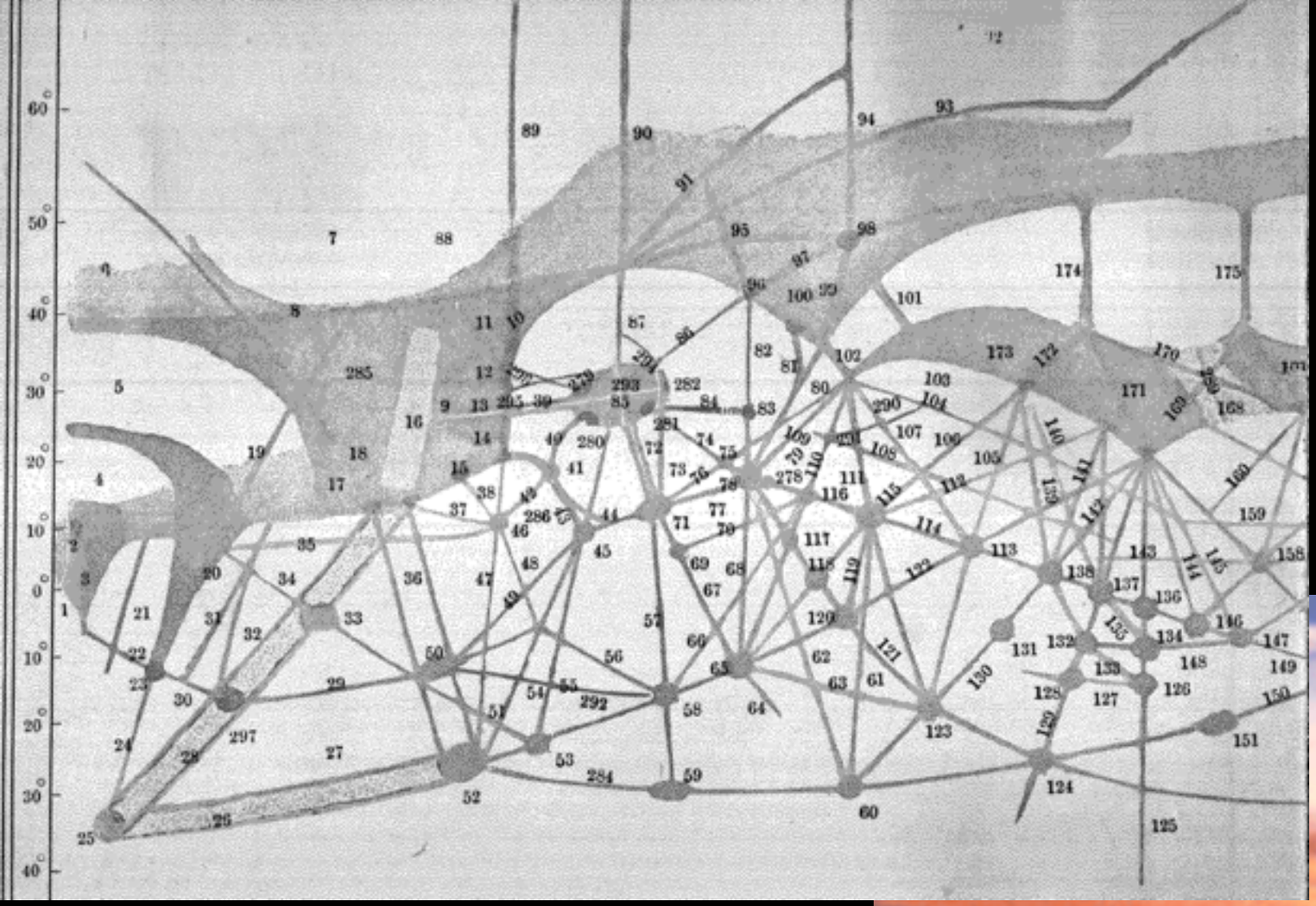
Life in our Solar System: Mars

Image Courtesy of Kees Veenenbos


60°
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40°
30°
20°
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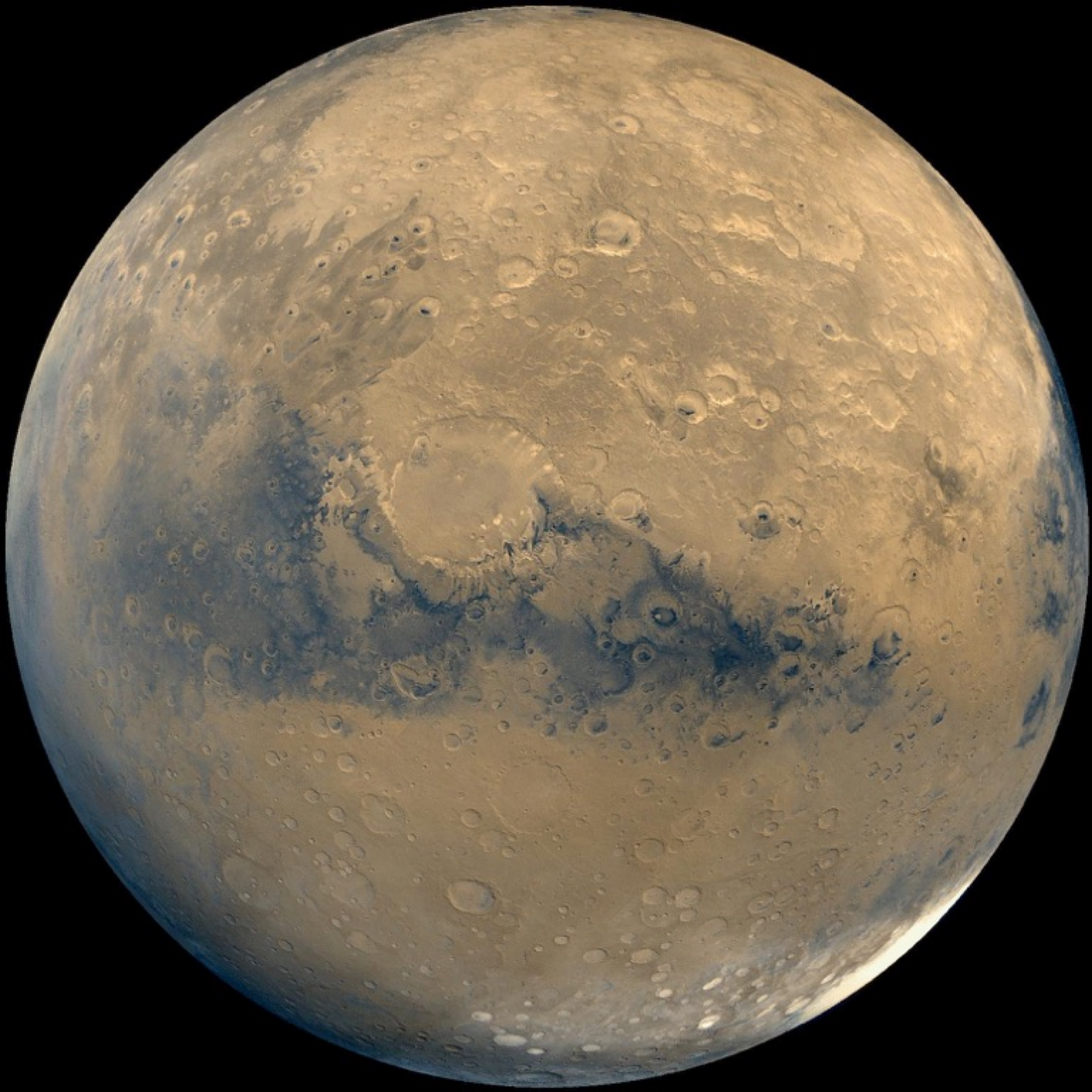
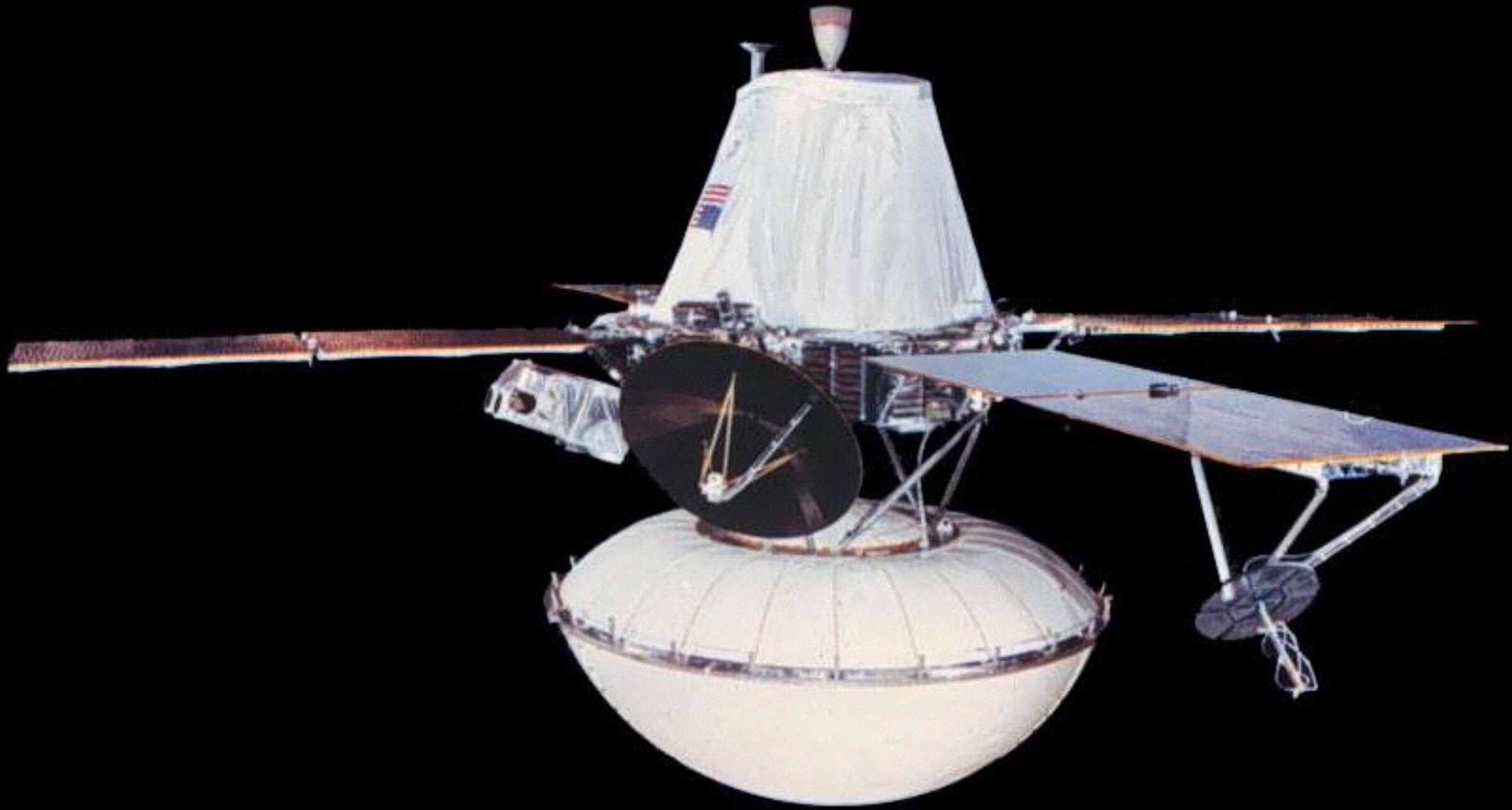
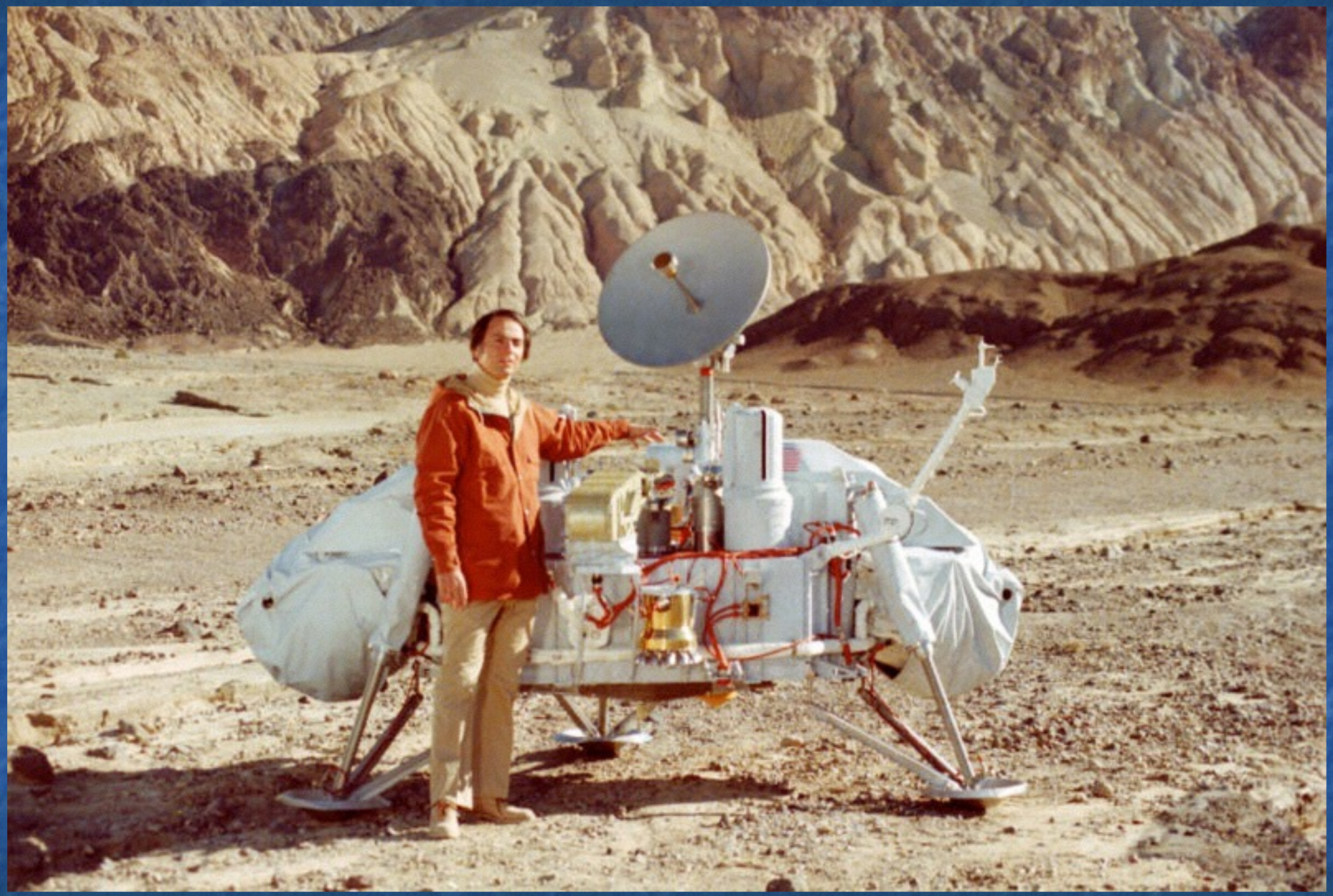
0°
10°
20°
30°
40°

