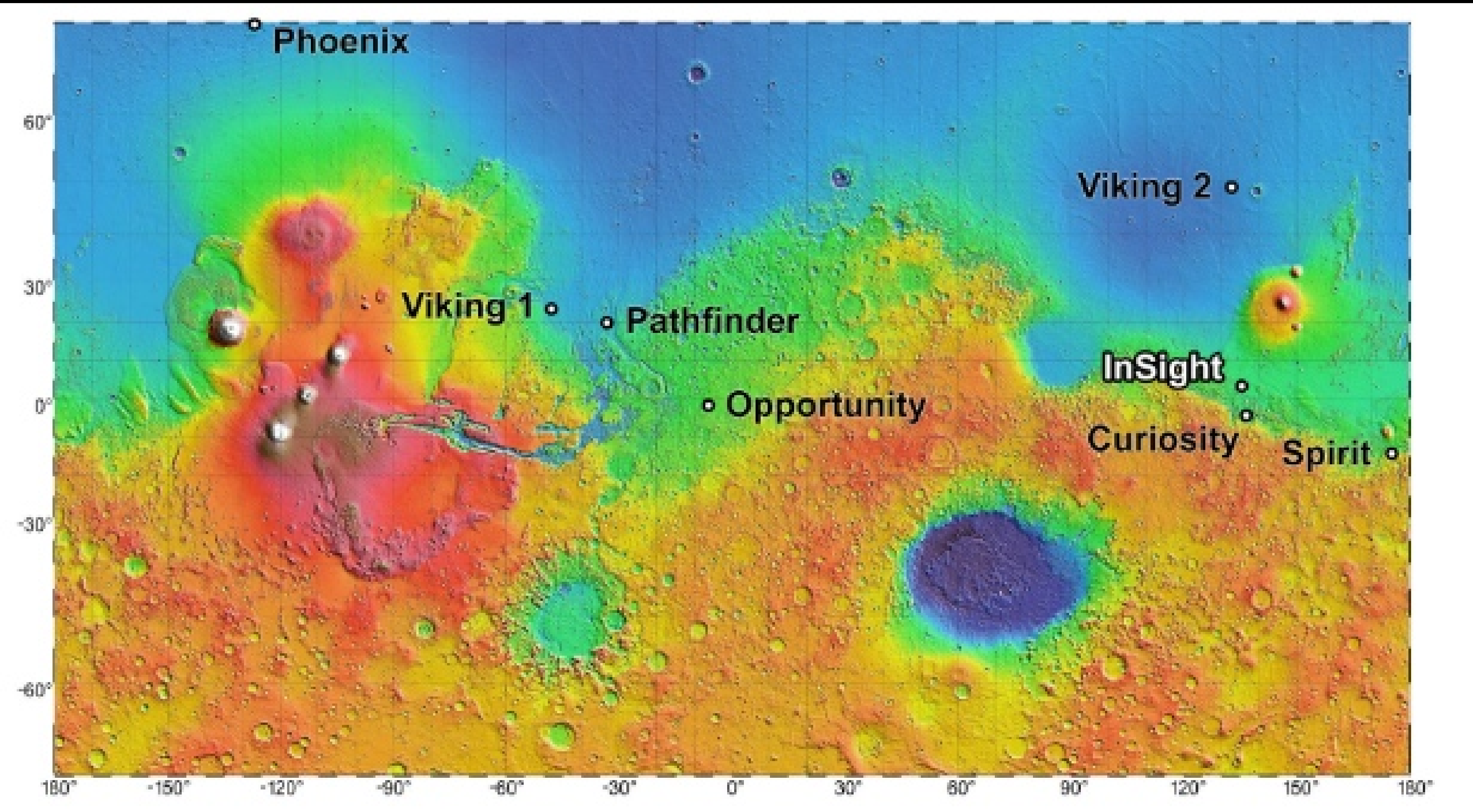


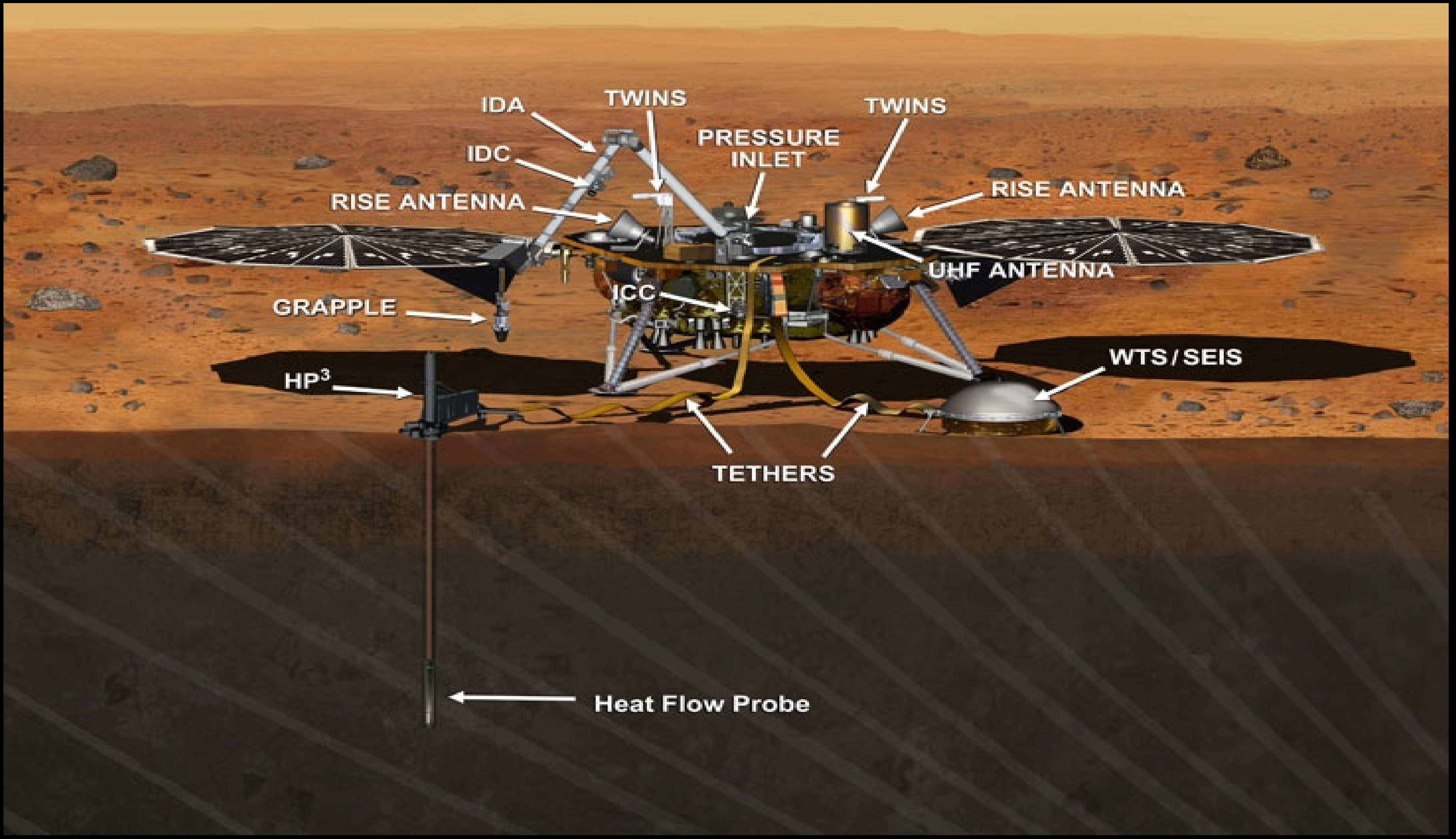
Humans on Mars may visit the site of the Viking 2 Lander to see the effects on the spacecraft.
Viking 2, launched 9/9/75, entered orbit 8/7/76. Viking 2 Lander reached Utopia Planitia on 9/3/76.
The two Vikings delivered seismometers mounted on the landers' legs. Viking 2 Lander ended communication on 4/11/80. To this day no seismometer has monitored the martian surface.

