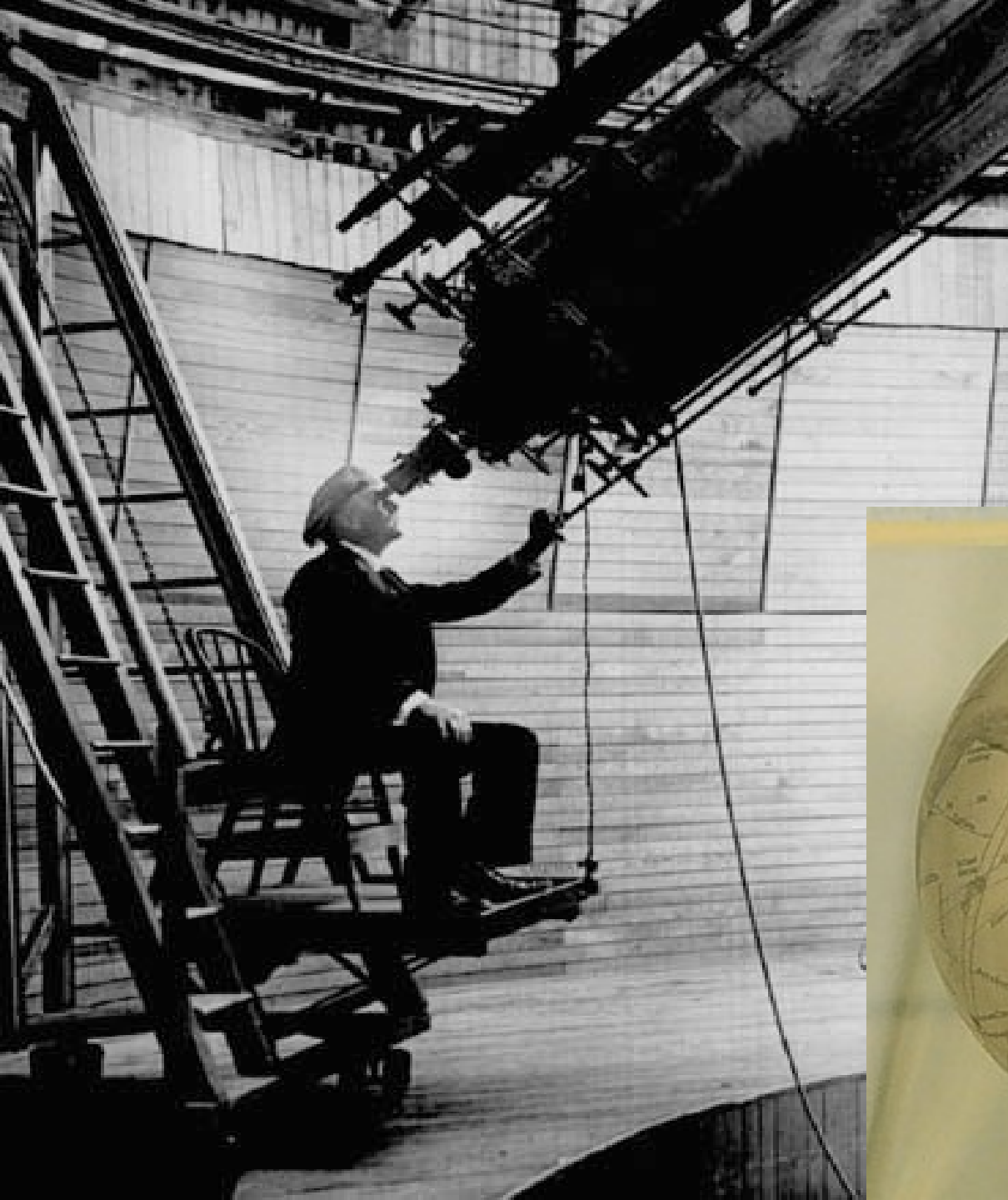


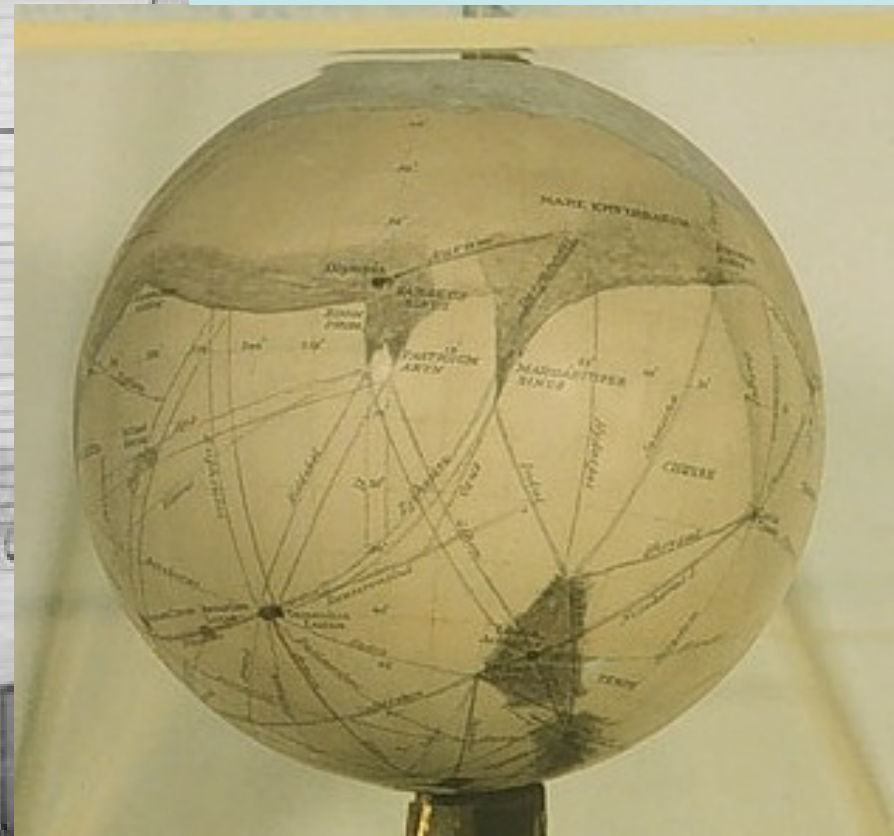
# *Mars Mysteries*

*Donna M. Jurdy  
Earth & Planetary Sciences  
Northwestern University*



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

BELOW IS A GLOBE  
CONSTRUCTED FROM HIS  
DRAWINGS



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

*The WAR of the WORLDS*  
*By H. G. Wells*

Author of "Under the Knife," "The Time Machine," etc.



## Mars • Global Dust Storm



June 26, 2001



September 4, 2001

**Hubble Space Telescope • WFPC2**

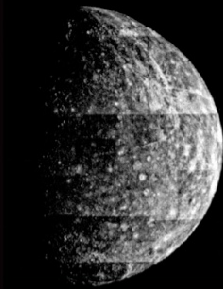
NASA, J. Bell (Cornell), M. Wolff (SSI), and the Hubble Heritage Team (STScI/AURA) • STScI-PRC01-31



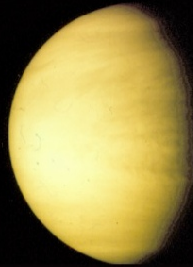
*When is a face not a face?*



Mercury



Venus



Earth



Moon



Mars



Radius (km)

2439

6052

6378

1738

3398

Mass (kg)

 $3.30 \times 10^{23}$  $4.87 \times 10^{24}$  $5.98 \times 10^{24}$  $7.35 \times 10^{22}$  $6.42 \times 10^{23}$ Density (kg/m<sup>3</sup>)