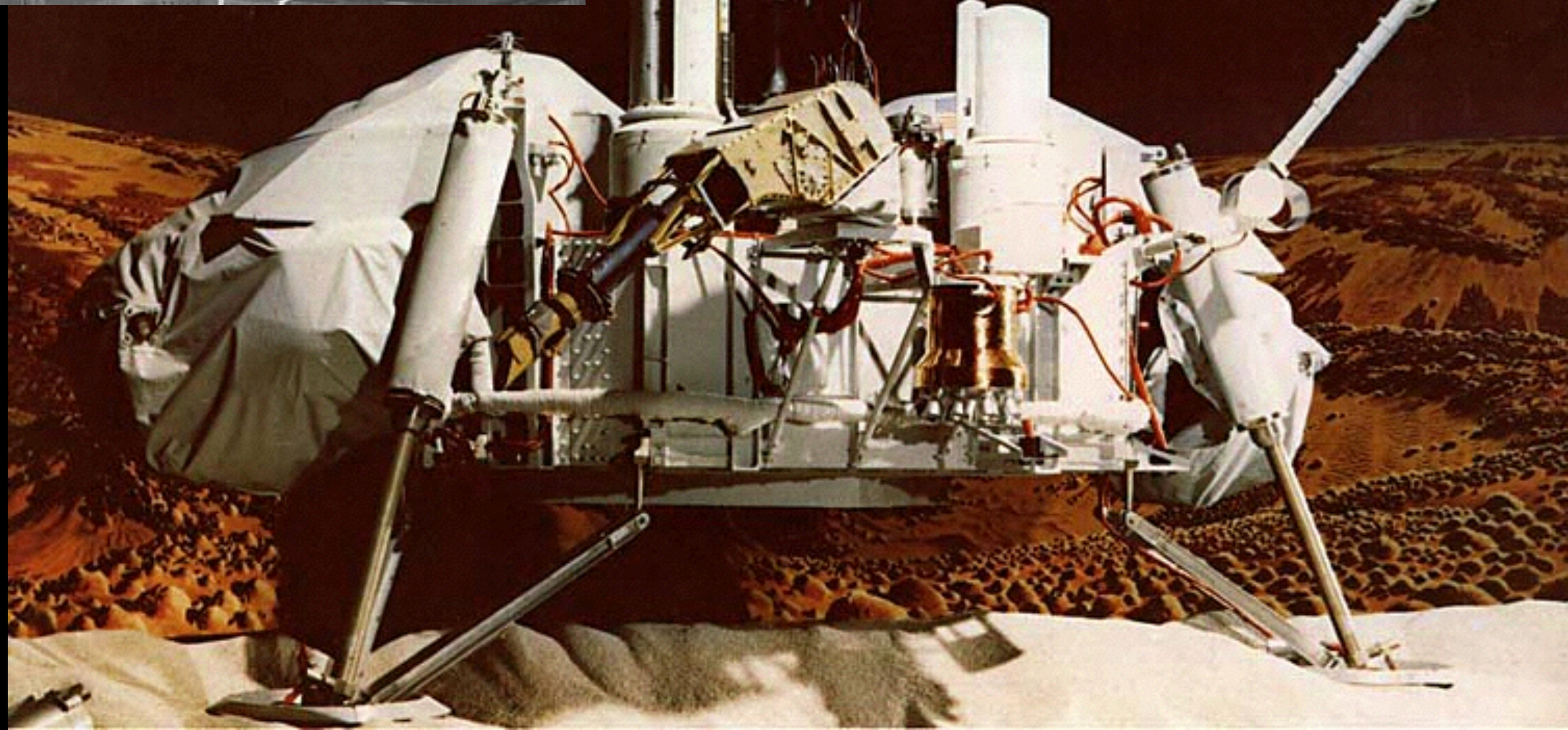


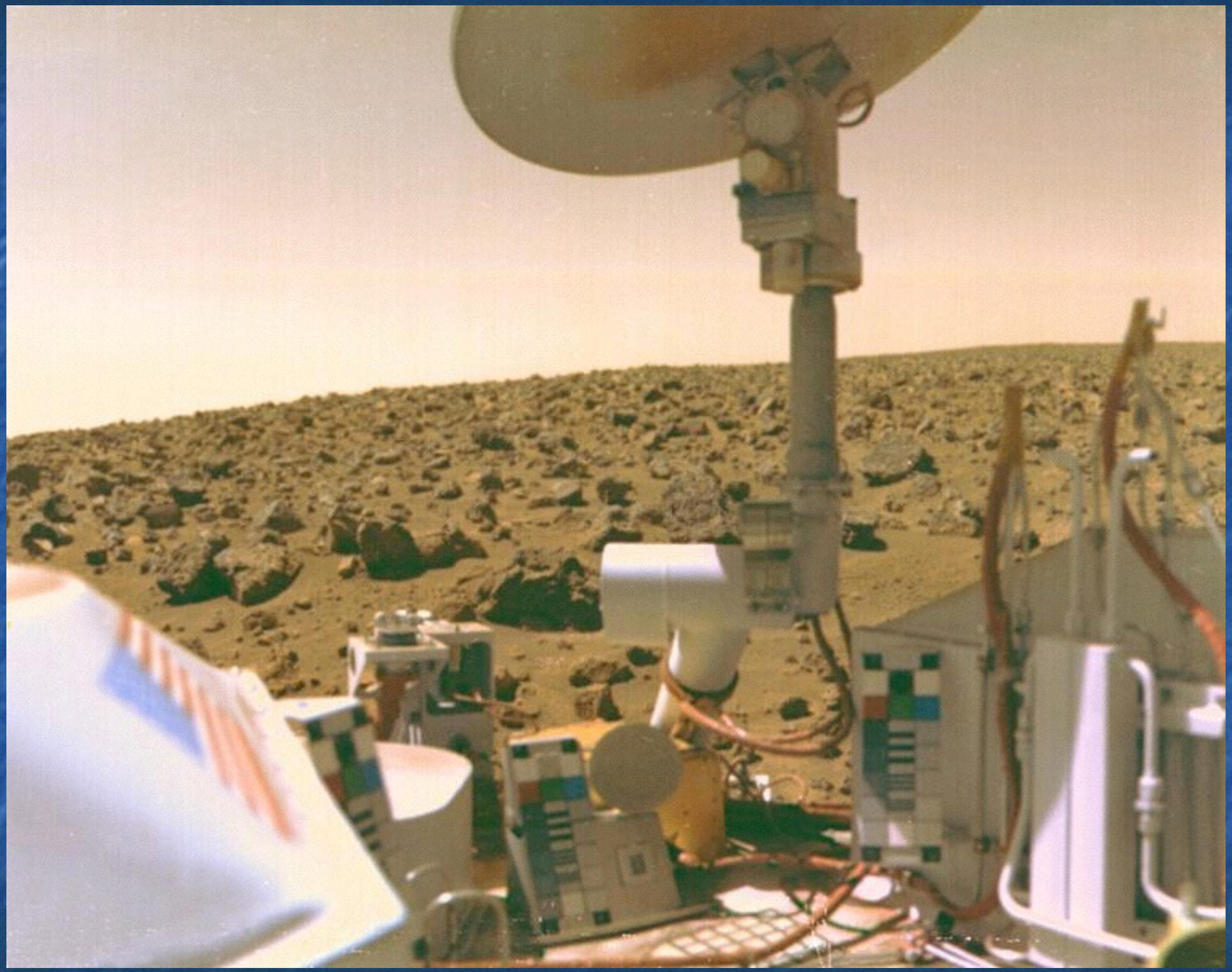
Mars as a life bearing planet?