(NASA by image Pat Rawlings. Technical concepts, Johnson Space Center,1991).

INSIGHT Mars Mission

- **In**terior Exploration using **S**eismic **I**nvestigations, **G**eodesy and **H**eat **T**ransport.
- Mission will be first to study the martian interior
- Launched May 5, 2018
- Drilling stopped.


Phoenix
Viking 2
Viking 1
Pathfinder
InSight
Opportunity
Curiosity
Spirit
60°
30°
0°
-30°
-60°
180°
-150°
-120°
-90°
-60°
-30°
0°
30°
60°
90°
120°
150°
180°

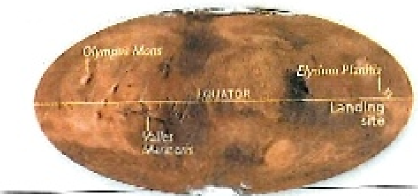

IDA
TWINS
TWINS
IDC
PRESSURE
INLET
RISE ANTENNA
RISE ANTENNA
UHF ANTENNA
ICC
GRAPPLE
WTS / SEIS
HP3
TETHERS
Heat Flow Probe

NAT GEO CHANNEL

Progress on *MARS*
In season two of the docu-drama series *MARS*, colonists encounter challenges as they build a new society and industries. Episodes air Mondays at 9/8c starting November 12, on National Geographic.