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

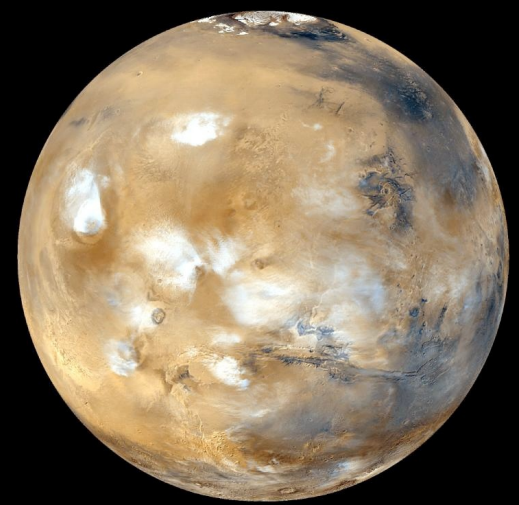
Atmosphere

---

CO<sub>2</sub>N<sub>2</sub>, O<sub>2</sub>

---

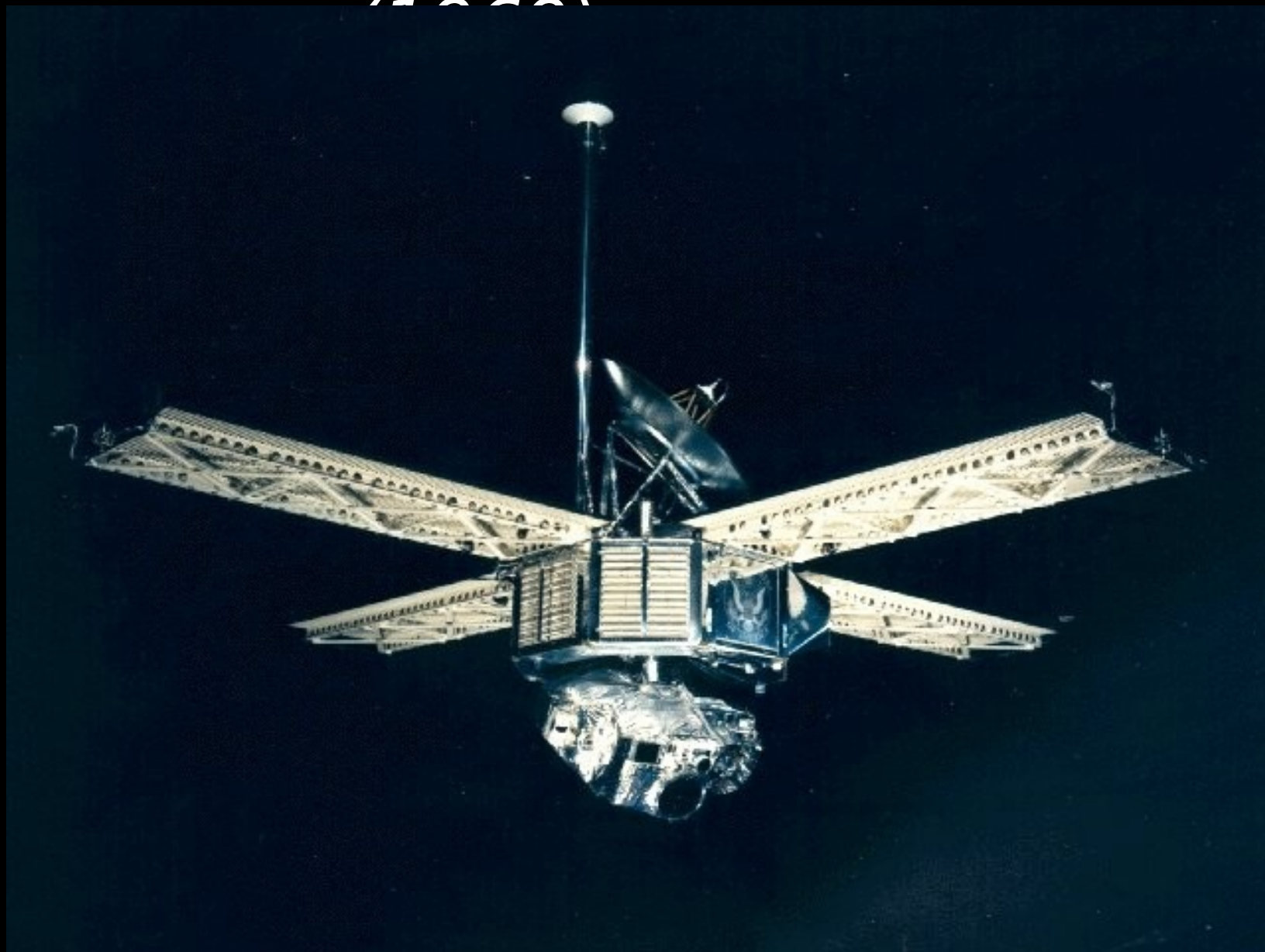
CO<sub>2</sub>



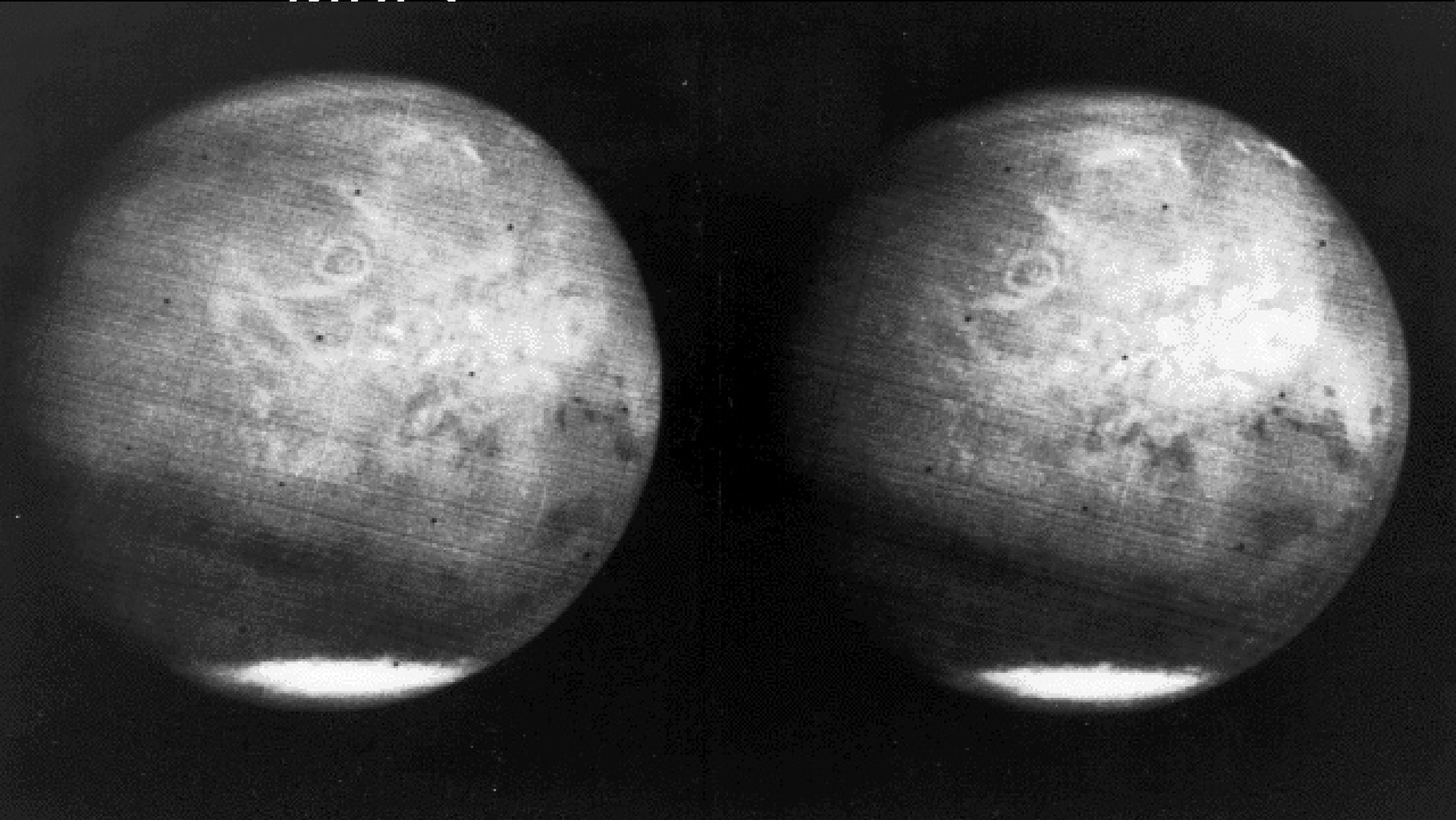


# Mariner 7

(1969)