- Mars has been visited by some 18 probes over the last 50 years and more will follow in the next decade.
- Why?
- As part of the general exploration of the Solar System.
- In addition, Mars offers one of the best environments in which to search for life in the Solar System.
- It is not the best possible habitat for life in the Solar System (some of the Jovian moons could be argued to offer that possibility)
- But it is one of the easier parts of the Solar System to travel to and land on.

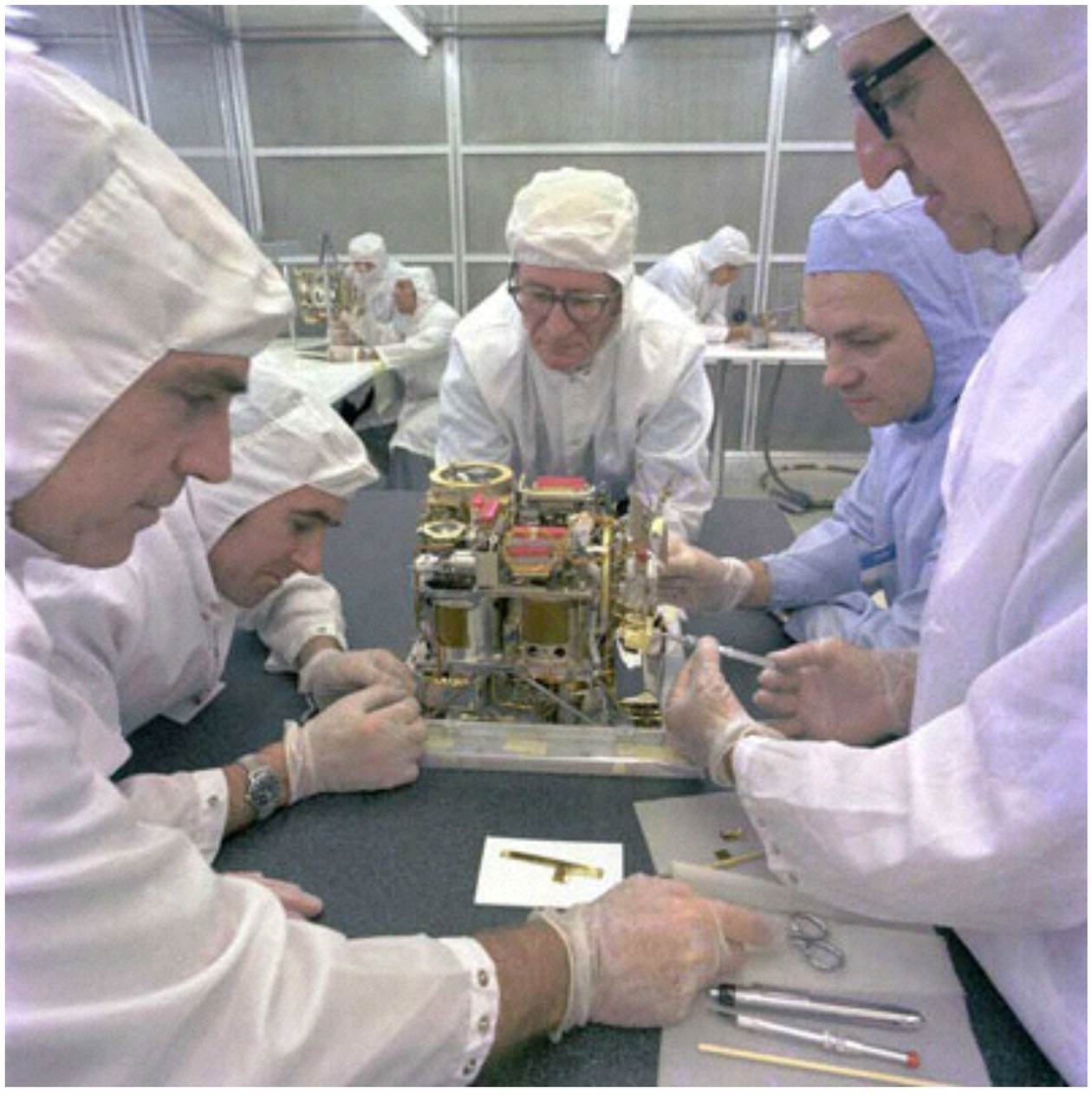






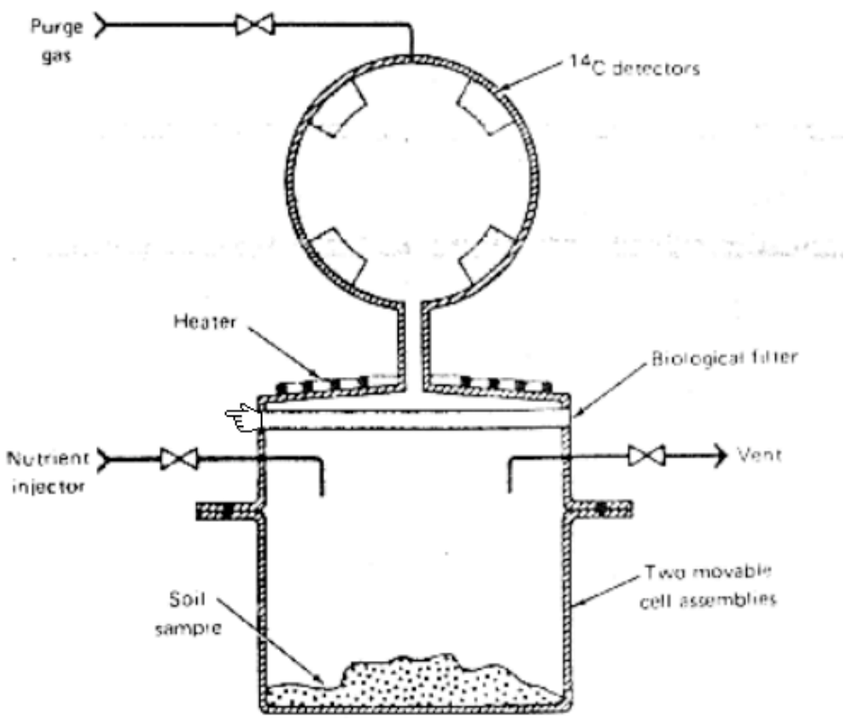


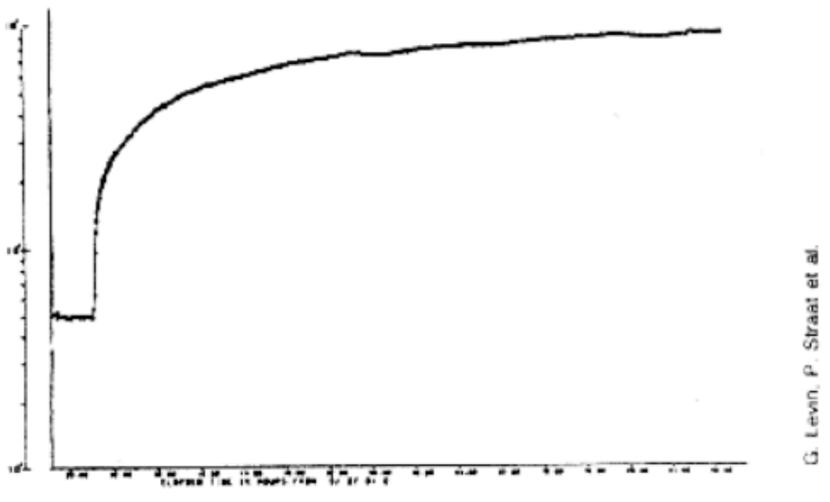
The Viking Biology Package



- Carbon Assimilation:
  - Expose soil to gases with radioactively labeled carbon, then pyrolize.
  - **Negative result**
- Gas Exchange:
  - Mix water and wet nutrients with soil and analyze released gases
  - **Negative result**
- Labeled Release
  - Feed radioactively labeled nutrients to martian microbes
  - **Positive result**
- GCMS: Failed to detect organics in martian soil at ppb