EXPLORE MARS

ILLUMINATING THE MYSTERIES—AND WONDERS—ALL AROUND US EVERY DAY
NATIONAL GEOGRAPHIC | VOL. 234 NO. 5



PLACE Elysium Planitia

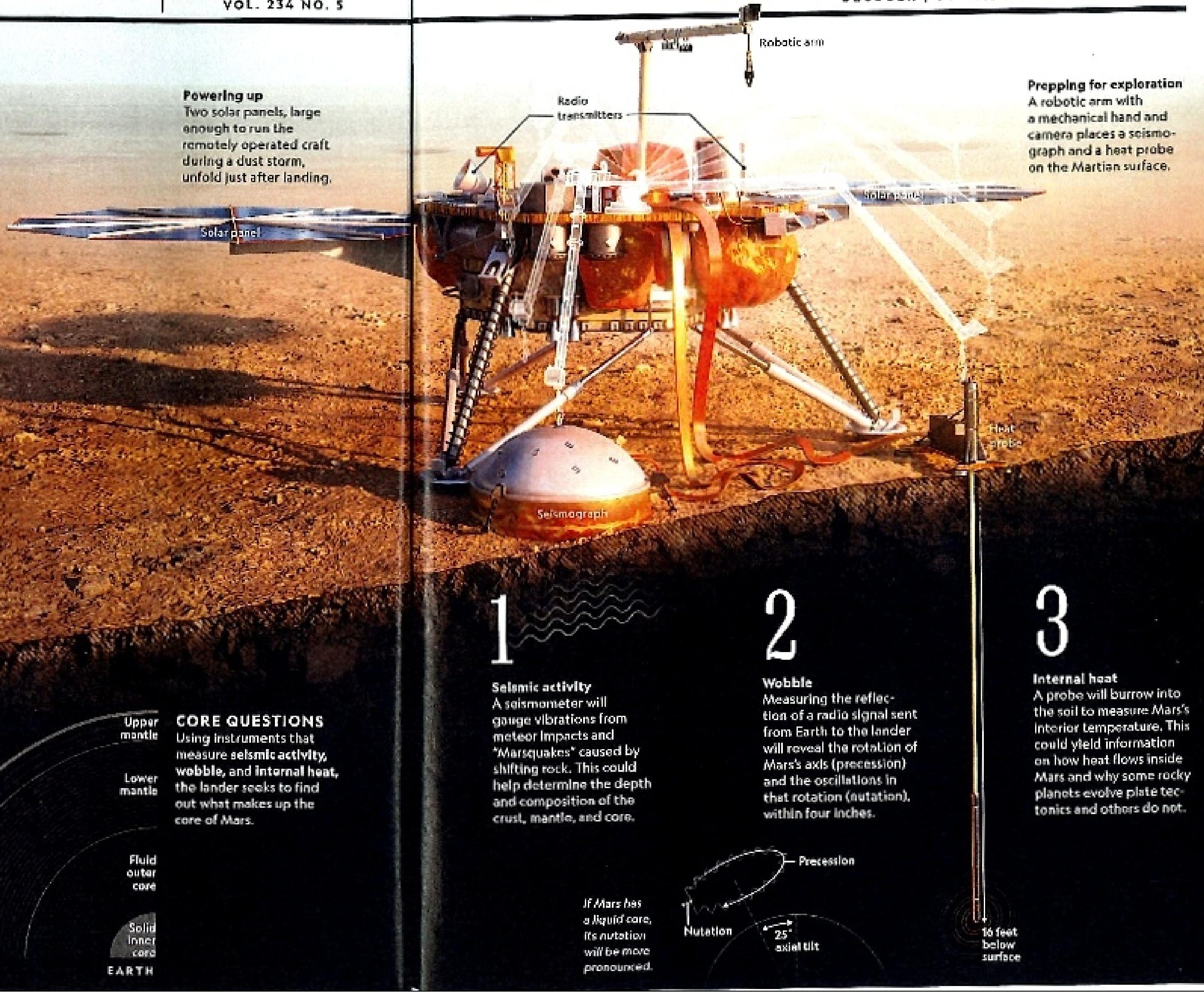
LOCATION Mars

DISTINCTION The landing site is ideal because of its flat surface and low elevation. The site also gets enough light daily to power the lander and keep its electronics from freezing.

DECODER | BY JASON TREAT

TAKING THE PULSE OF THE RED PLANET

NASA'S INSIGHT LANDER IS EXPECTED to set down along the sunny equator of Mars in late November. Its mission: Study Mars's ancient interior, a task that might shed some light on our own planet. That's because the same plate tectonics that give Earth its mountain ranges—and the conditions for life itself—have over eons transformed our ancient geology. Mars, on the other hand, has had a comparatively uneventful past three billion years, likely because it's too small to produce the energy for history-erasing tectonic shifts. So it might still hold clues to how rocky worlds, like ours, first formed and evolved.



Powering up
Two solar panels, large enough to run the remotely operated craft during a dust storm, unfold just after landing.

Prepping for exploration
A robotic arm with a mechanical hand and camera places a seismograph and a heat probe on the Martian surface.

1

Seismic activity
A seismometer will gauge vibrations from meteor impacts and "Marsquakes" caused by shifting rock. This could help determine the depth and composition of the crust, mantle, and core.

2

Wobble
Measuring the reflection of a radio signal sent from Earth to the lander will reveal the rotation of Mars's axis (precession) and the oscillations in that rotation (nutation), within four inches.

If Mars has a liquid core, its nutation will be more pronounced.

3

Internal heat
A probe will burrow into the soil to measure Mars's interior temperature. This could yield information on how heat flows inside Mars and why some rocky planets evolve plate tectonics and others do not.

CORE QUESTIONS

Using instruments that measure **seismic activity, wobble,** and **internal heat,** the lander seeks to find out what makes up the core of Mars.

Conclusions

- *Mars had a strong magnetic field early in its history.*
- *Martian crust is either very strongly magnetized or goes to great depth. Perhaps both.*
- *Magnetic mineral carrier remains unknown.*
- *True Polar Wander may have occurred on Mars, as evidenced by location of Tharsis.*
- *The InSight lander, with seismometer and heat flow experiments, now on Mars' surface as the first mission to study the interior. Drilling suspended.*

Sunset on Mars (Spirit)