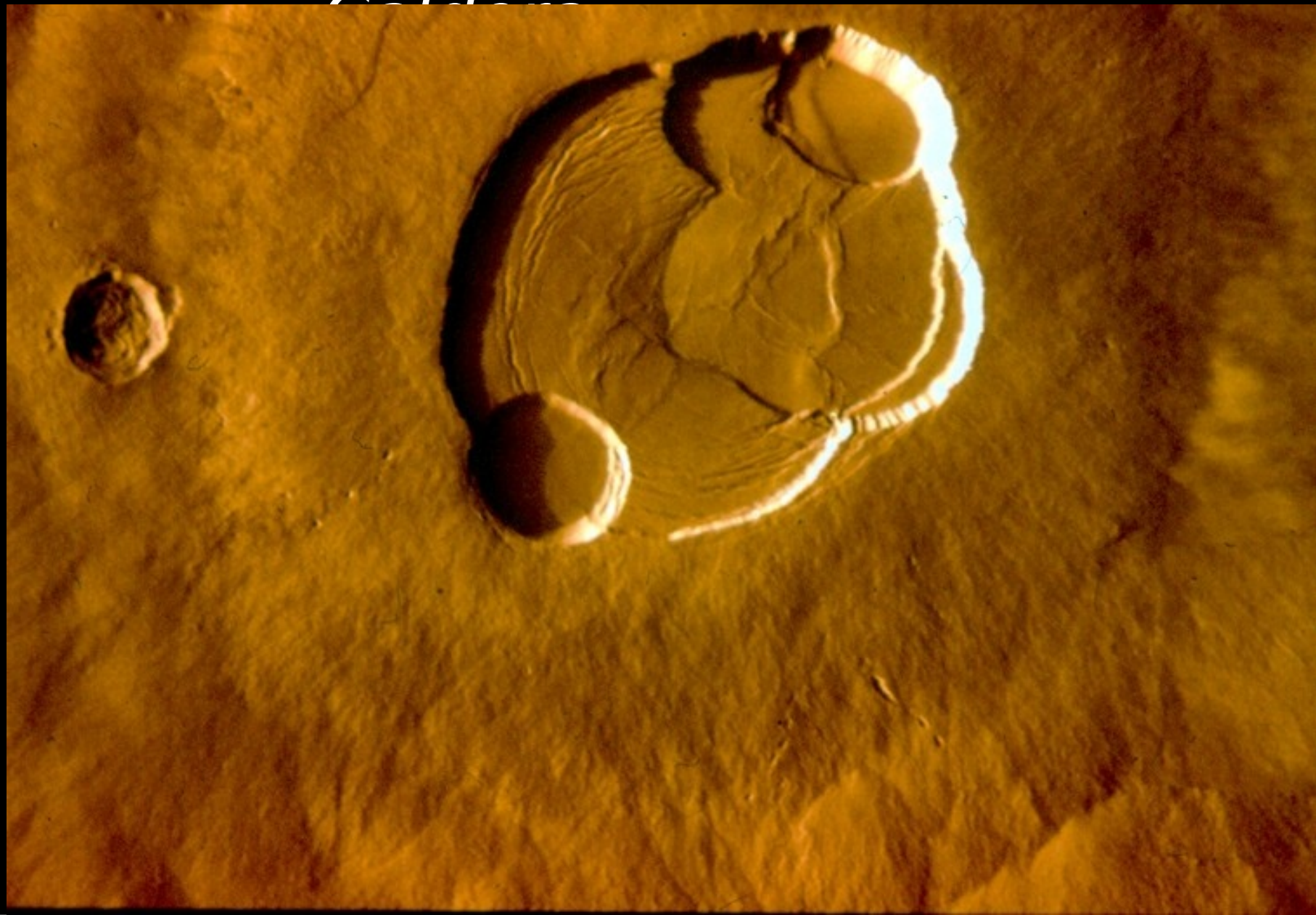
# *Mariner 7 Approach to Mars*



*Olympus Mons, as seen from Mariner*



# Olympus Mons

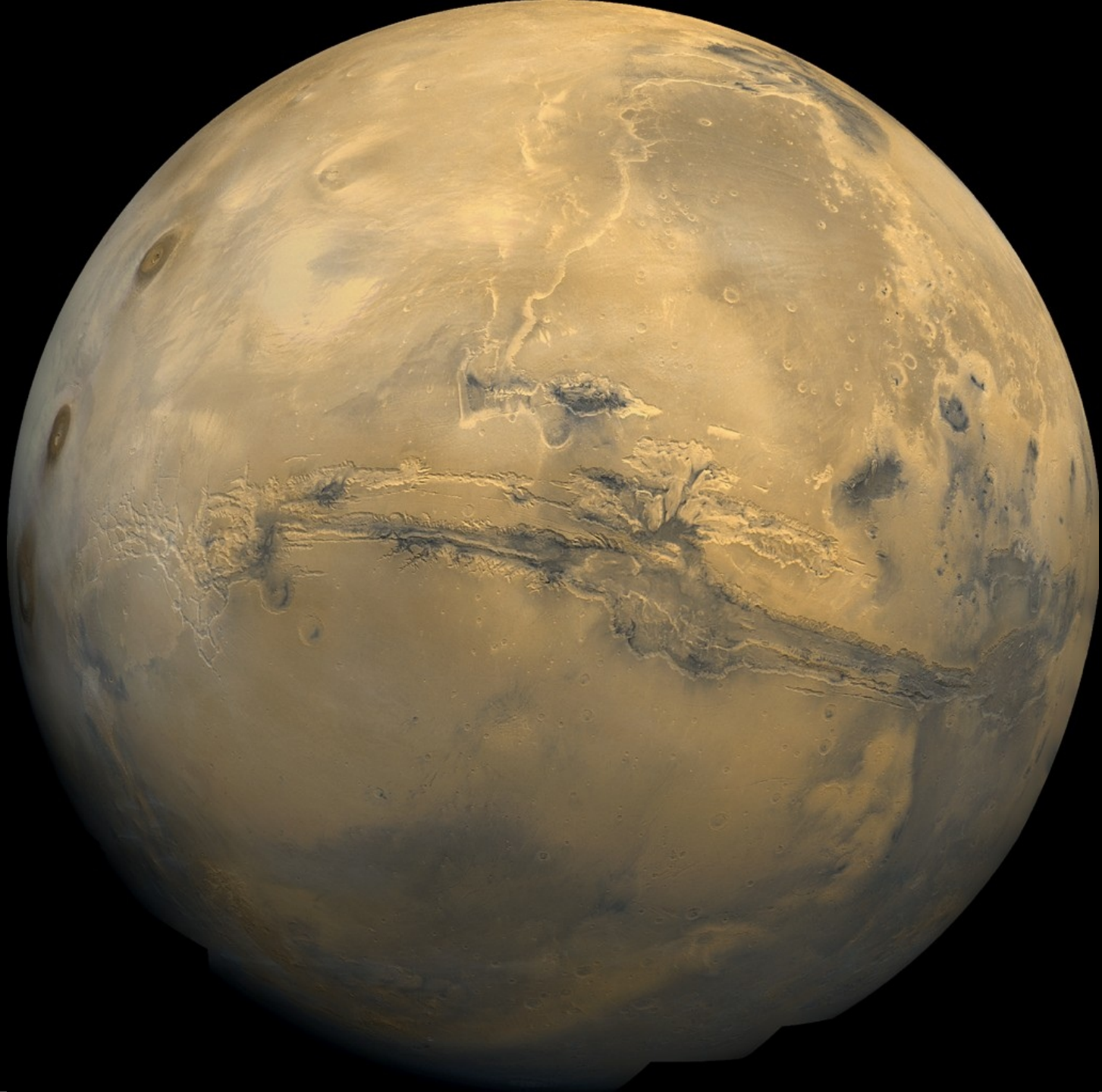


*Viking 2 Liftoff, Sept 5,  
1975*



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

Mid  
1970'S



# *Viking Lander*



*Viking 2 Landing Site (Sept,  
1976)*





# Evidence for (really old, really tiny) Martians?



# Mars

Geology

Oceanus Borealis

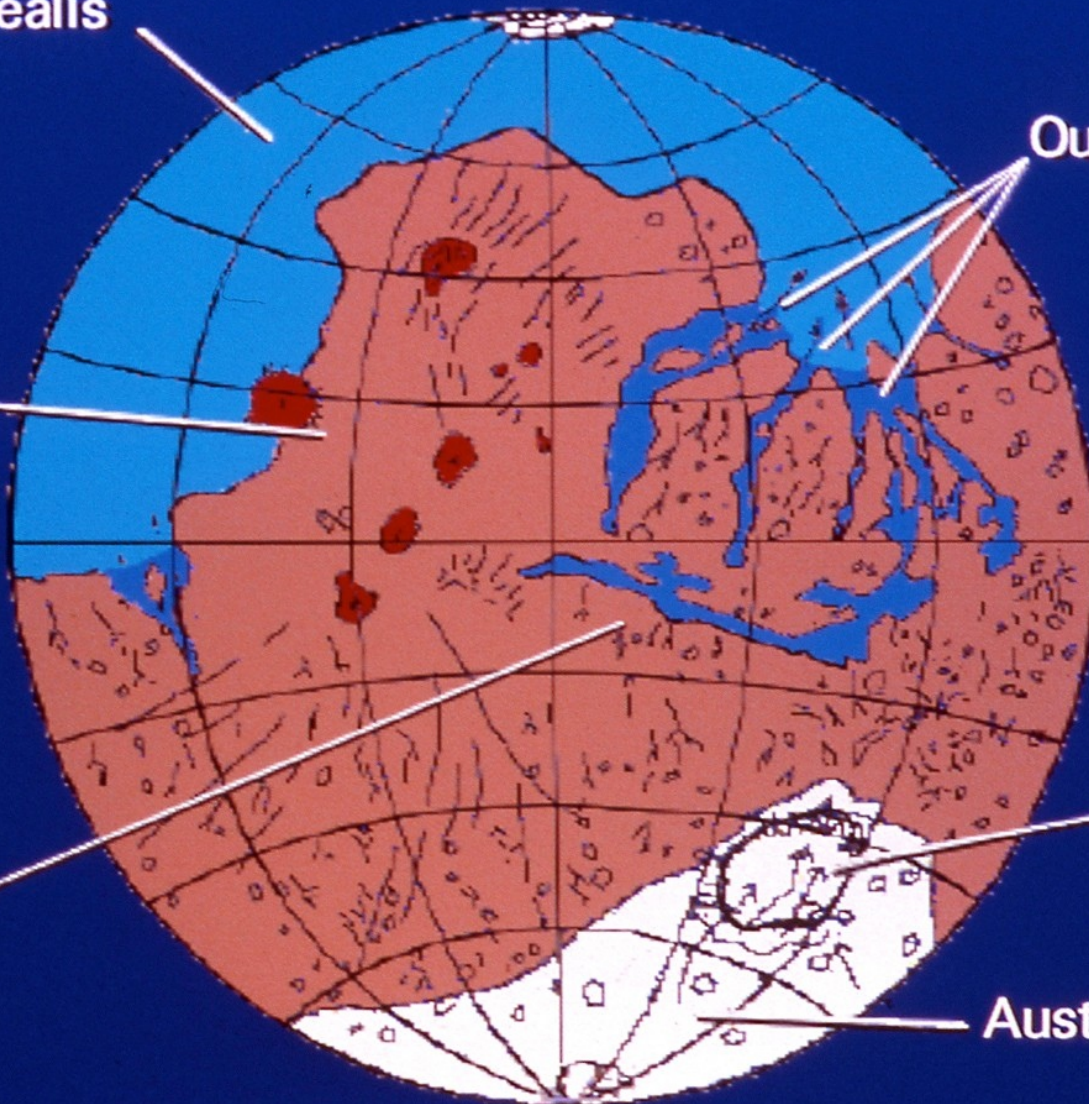
Outflow Channels

Tharsis  
Volcanic  
Province

Argyre Basin

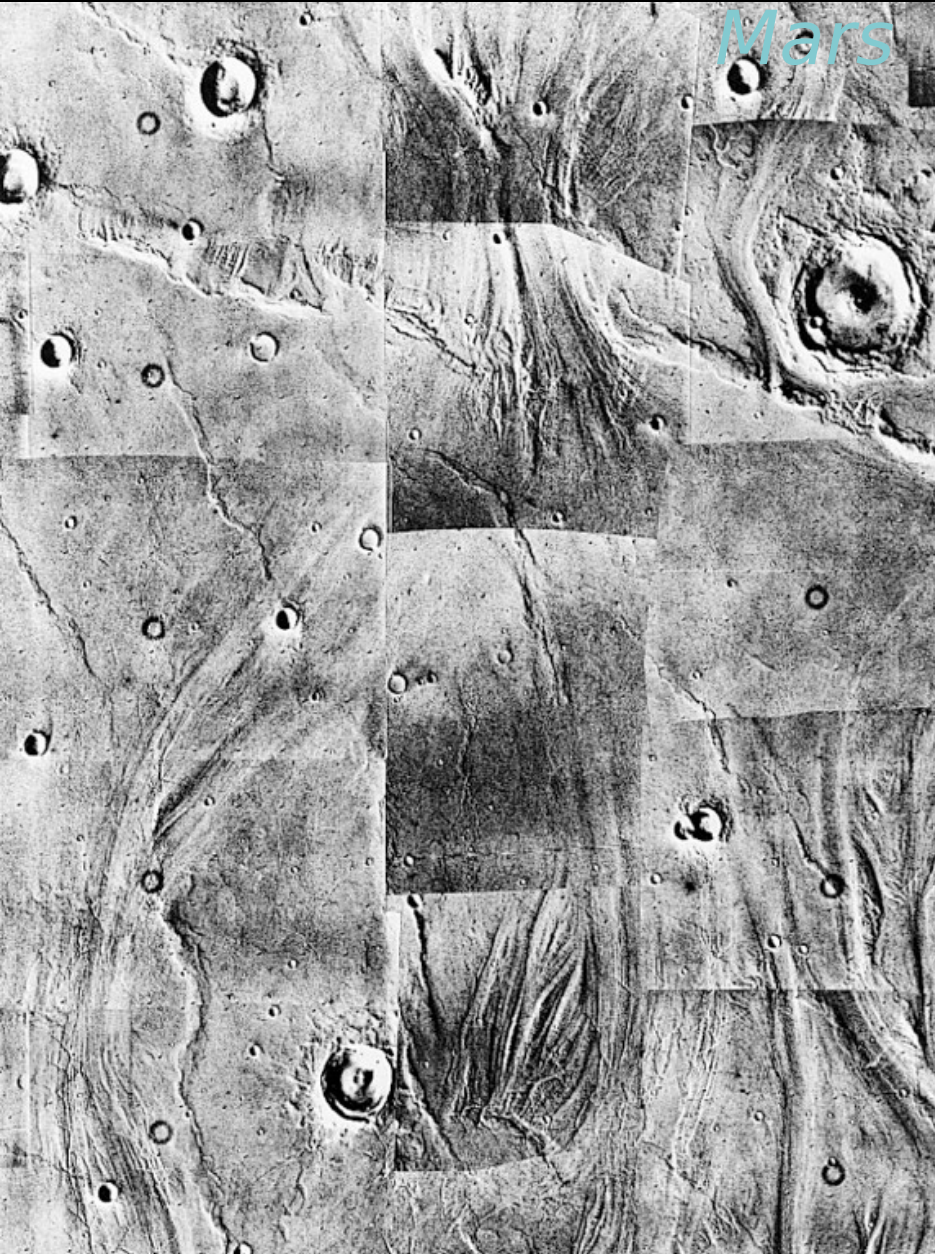
Valles  
Marineris

Austral Ice Sheet



# Water on

## Mars



⇒ Ancient Mars had flowing water on its surface.

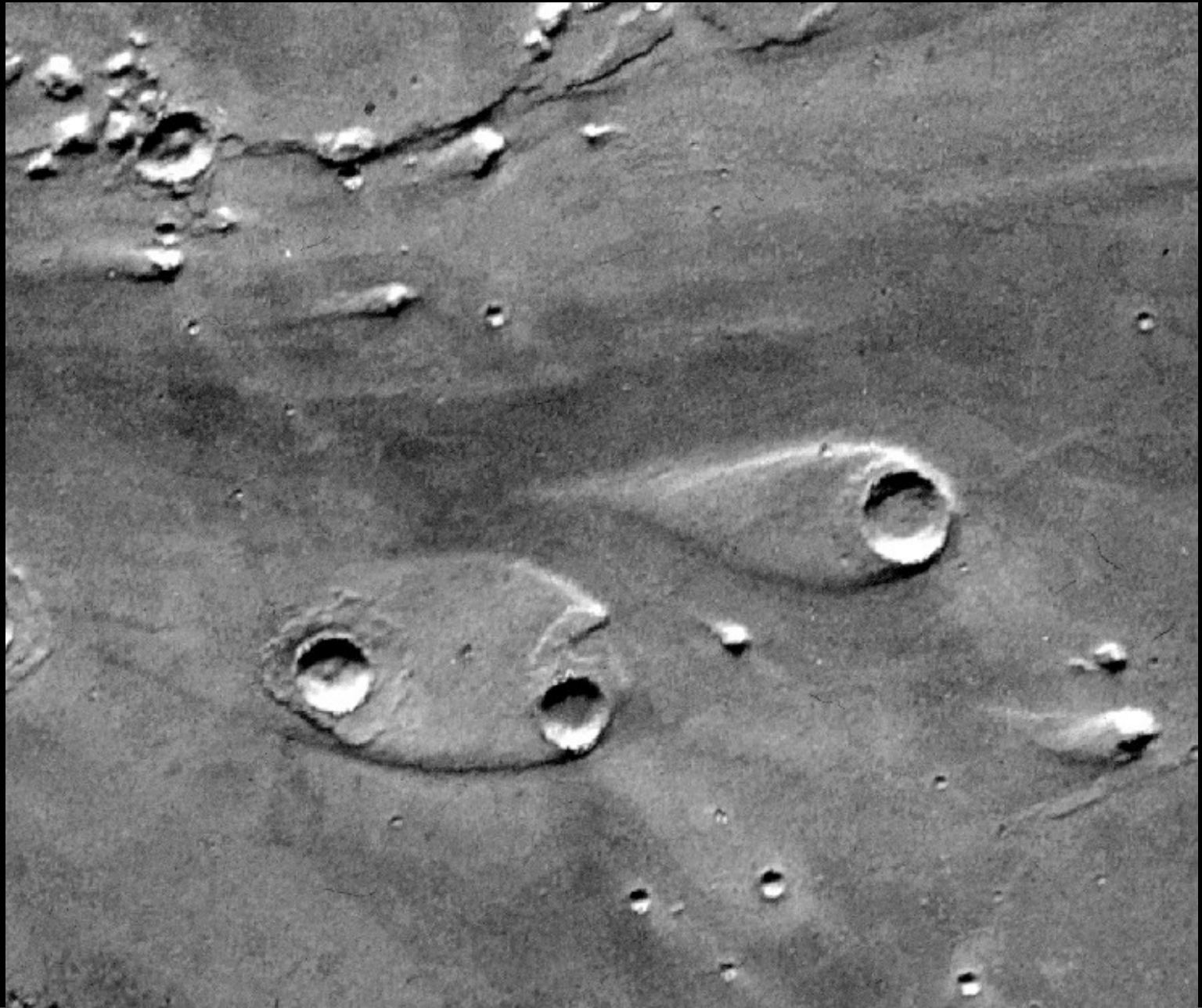
⇒ These images clearly show the results of what appears to have been flowing water.

⇒ The Viking landers actually recorded frost then forming, then evaporating.

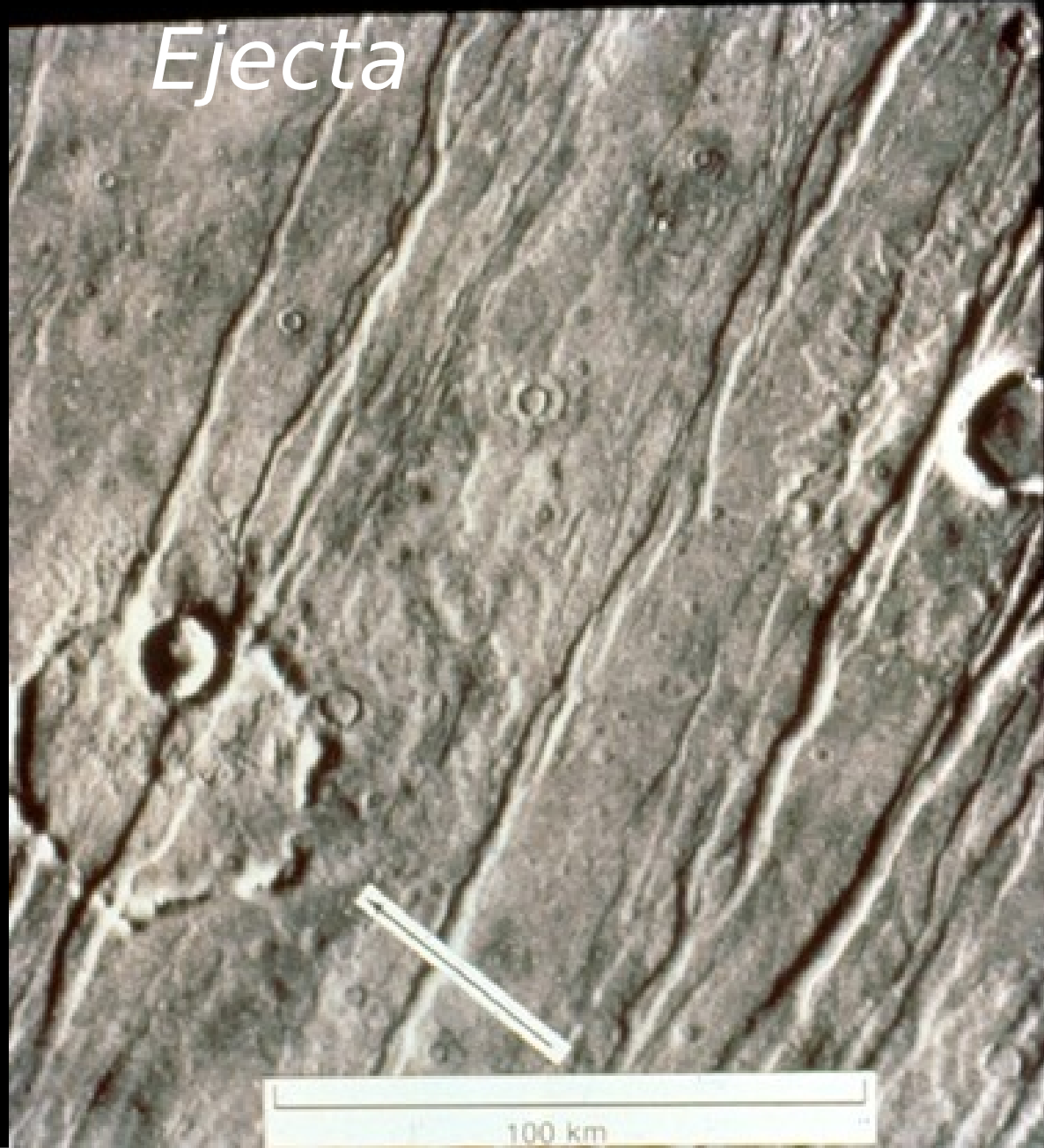
⇒ There does not seem to be any liquid water on Mars today.