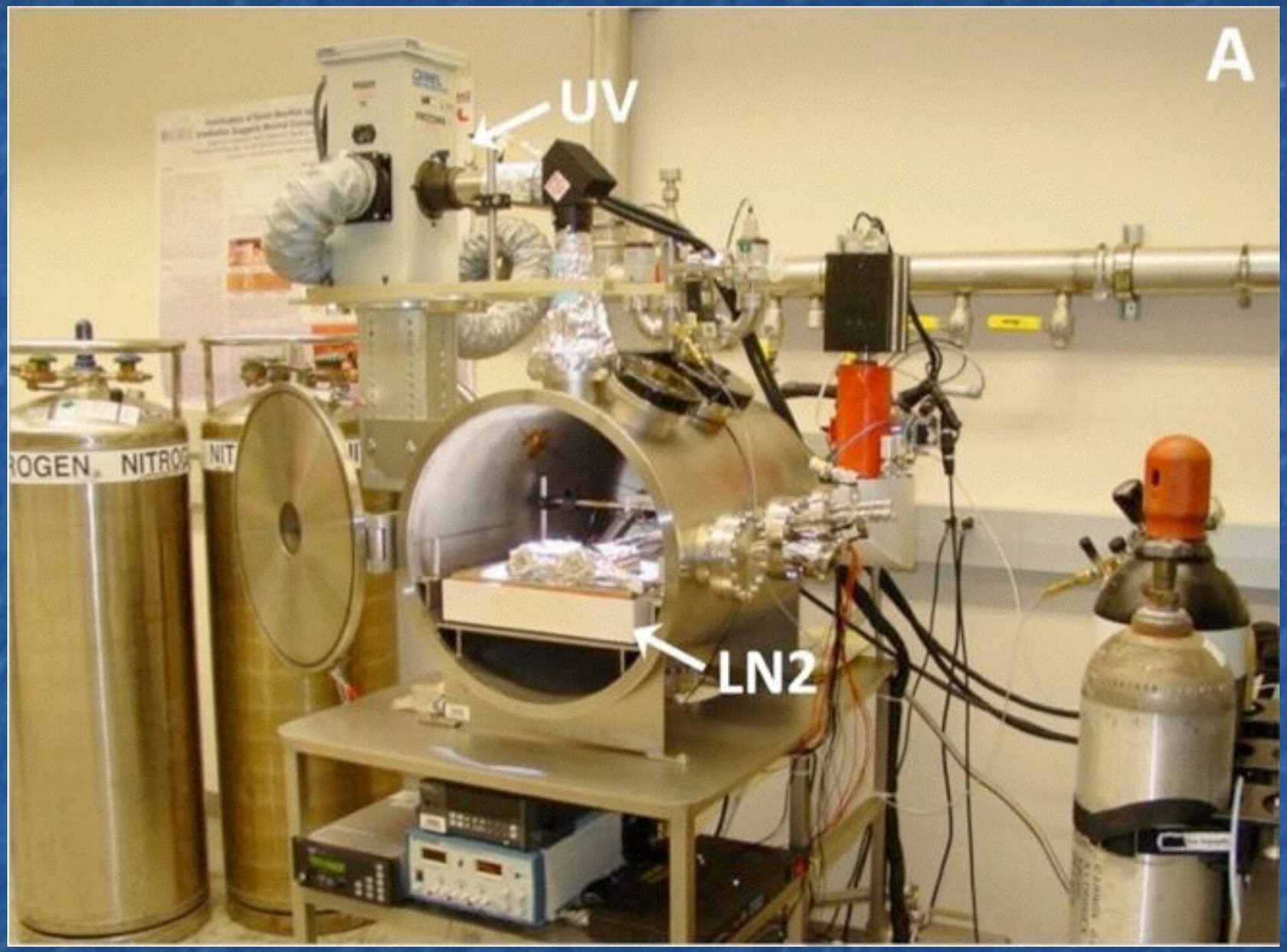
The Viking Labeled Release Experiment

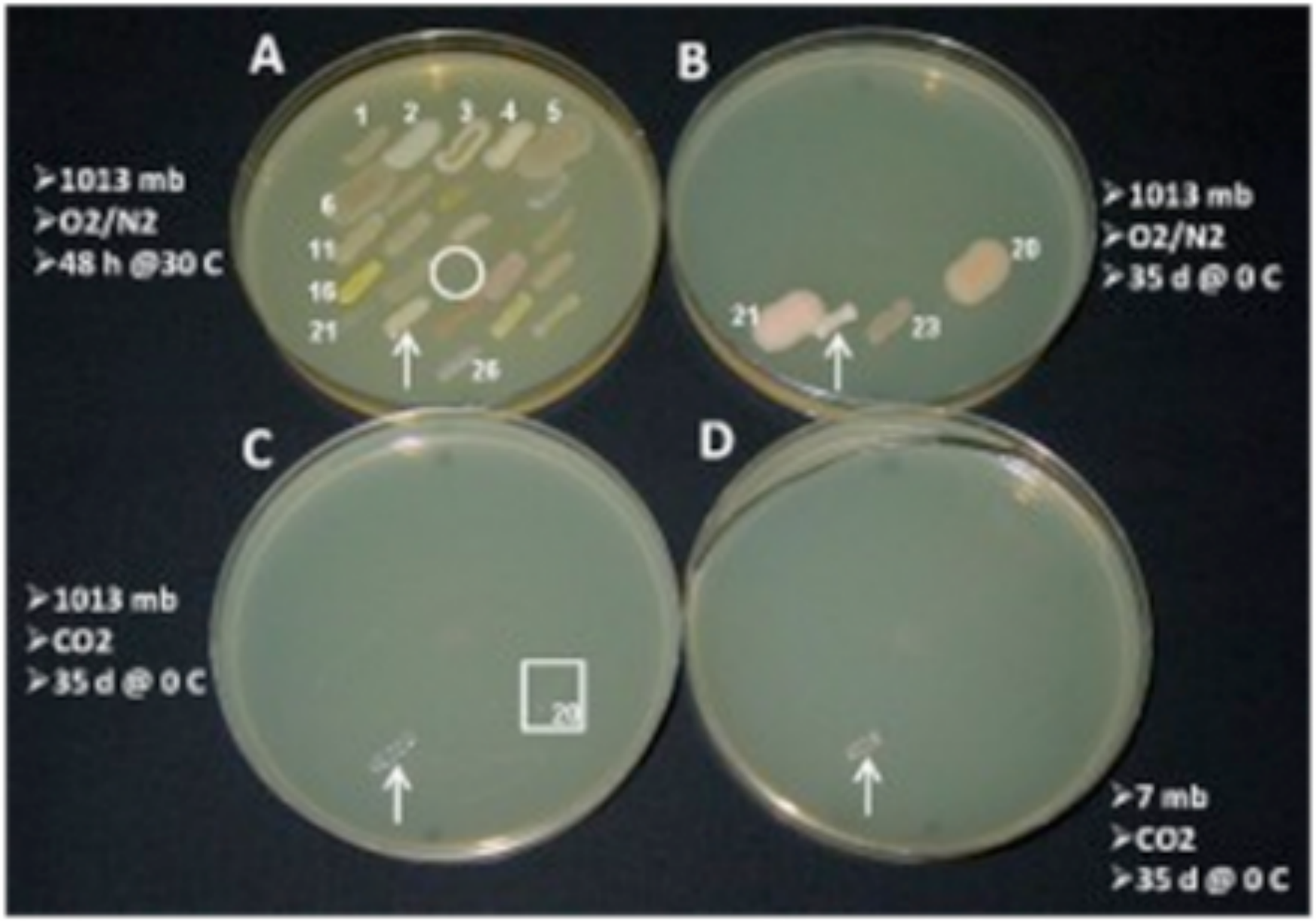


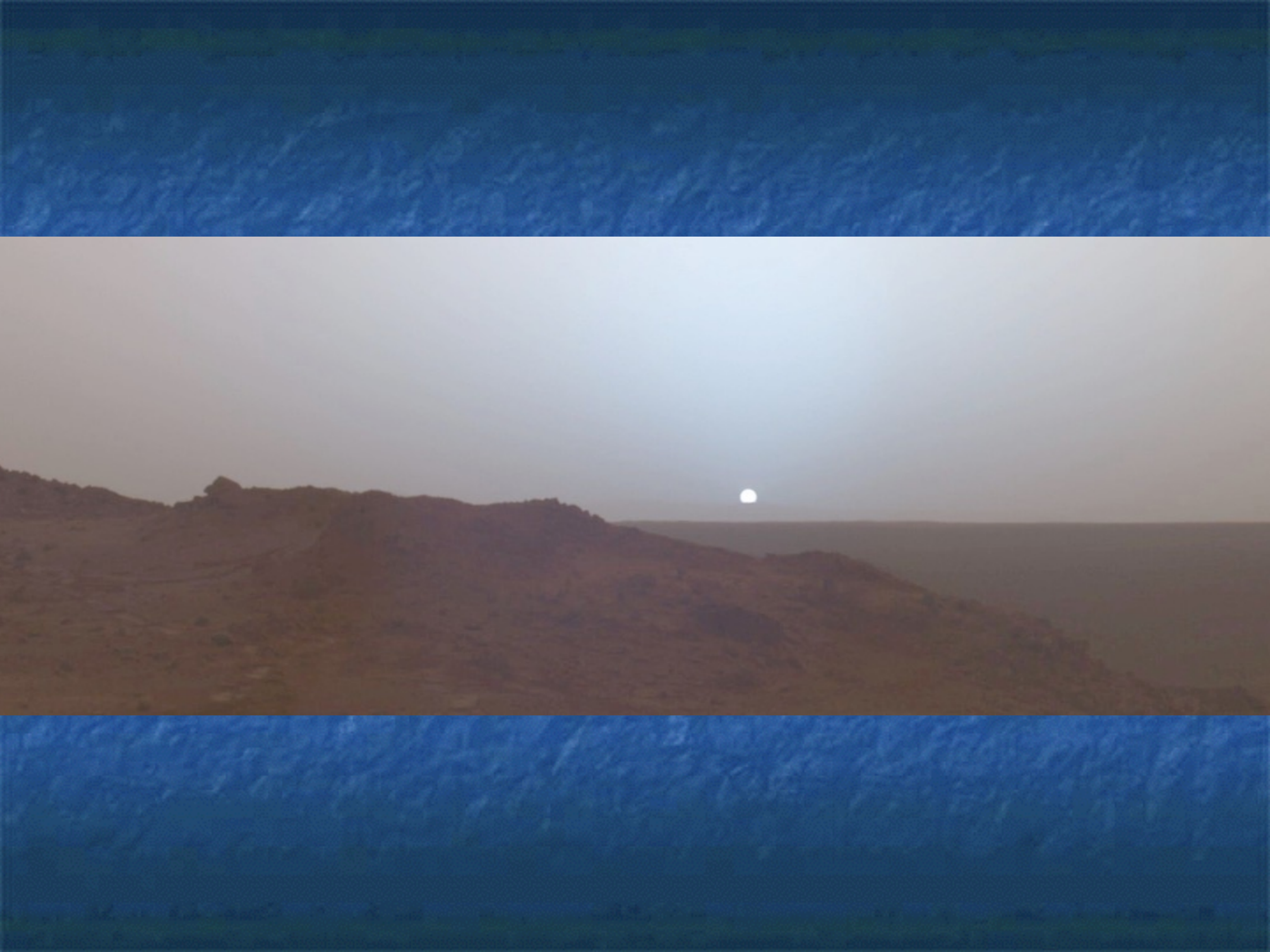


In the labeled release experiment, radioactively tagged carbon-14 in the nutrient showed up almost immediately in gases given off by the wetted sample, climbed steeply, and then leveled off after 9 hours.

- Soil sample incubated with ^{14}C-labeled formate, glycine, D/L alanine, D/L lactate, and glycolate
- ^{14}C in evolved gases is detected
- Second application of labeled medium. Both responses are compared to heat-sterilized control.
- Result: ^{14}C-labeled gas was evolved. Levels fell initially after the 2nd application, but then increased. No gas evolution from heat-sterilized samples.
- Interpretations:
  - Met pre-mission criteria for positive detection of microbial life.
  - UV-produced oxidants (e.g., H_2O_2) lead to oxidation and gas release.


A
UV
LN2

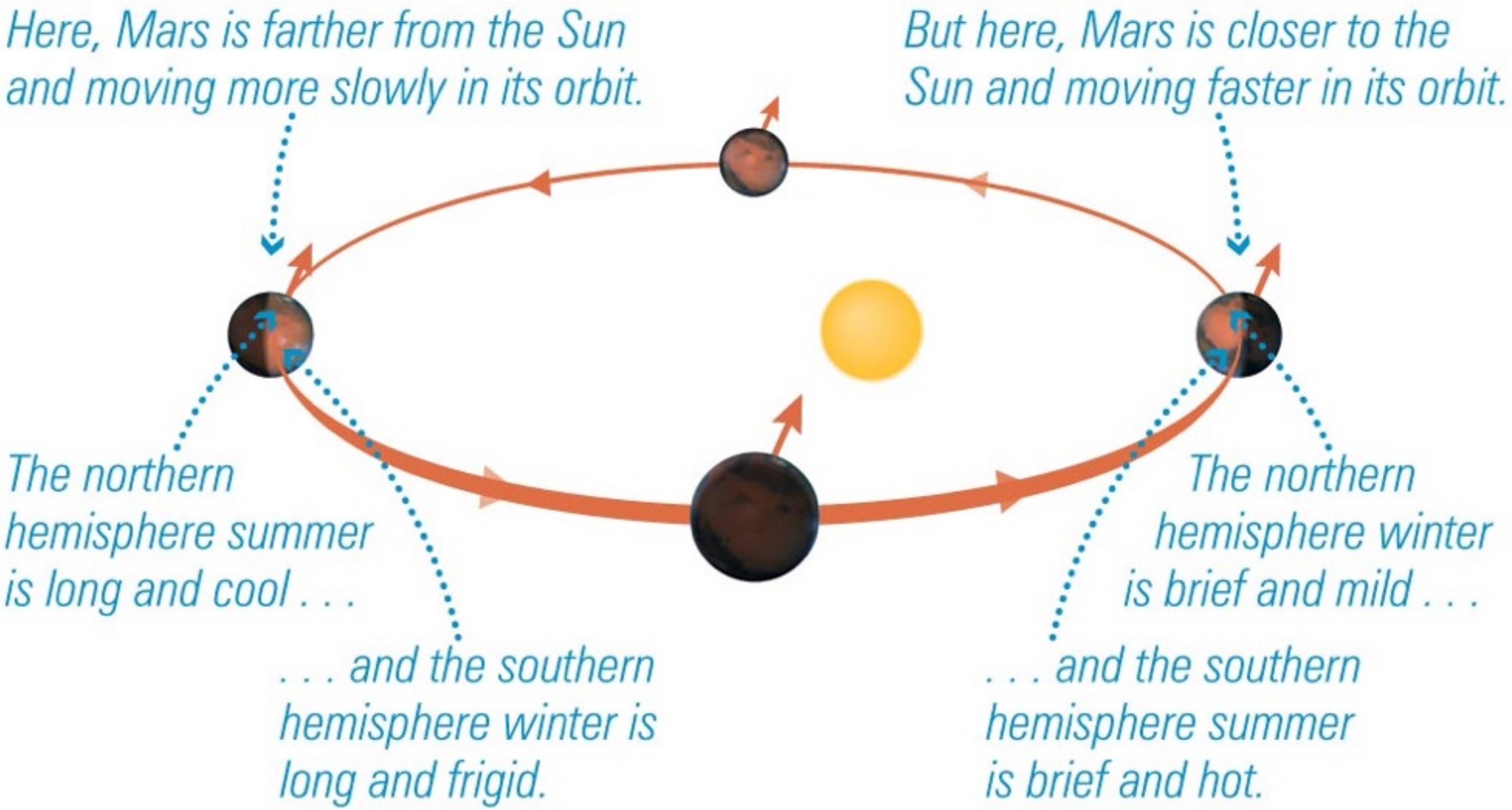

A
1 2 3 4 5
6
11
16
21
26
➢1013 mb
➢O2/N2
➢48 h @30 C
B
20
21
23
➢1013 mb
➢O2/N2
➢35 d @ 0 C
C
➢1013 mb
➢CO2
➢35 d @ 0 C
D
➢7 mb
➢CO2
➢35 d @ 0 C



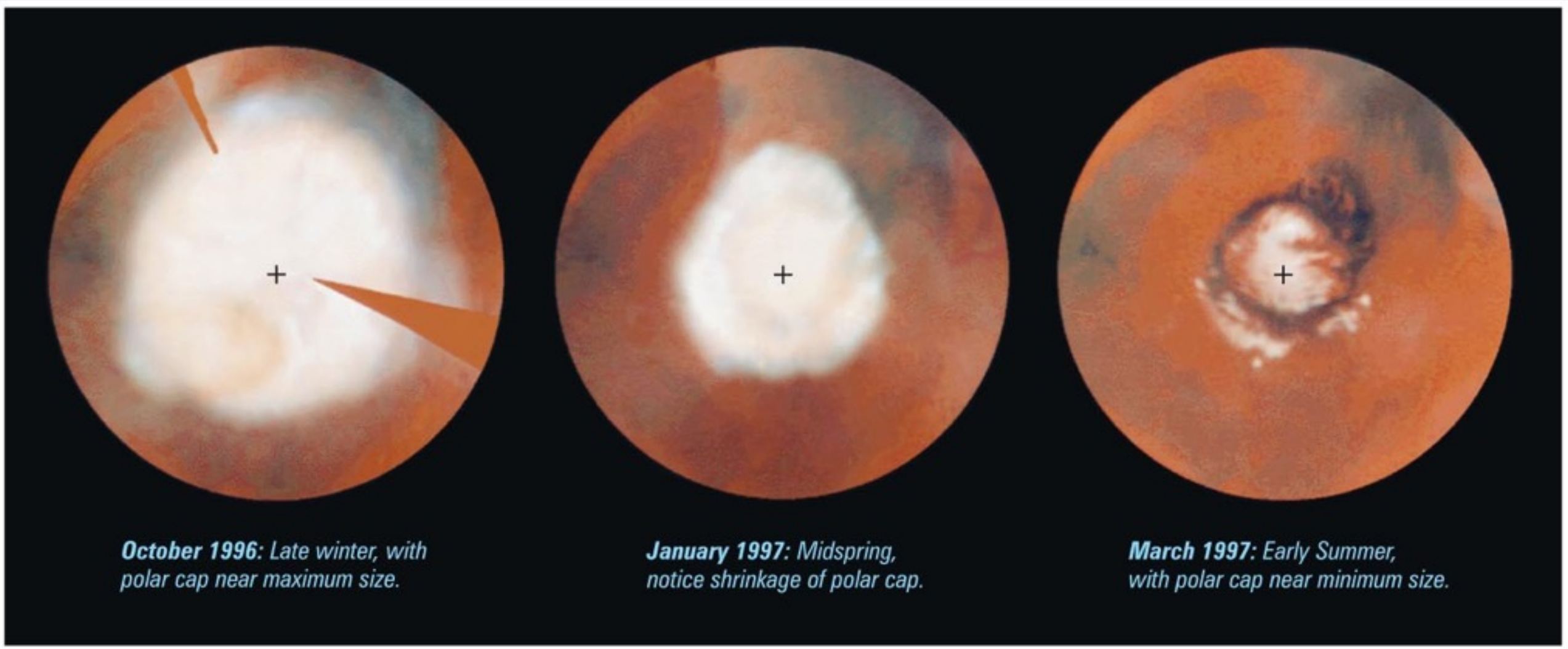
Mars is like Earth
Relative size (gravity)
Solar energy
Geology
Seasons
Length of day
Weather

Mars is not like Earth
Atmosphere
Surface temperature
Surface liquid water

Seasons on Mars



Seasonal variation of the ice-cap



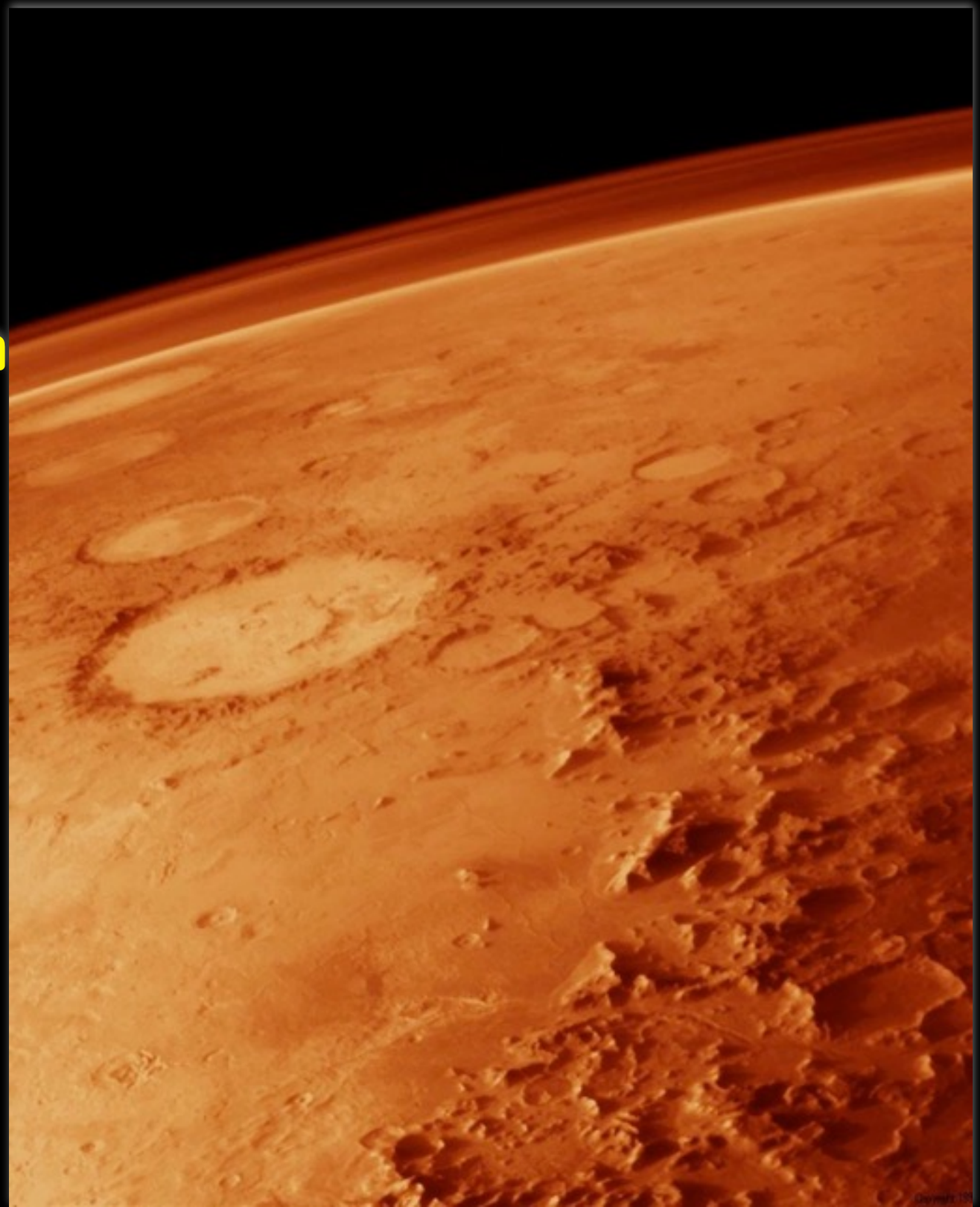
October 1996: *Late winter, with polar cap near maximum size.*