⇒ It is possible that there may be surface water in shallow lakes under ice.

# *Channel*



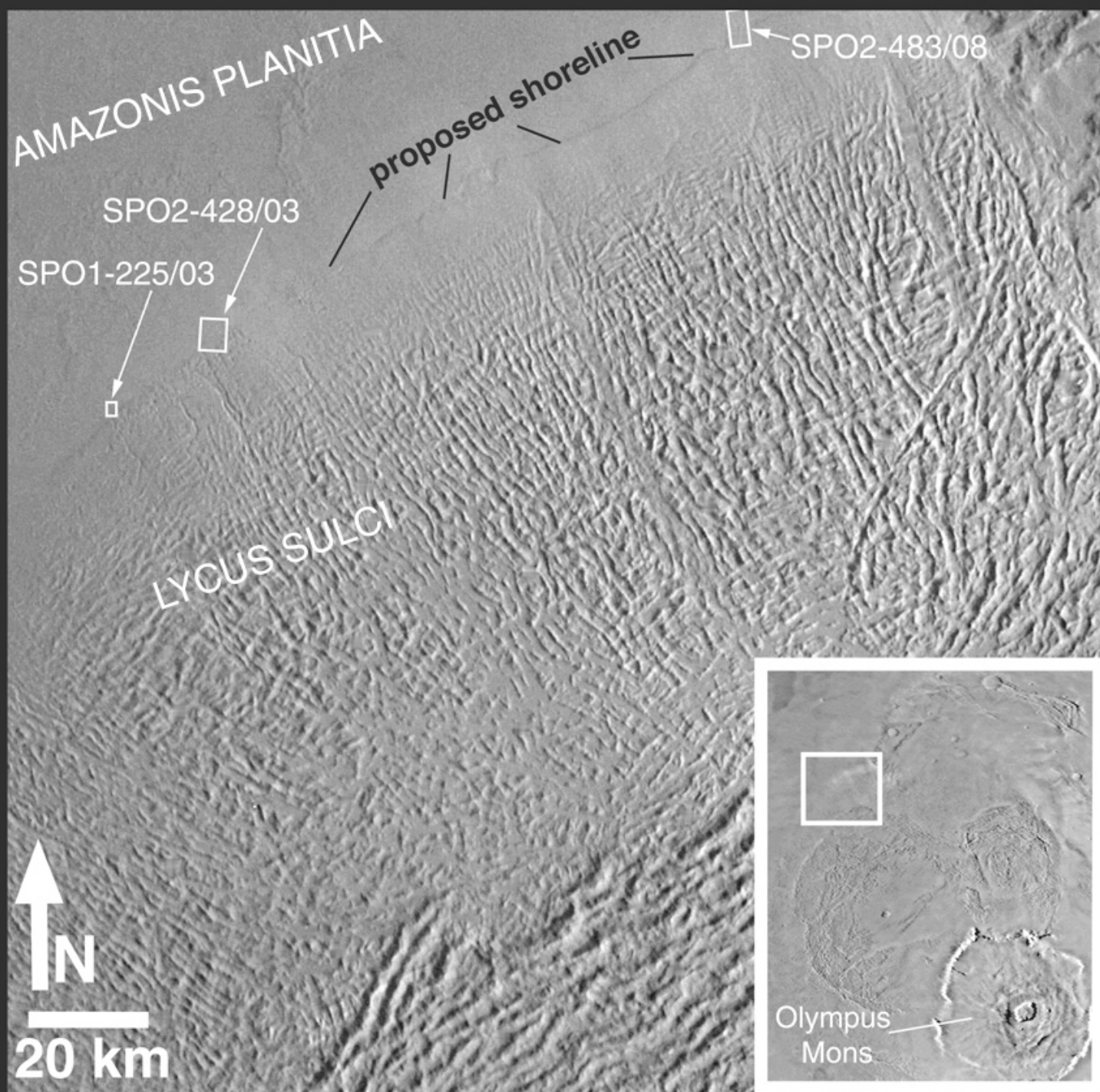
# *Erosion, Lobate Ejecta*



# *River*



# Ancient Martian Shoreline?



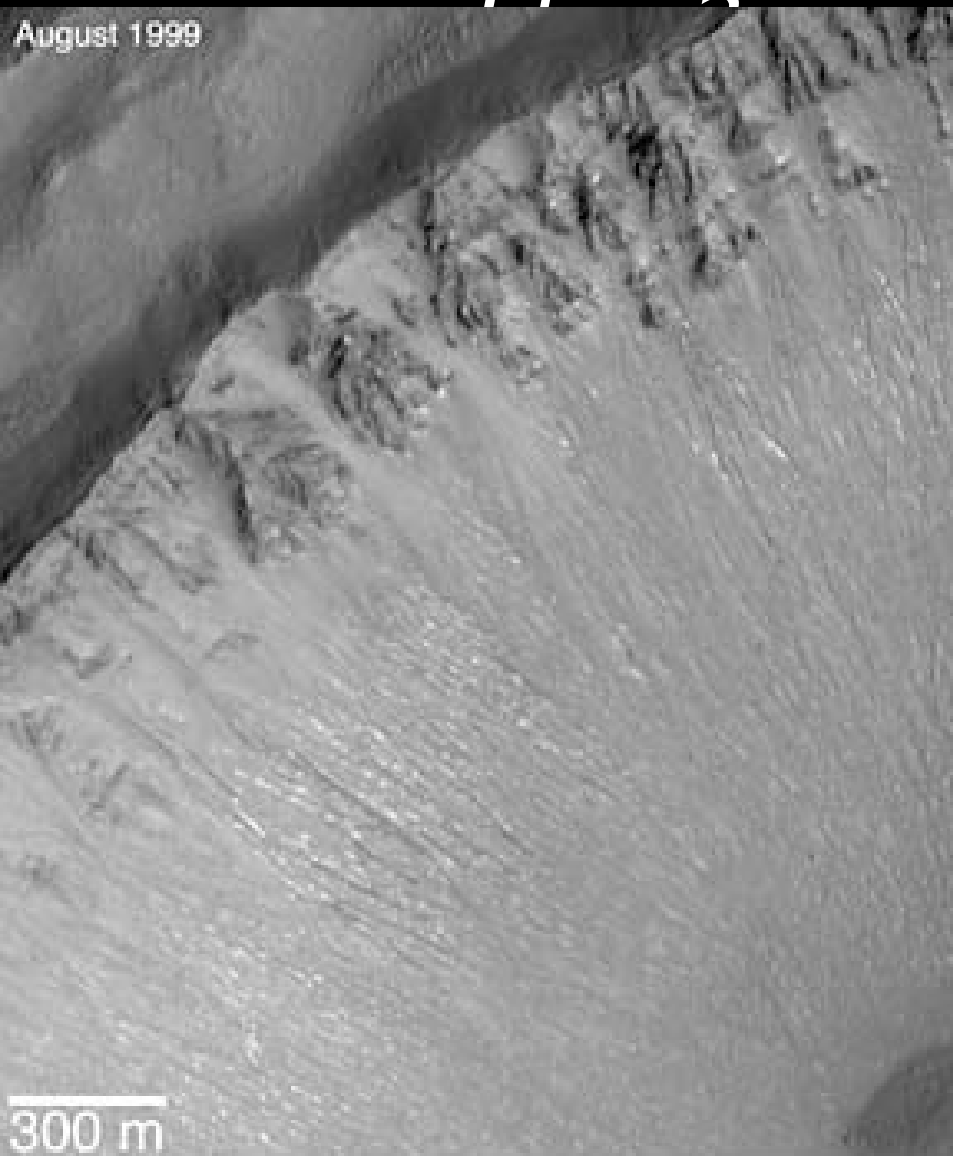
Shoreline? –  
Up Close  
and Personal



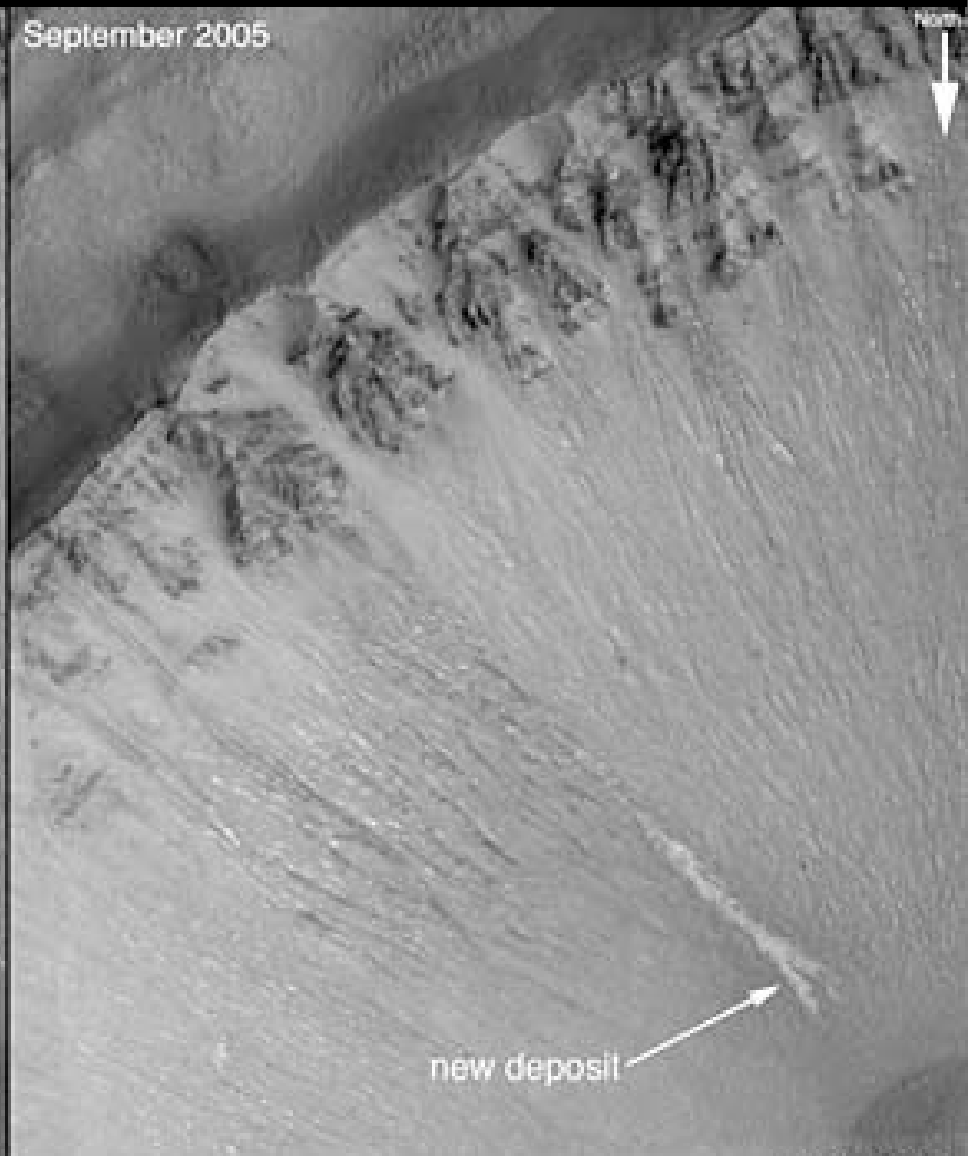


# New Groundwater

August 1999



September 2005



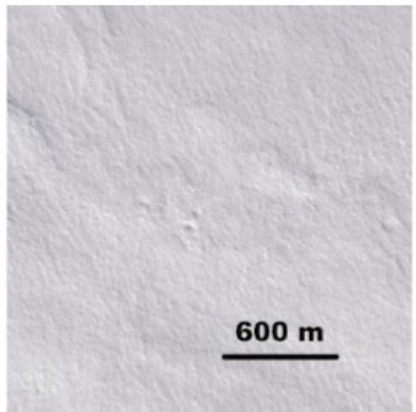
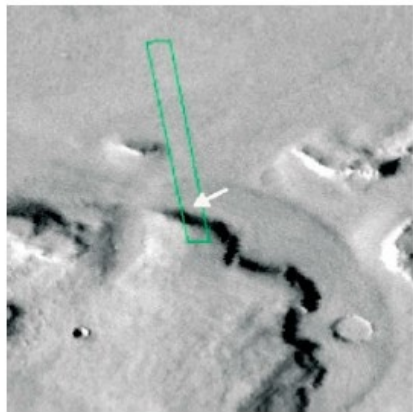
Normal