January 1997: *Midspring, notice shrinkage of polar cap.*

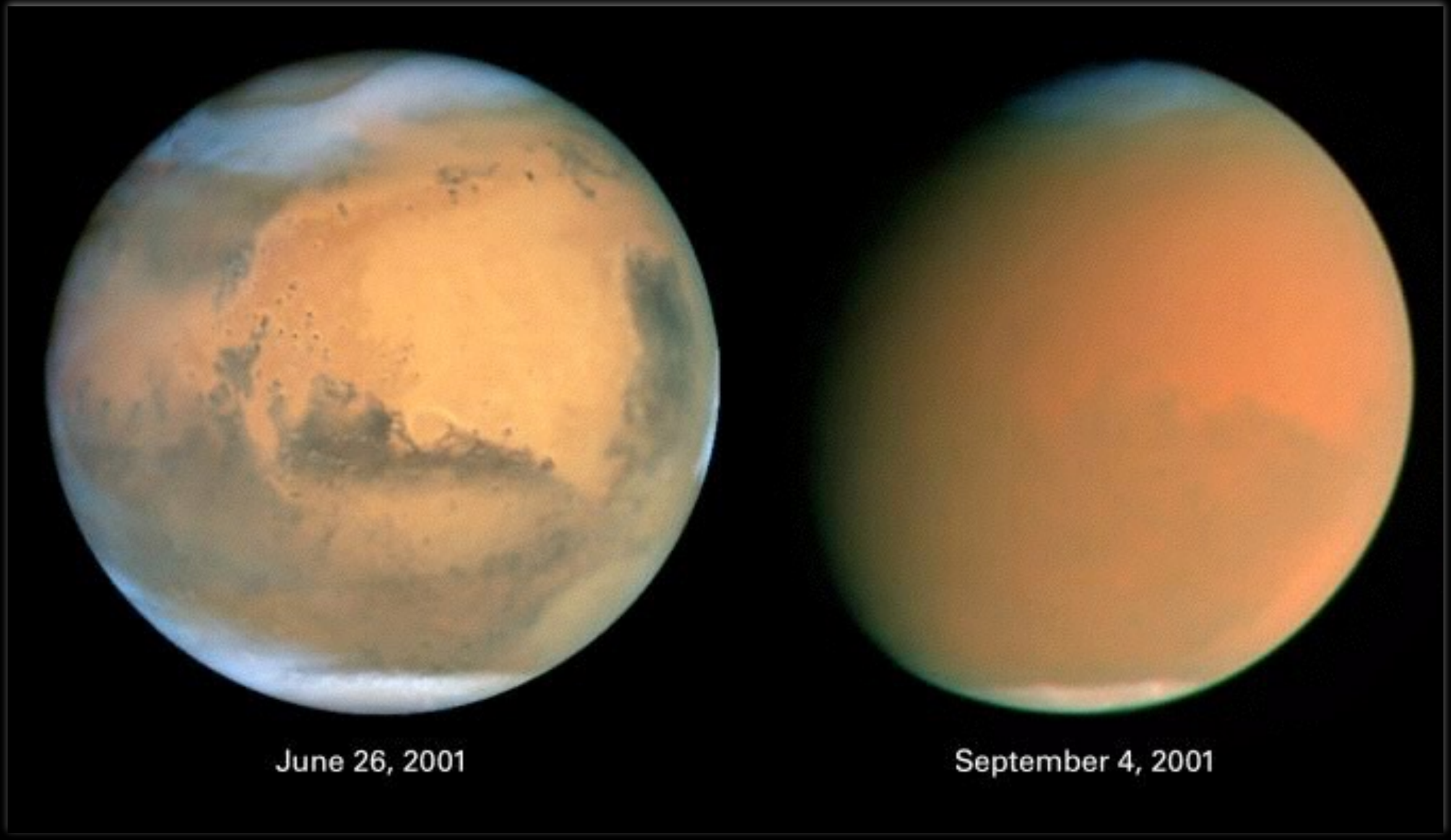
March 1997: *Early Summer, with polar cap near minimum size.*

The Atmosphere of Mars

- Mars has a very thin atmosphere
- It is made mostly of **carbon dioxide** (95%)
  - it also has some nitrogen, argon, oxygen and water
- It is thick enough to support strong winds and huge dust storms



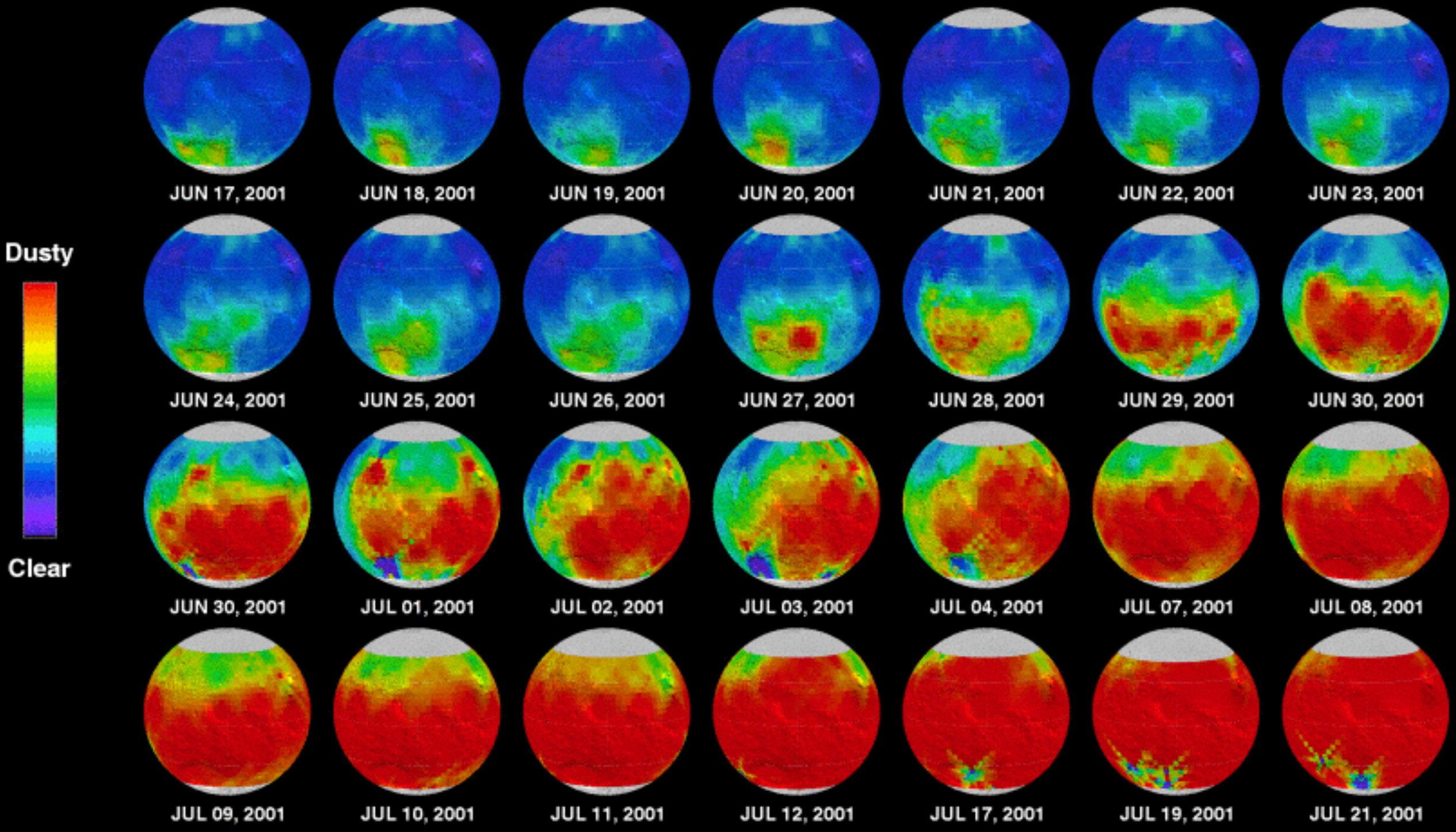
Global Dust Storms on Mars



June 26, 2001

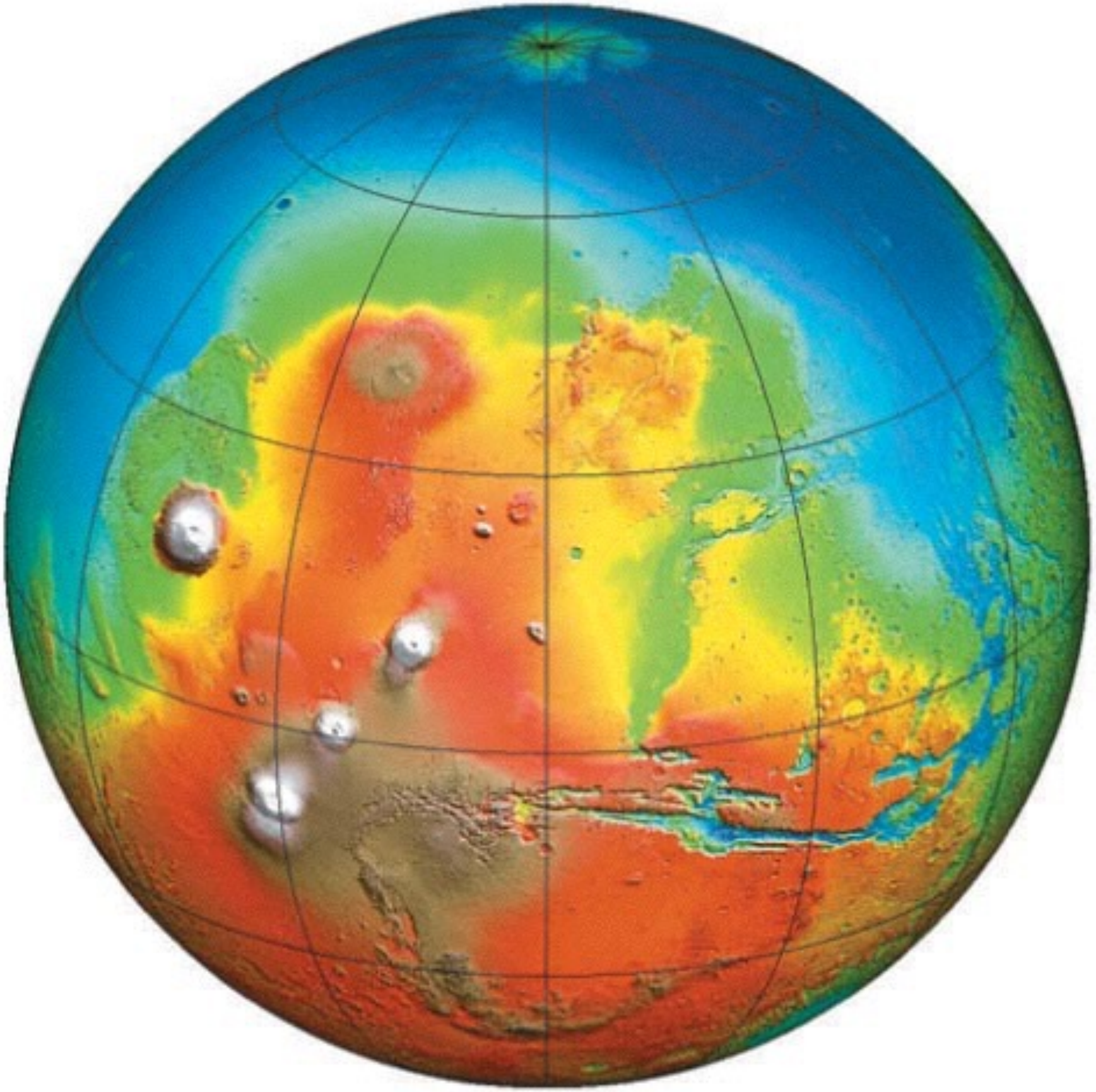
September 4, 2001

Martian Dust Storm Activity

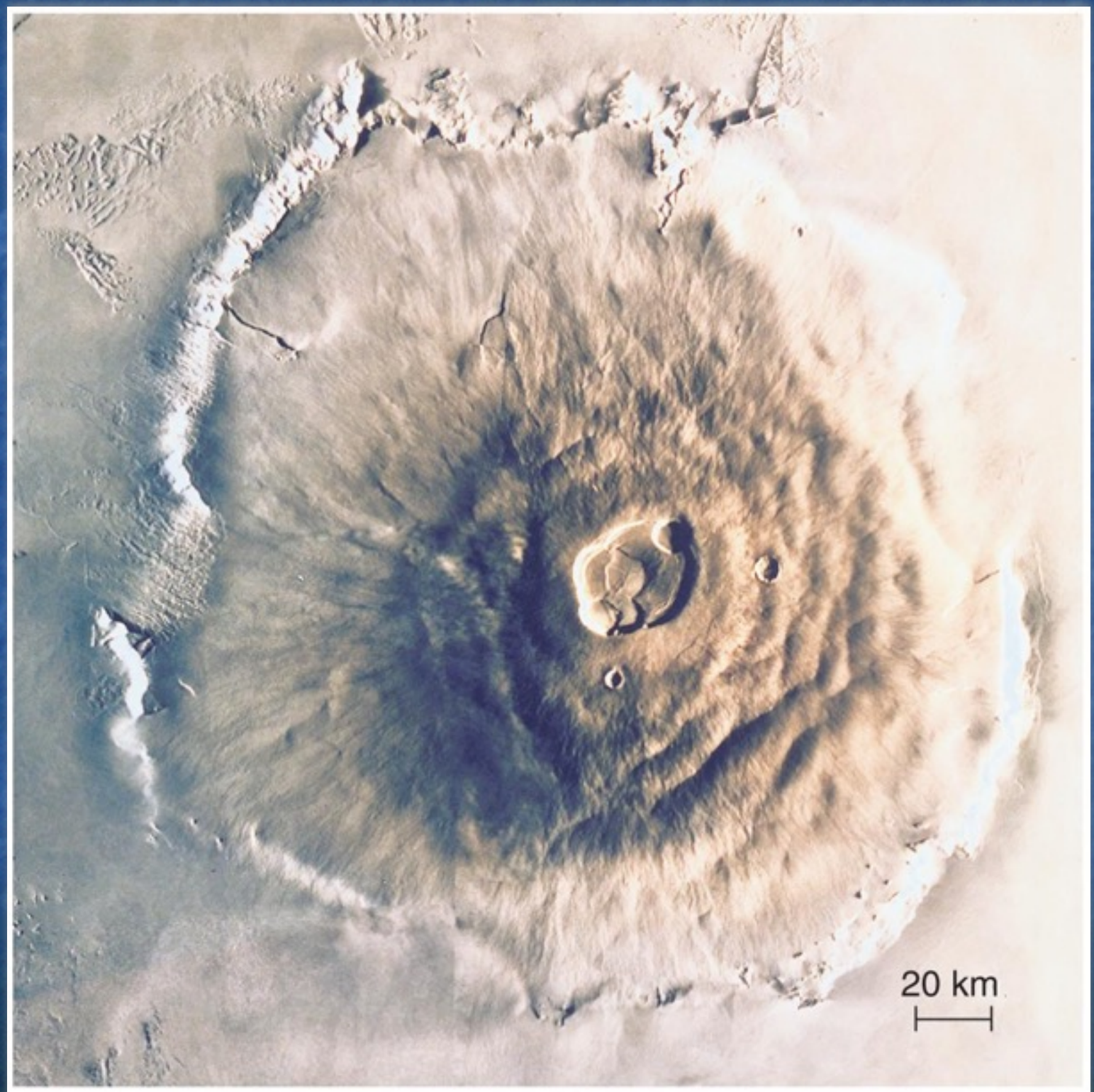


270 W

Thermal Emission Spectrometer



Olympus Mons



The Habitability of Mars

- Mars is currently very cold and dry, and has little geological activity
- However, in the past, it appears to have been warm and wet, with active volcanoes
- Spacecraft which have visited Mars have found numerous lines of evidence that water flowed on Mars in the past, and may still trickle in places today

[READY, SET, GO]

MISSION(S) TO MARS

Though most missions TO THE RED PLANET HAVE FAILED, THE SUCCESS RATE IS DEFINITELY IMPROVING + + +

SOURCES: CORNELL UNIVERSITY, EUROPEAN SPACE AGENCY, NASA, RUSSIANSPACEWEB.COM

MISSION FAILURE
FLYBY
ORBITER
LANDER
ROVER

1960
1962
1963
1964
1965
1969
1971
1973
1975
1988
1992
1996
1998
1999
2001
2003
2004
2005
2007
FUTURE

MARSNIK 1
MARSNIK 2
SPUTNIK 22
MARS 1
SPUTNIK 24
KOSMOS 21
MARINER 3
MARINER 4
ZOND 2
ZOND 3 (PRIMARY MISSION NOT MARS)
MARINER 6
MARINER 7
MARS 1969A
MARS 1969B
MARINER 8
KOSMOS 419
MARS 2
MARS 3
MARINER 9
MARS 4
MARS 5
MARS 6
MARS 7
VIKING 1
VIKING 2
PHOBOS 1
PHOBOS 2
MARS OBSERVER
MARS GLOBAL SURVEYOR
MARS 96
MARS PATHFINDER
NOZOMI
MARS CLIMATE ORBITER
MARS POLAR LANDER / DEEP SPACE 2 PROBES
MARS ODYSSEY
MARS EXPRESS / BEAGLE 2
MARS EXPLORATION ROVER: SPIRIT
MARS EXPLORATION ROVER: OPPORTUNITY (SPIRIT MISSION NOT FAR)
ROSETTA (PRIMARY MISSION NOT MARS)
MARS RECONNAISSANCE ORBITER
PHOENIX MARS LANDER
DAWN (PRIMARY MISSION NOT MARS)
PHOBOS-GRUNT / YINGHUO-1 (2009)
MARS SCIENCE LABORATORY (2011)
MAVEN (2013)
EXOMARS (2016)

MARINER 4

Success. Returned 21 images. First successful flyby.

MARS 3

Partial success. Orbiter obtained eight months of data. Lander landed but gathered only 20 seconds of data. First successful landing on Mars.

MARS 5

Partial success. Returned 60 images but failed after only nine days.

MARS 6

Partial success. Lander produced data during descent but failed before landing.

PHOBOS 2

Partial success. Returned some data but lost contact before deploying lander.

MARS EXPRESS/ BEAGLE 2

Partial success. Orbiter completed primary mission in November 2005 and is still in orbit on extended mission. Beagle 2 lander lost on arrival.

DAWN

On its way to proto-planets Vesta and Ceres. Completed Mars flyby in February 2009.

FUTURE

Phobos-Grunt/Yinghuo-1 will be a sample-return lander/orbiter, Mars Science Laboratory will be a rover, MAVEN will be an orbiter, and ExoMars will be an orbiter/lander/rover.