MOC wide angle

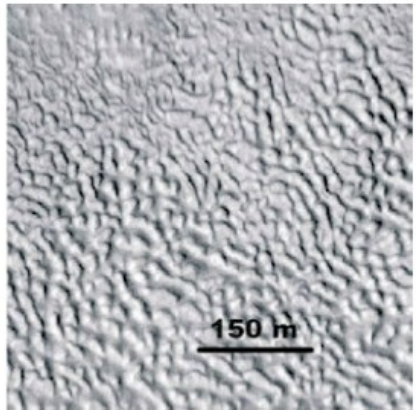
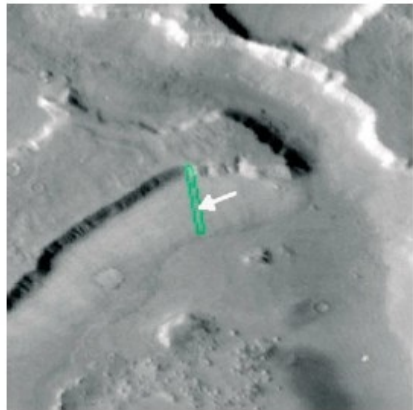
MOC narrow angle

# Debris Aprons



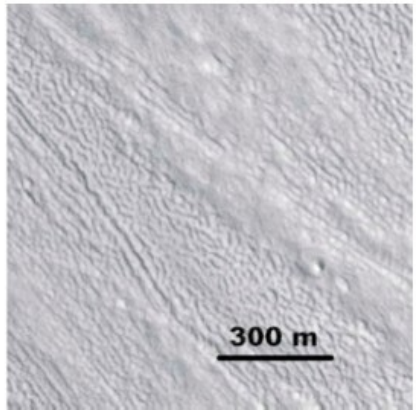
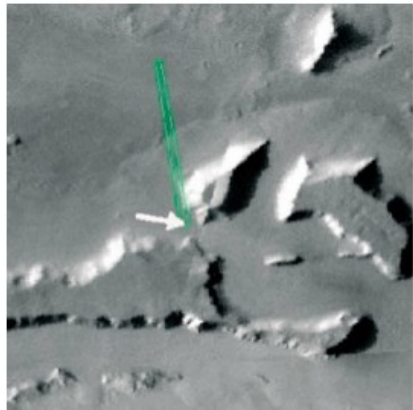
(a)

(a) Smooth surface texture may represent original apron surface



(b)

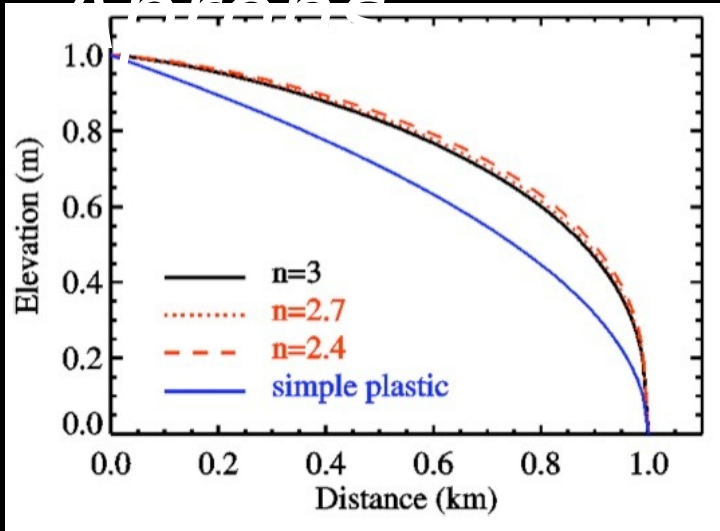
(b) Pitted surface texture may develop through ice sublimation induced collapse



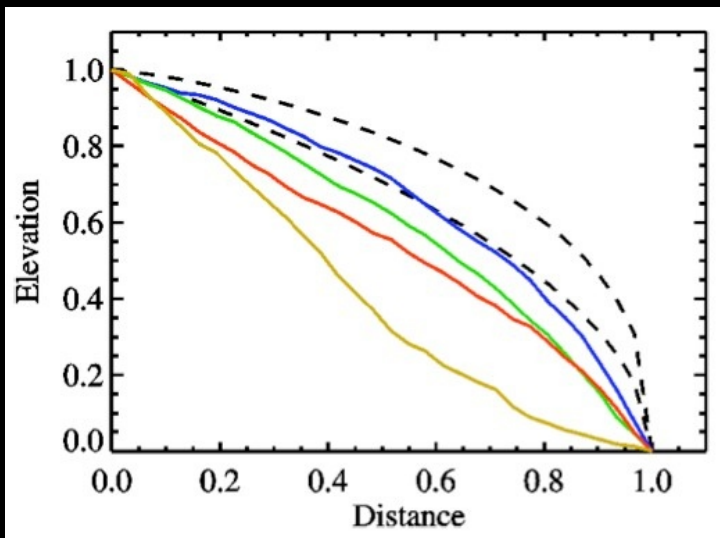
(c)

(c) Ridged texture

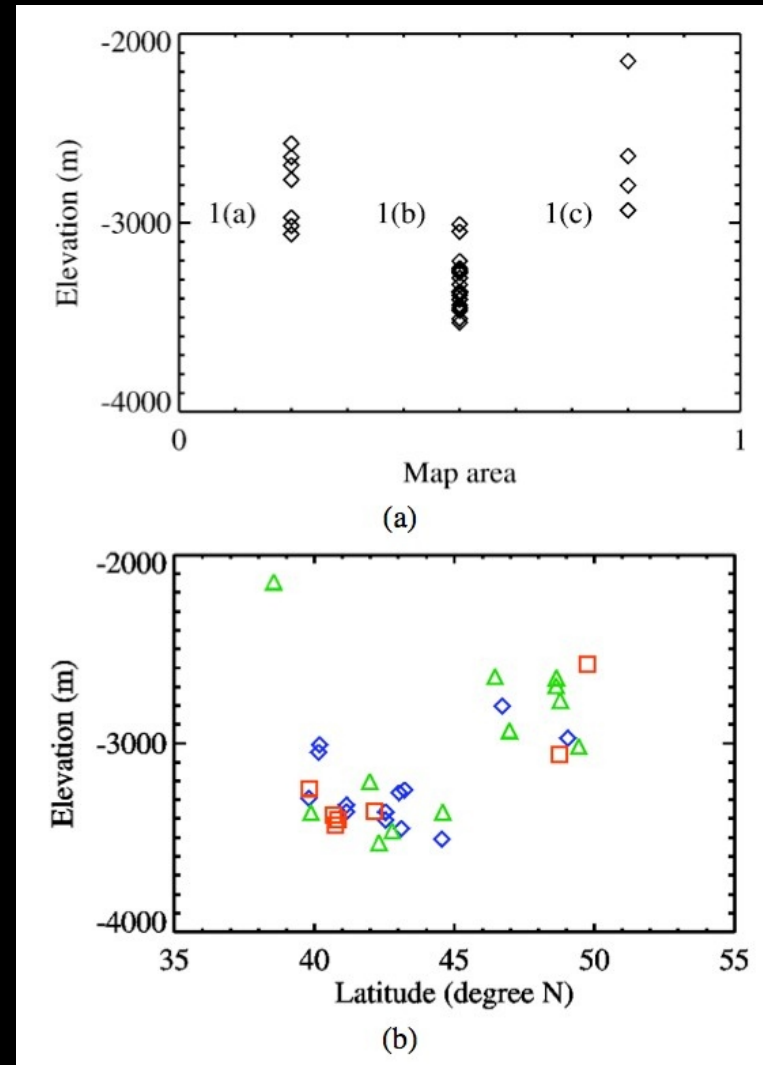
# Debris Aprons



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.



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

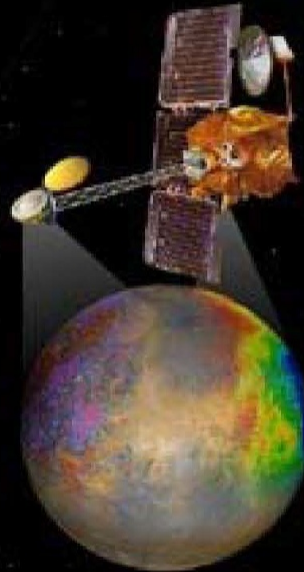


# NASA's Mars Exploration Program

Mars Global Surveyor (MGS)



Mars Odyssey



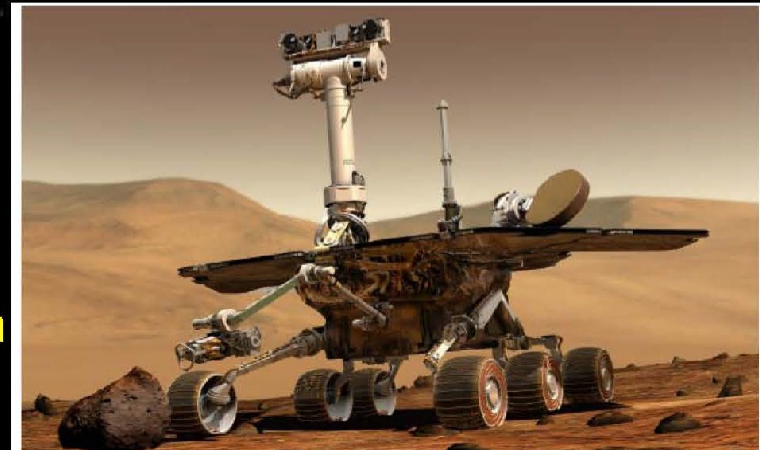
Mars Reconnaissance Orbiter



Mars Express



Mars Exploration Rovers (MERs)



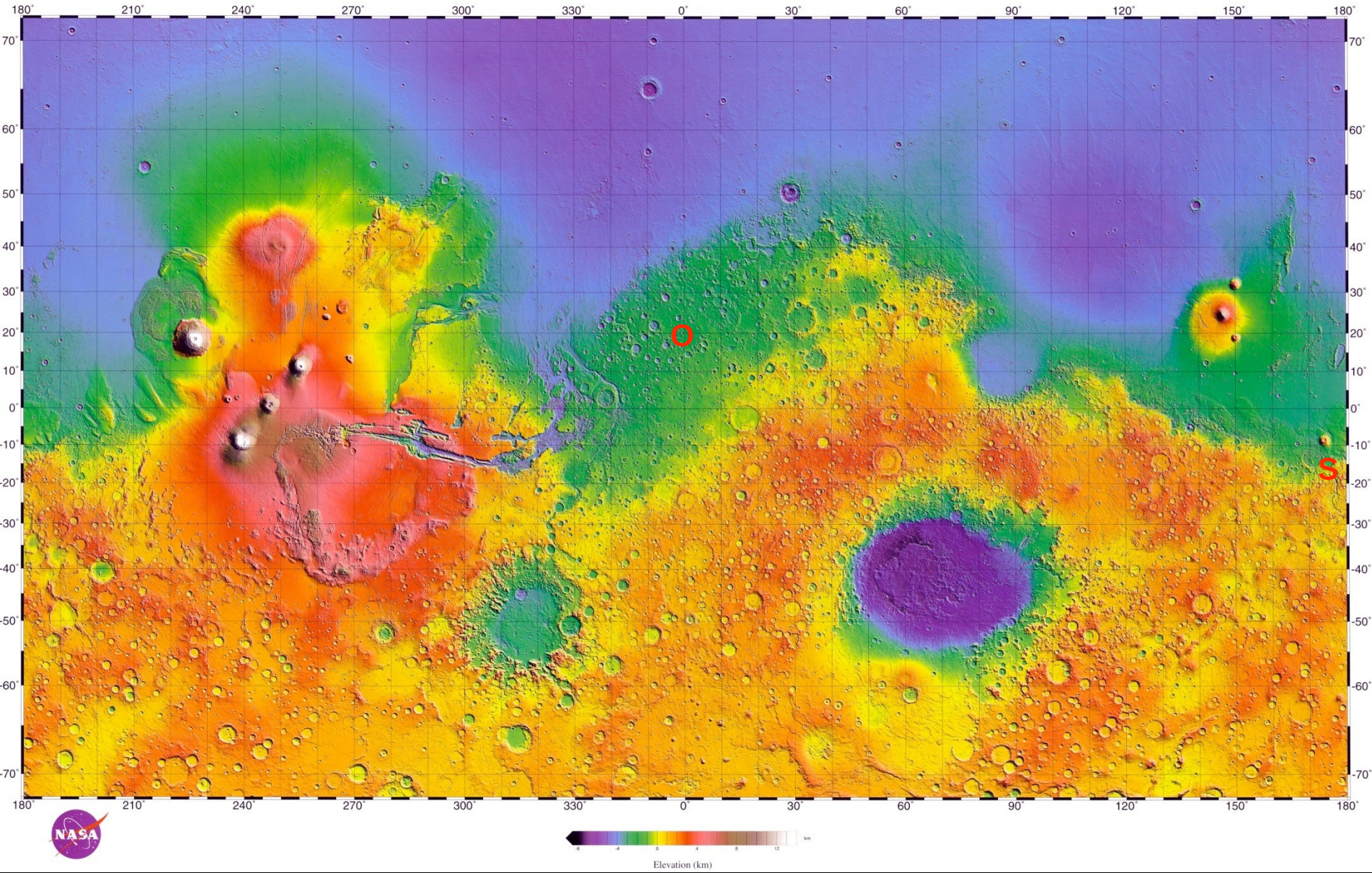
Artist's simulation of a Mars Exploration Rover at work on Mars.

# *Mars Global Surveyor Liftoff*

*November 7,  
1996*



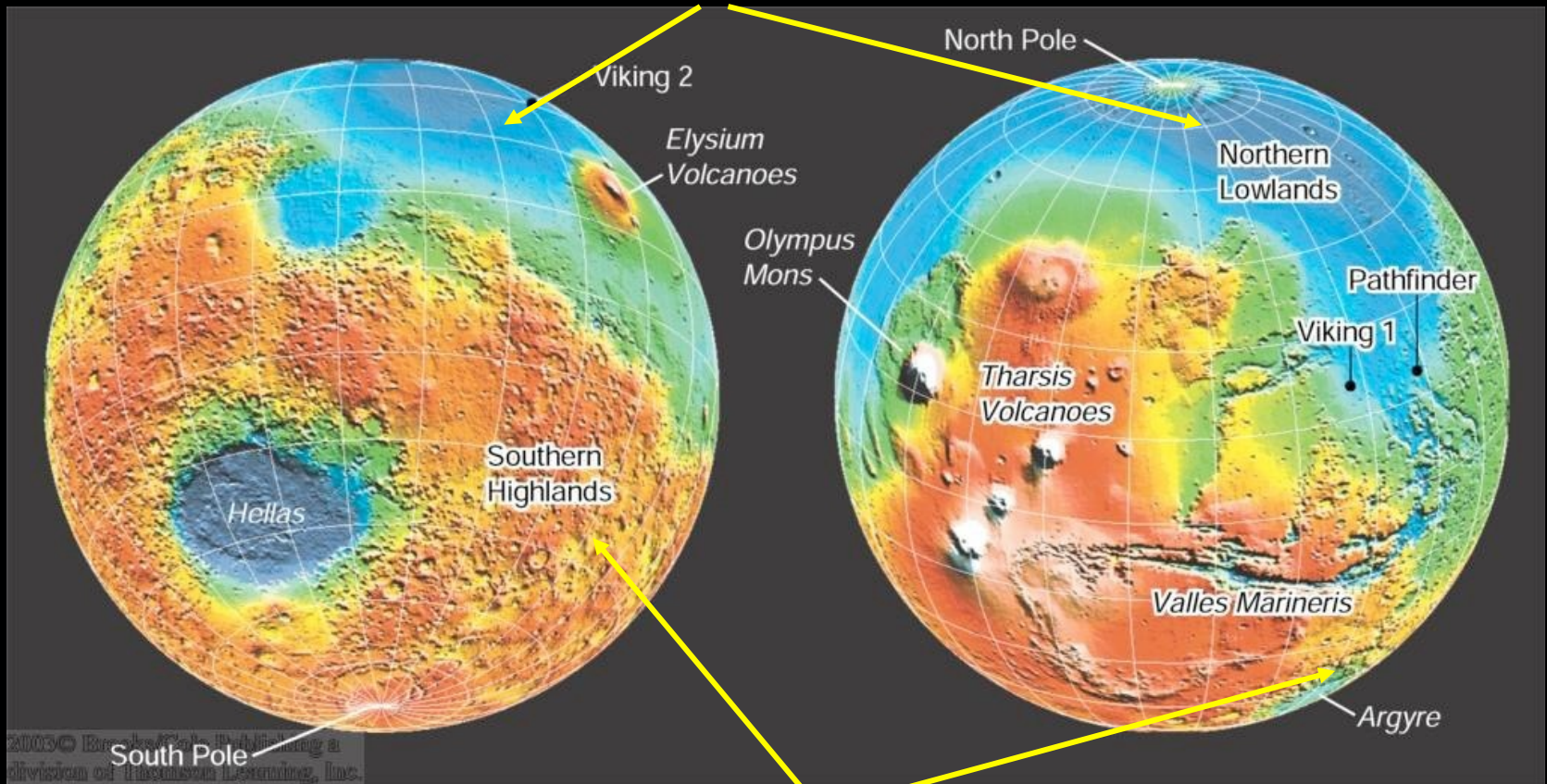
# The Topography of Mars



# The Geology of Mars

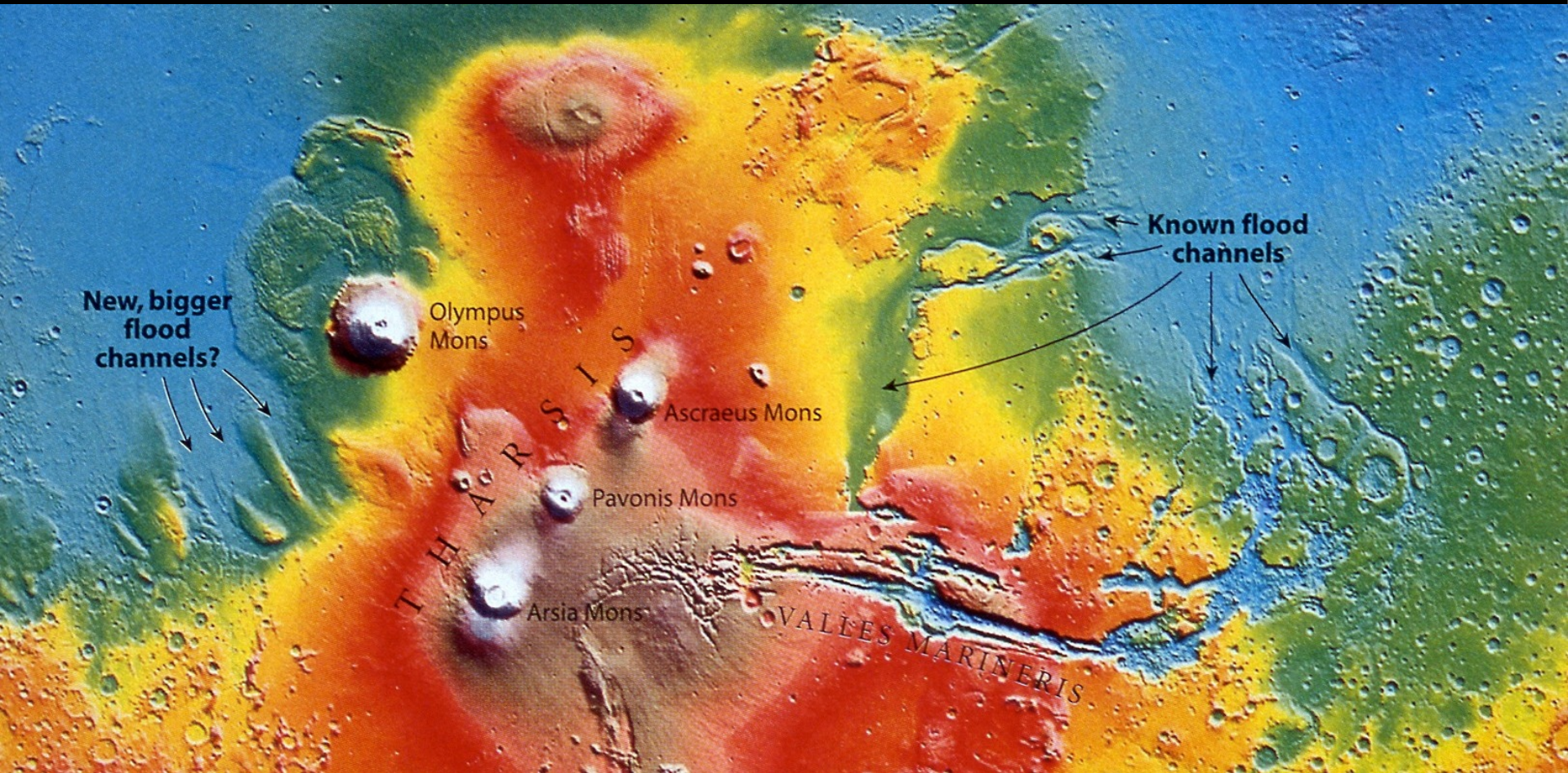
Northern Lowlands: Free of craters; probably re-surfaced a few billion years ago.

Possibly once filled with water.



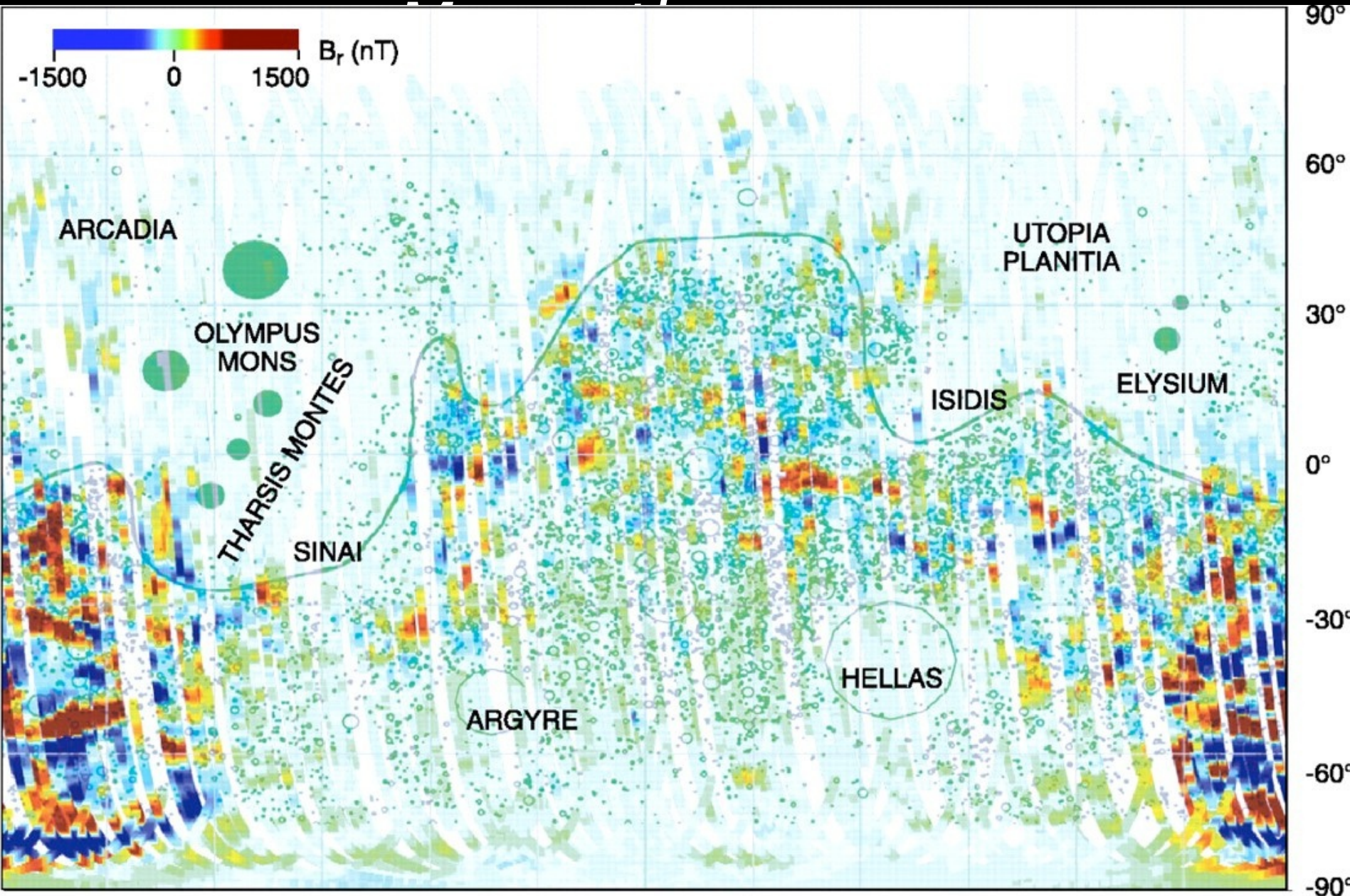
Southern Highlands: Heavily cratered; probably 2 – 3 billion years old.

# Tharsis Region Topography

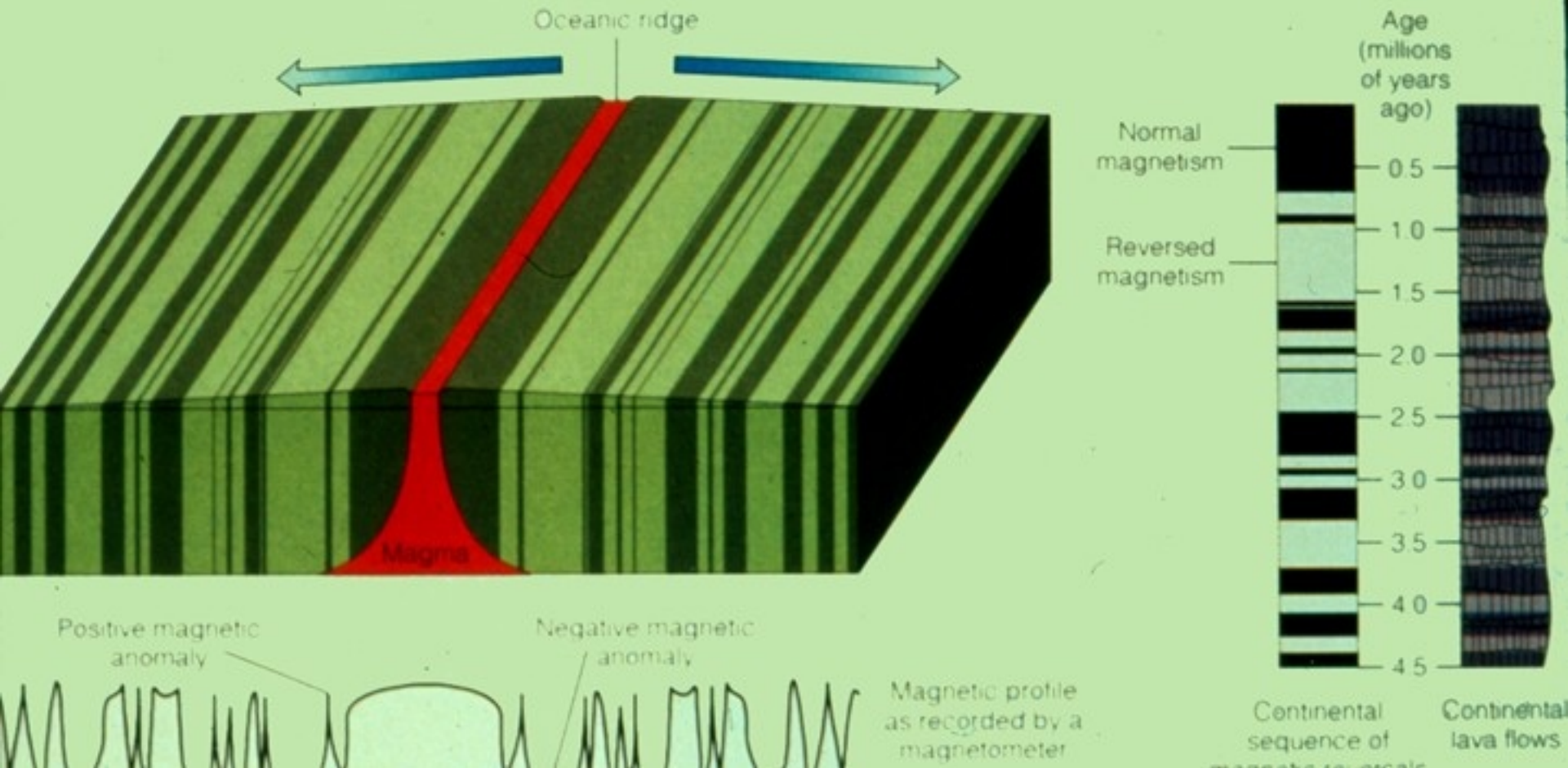




# Martian



# Generation of Magnetic Lineations



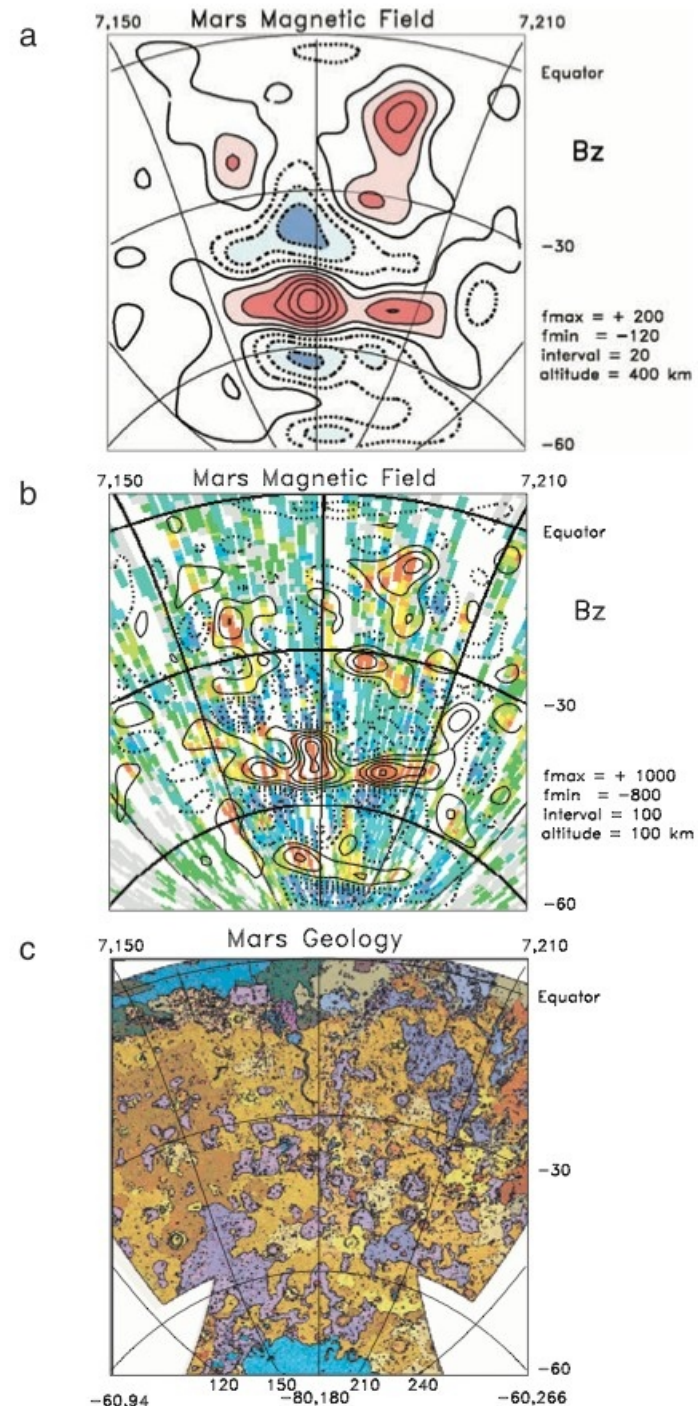
# Magnetization of Mars

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.

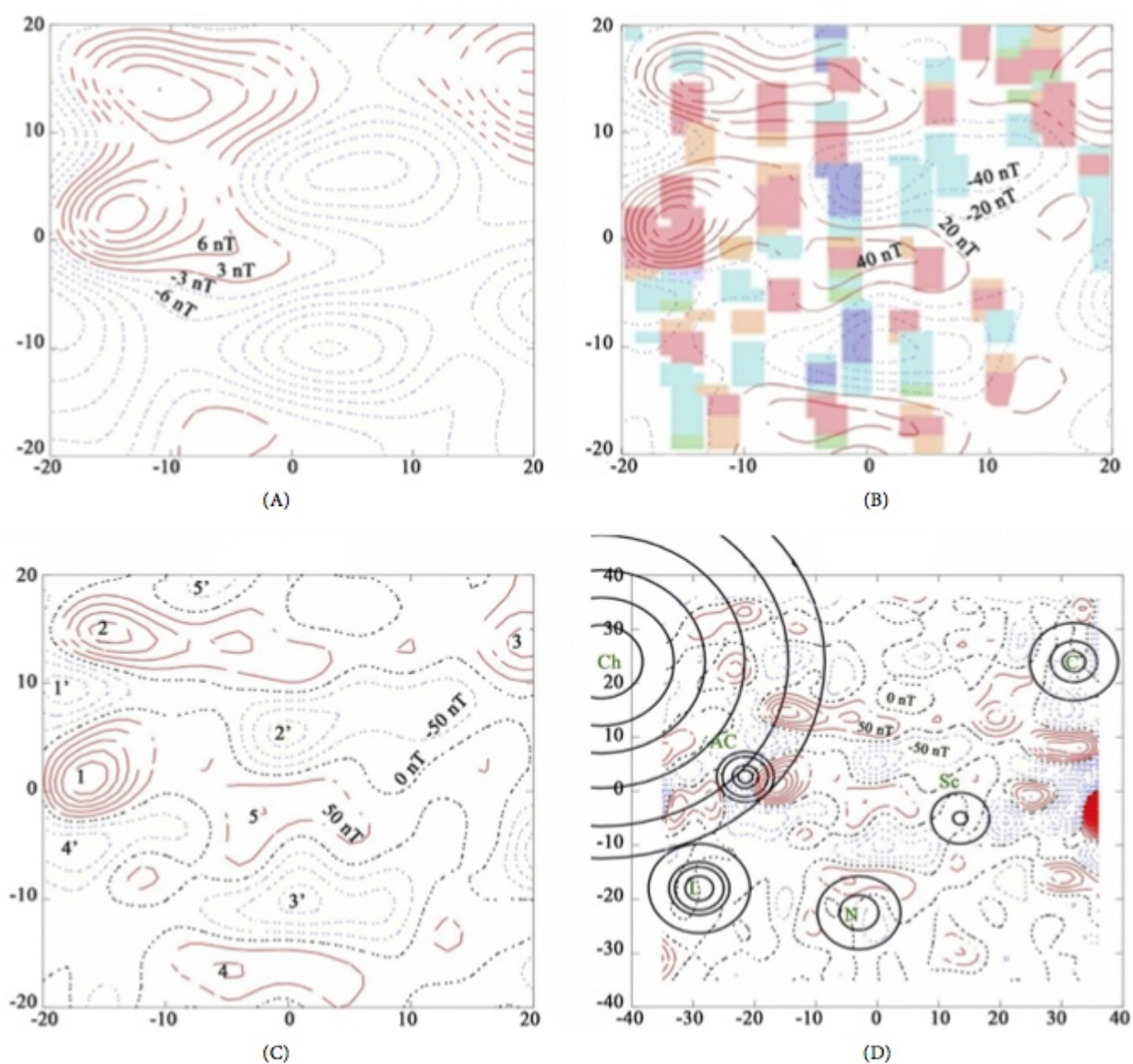
(c) Geology of Mars' highland terrain.



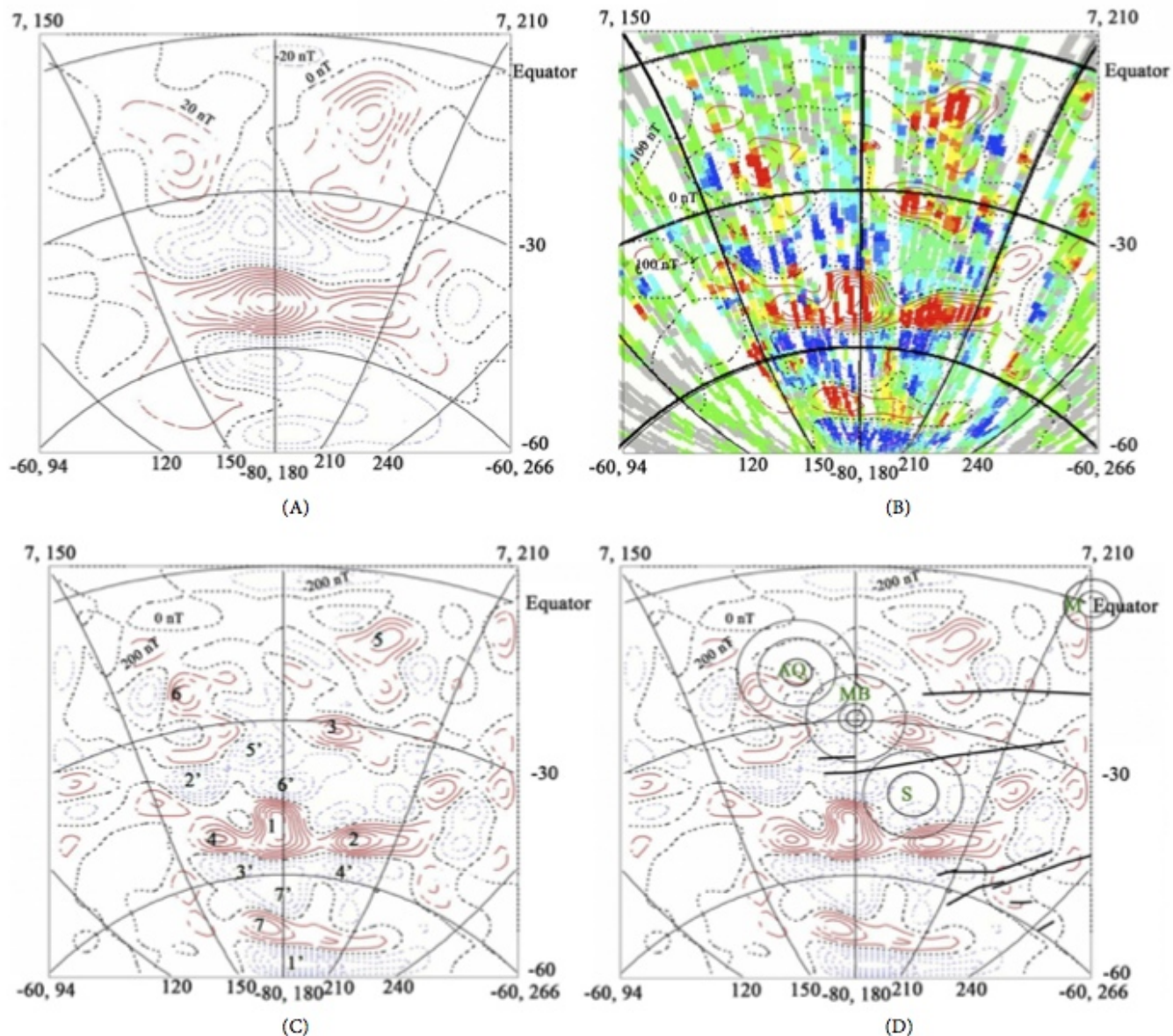
**Table 1.** Possible magnetic minerals of the Martian crust, their Curie temperatures [46], and the depth at which their Curie temperature is reached for multiple estimates of Martian heat flux ~3.7 - 4.5 Ga. Magnetic minerals are considered end members if part of a series (e.g., magnetite-titanomagnetite).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

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<sup>2</sup> [42]. b Using a 4 Ga heat flux range of ~2 - 100 mW/m<sup>2</sup> [41]. c Using a 4 Ga heat flux range of 53 - 67 mW/m<sup>2</sup> [29]. d Using a 4 Ga heat flux of 66 mW/m<sup>2</sup> [22]. e Using a 4.0 - 3.7 Ga global mean heat flux range of 17 - 32 mW/m<sup>2</sup> [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<sup>2</sup> [44]. g Using an "early" Mars heat flux range of 37 - 57 mW/m<sup>2</sup> 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  $\sim 35^\circ \times 35^\circ$  with regional multi-ringed basins [49] (Ch = Chryse, L = Ladon, AC = Aram Chaos, N = overlapped by Newcomb, Sc = overlapped by Schiaparelli, C = Cassini).

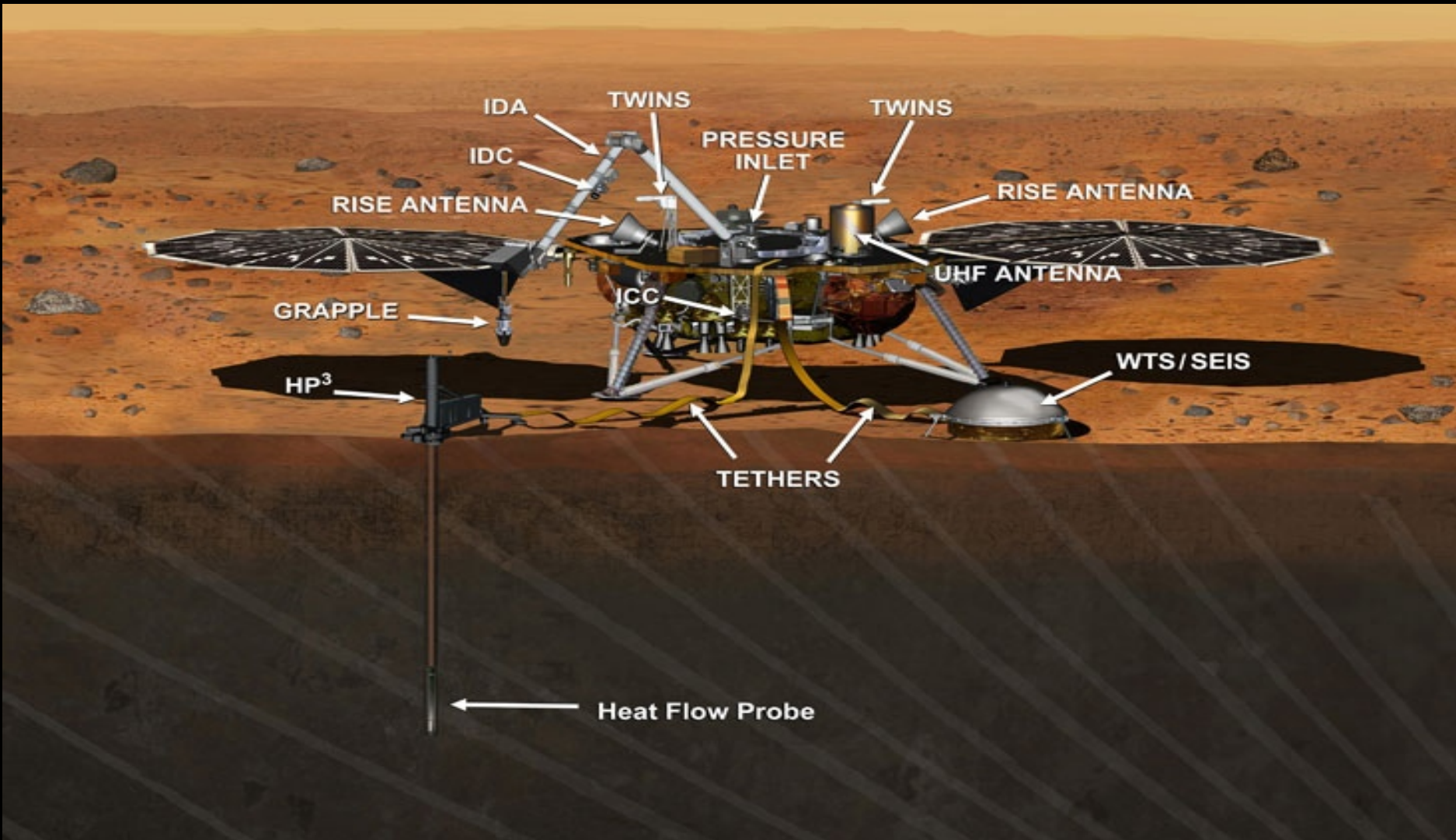


**Figure 2.** Magnetization in Terra Sirenum. Each base map uses MGS MAG Br data. (A) Data collected at 400 km (mapping) altitude (contour interval is 20 nT); (B) 400 km data downward continued to 100 km (contour interval is 100 nT) and correlated with aerobraking data (swaths) collected at the same 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).

# INSIGHT Mars Mission

- Interior Exploration using **S**eismic Investigations, **G**eodesy and **H**eat Transport.
- The mission's objective is to study early geological evolution.
- Launching May 5, 2018





IDA

TWINS

TWINS

IDC

PRESSURE INLET

RISE ANTENNA

RISE ANTENNA

UHF ANTENNA

GRAPPLE

ICC

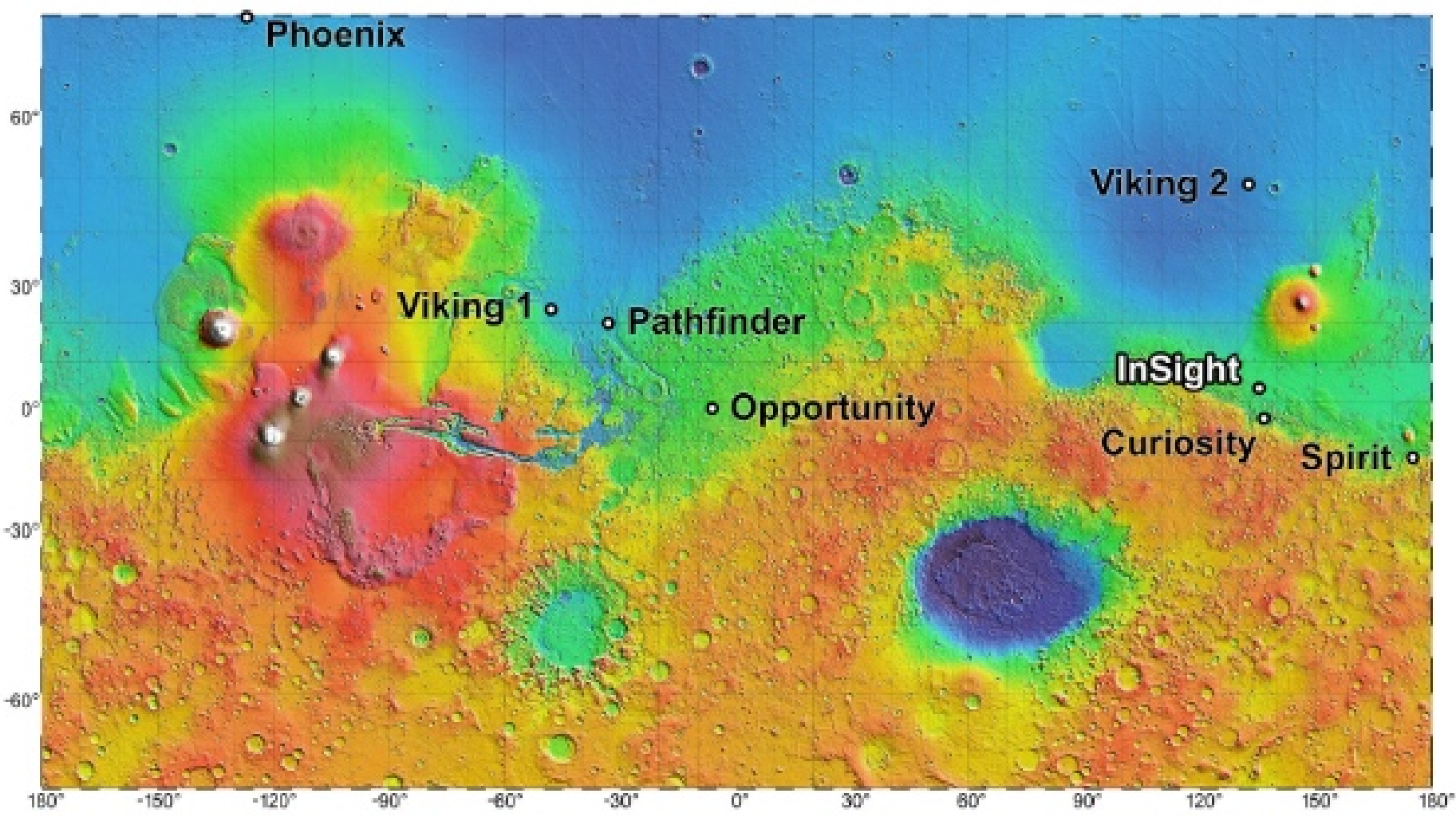
HP<sup>3</sup>

WTS/SEIS

TETHERS

Heat Flow Probe





# Conclusions

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- *Mars had a magnetic field early in its history.*
- *Martian crust either very strongly magnetized or extending to great depth. Perhaps both.*
- *True Polar Wander may have occurred on Mars.*
- *InSight lander will include seismometer and heat flow experiment, projected launch May 5, 2018.*