SOVIET UNION
UNITED STATES
RUSSIA
JAPAN
EUROPEAN SPACE AGENCY
RUSSIA/CHINA

MISSION FAILURE
FLYBY
ORBITER
LANDER
ROVER

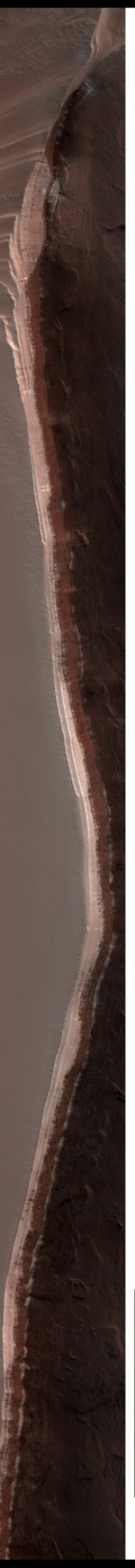
BY NAN CHRISTIE DESIGN

Current Mars Orbiters

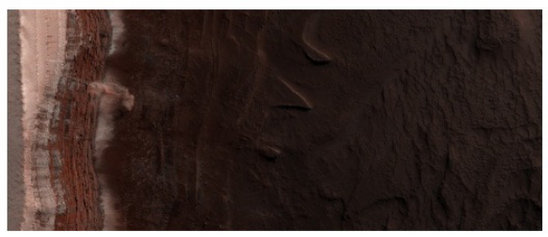
Mars Odyssey

Mars Express

Mars Reconnaissance Orbiter

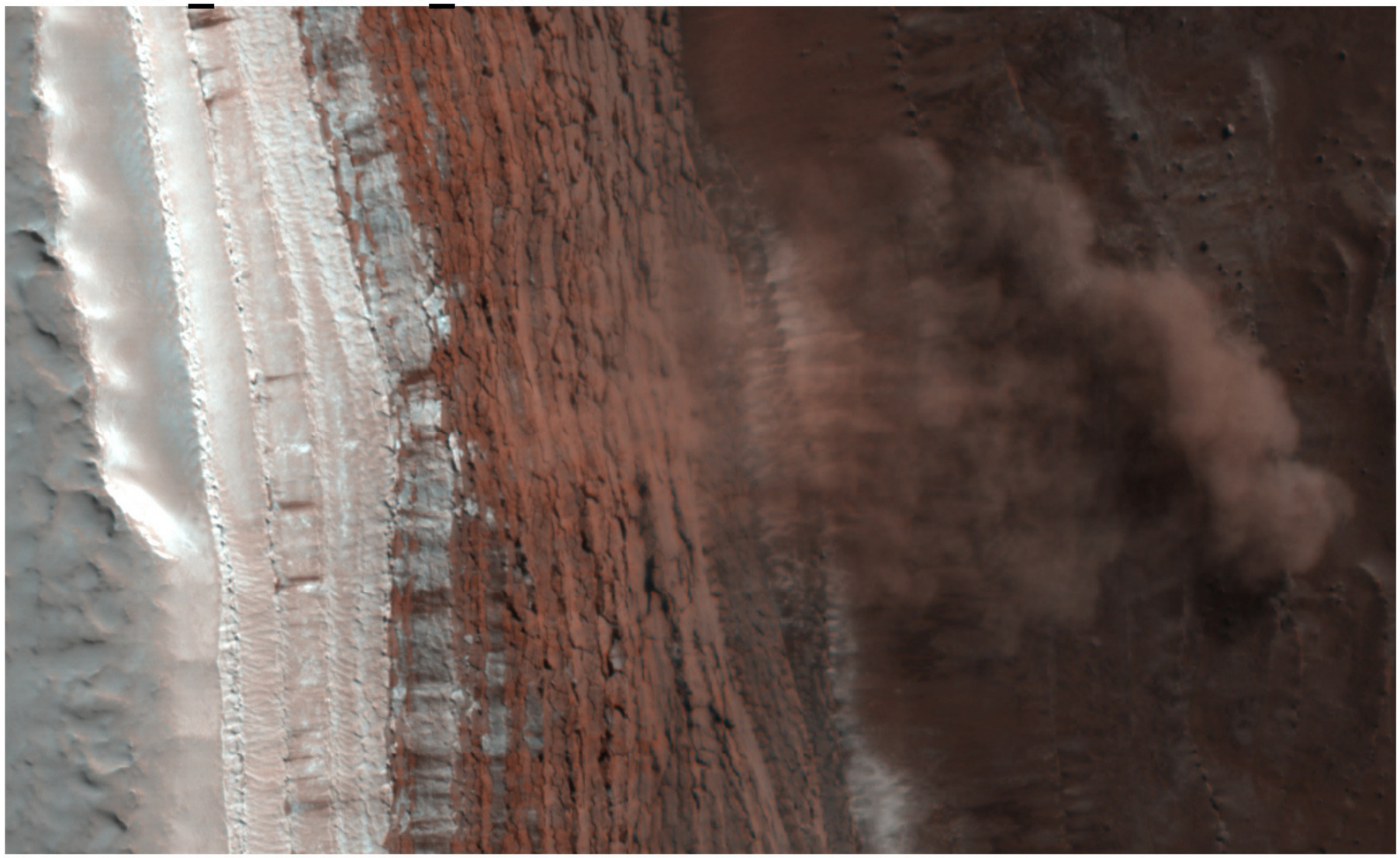


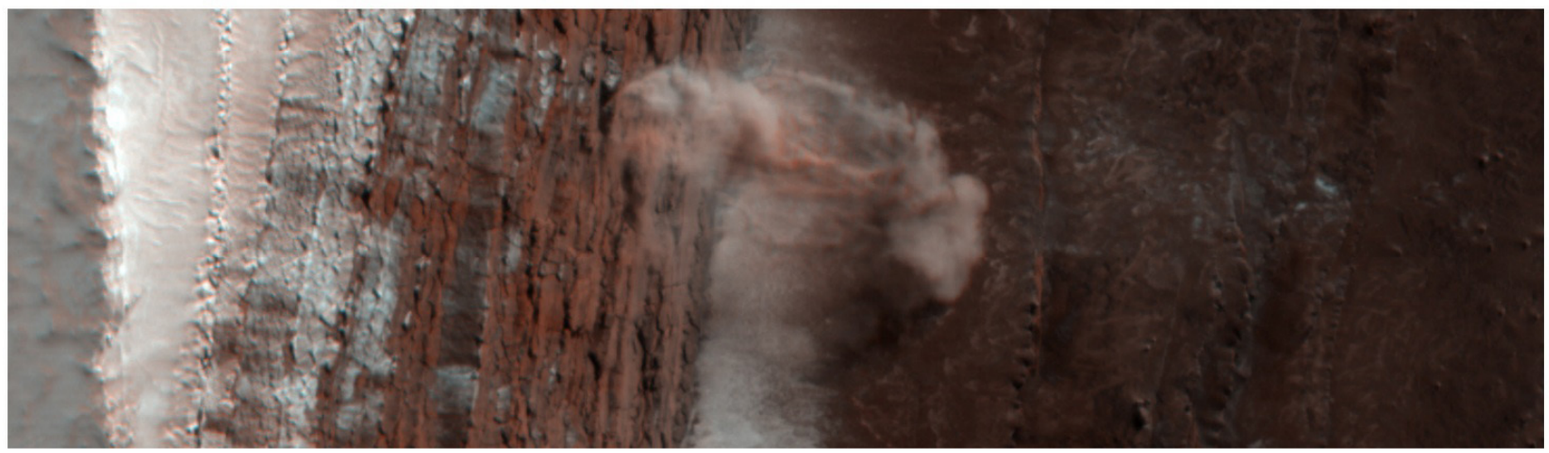
"Ingrid's Avalanches" 2008 Feb 19



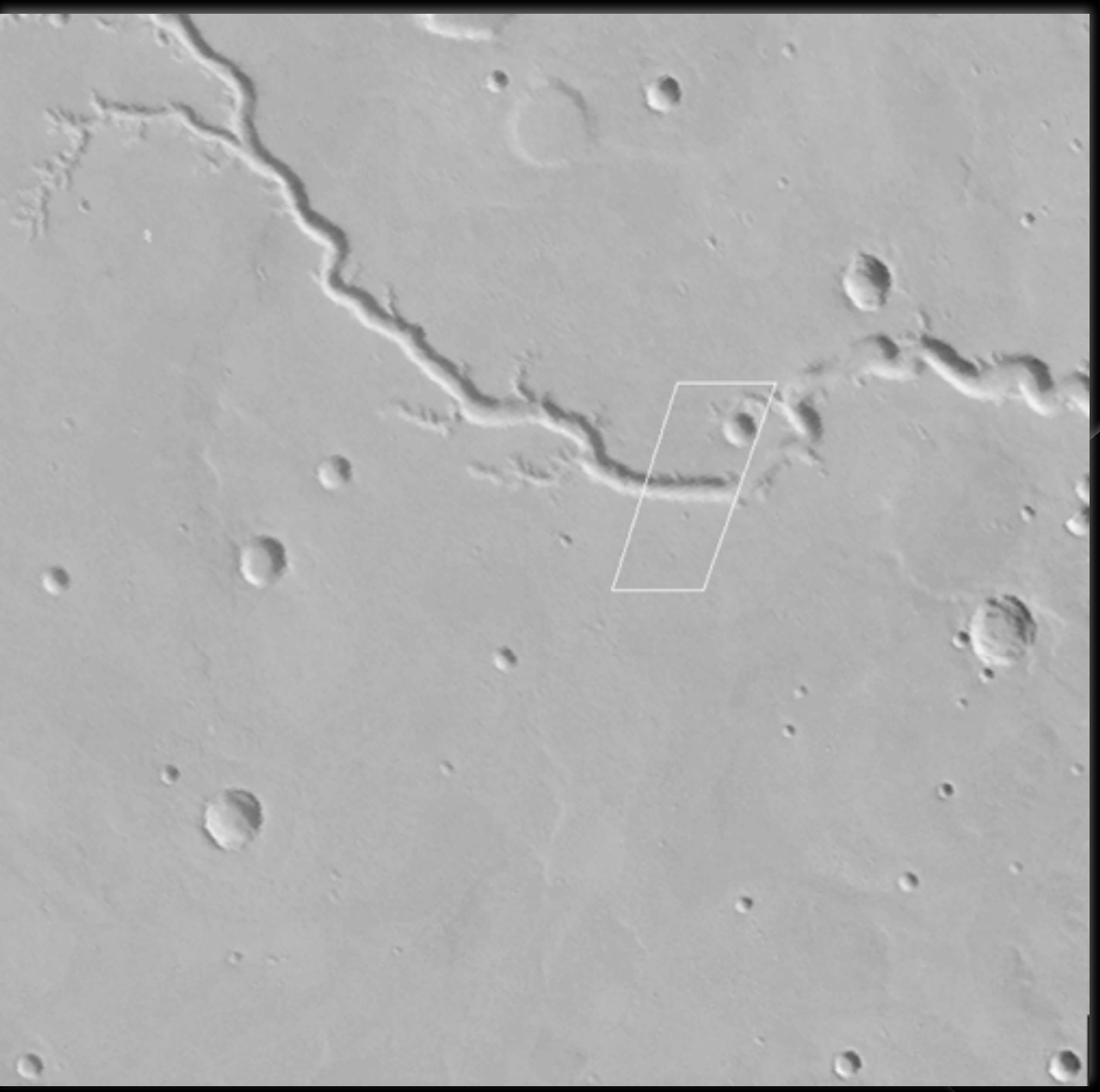
83.7N 235.8E

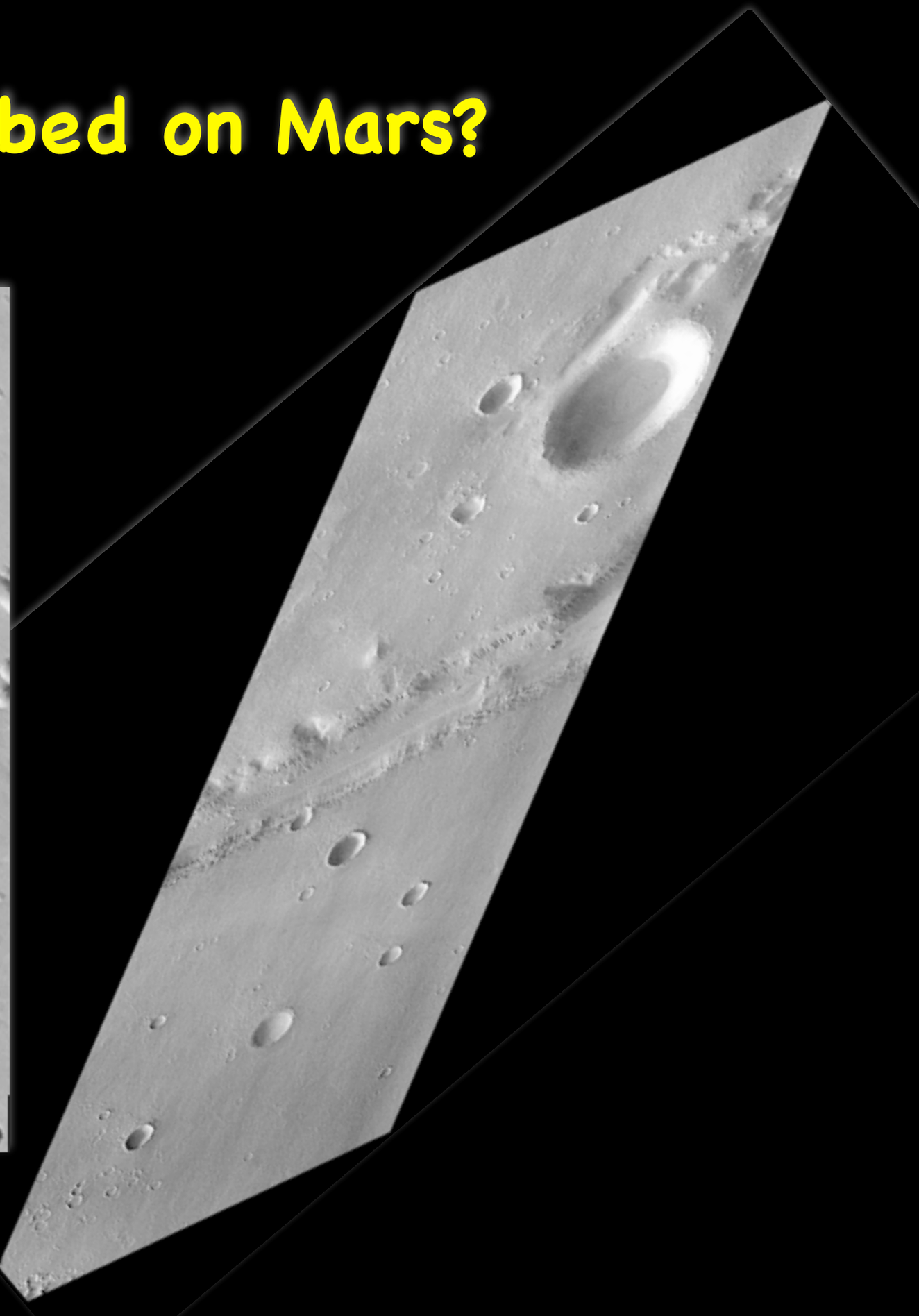
PSP_007338_2640

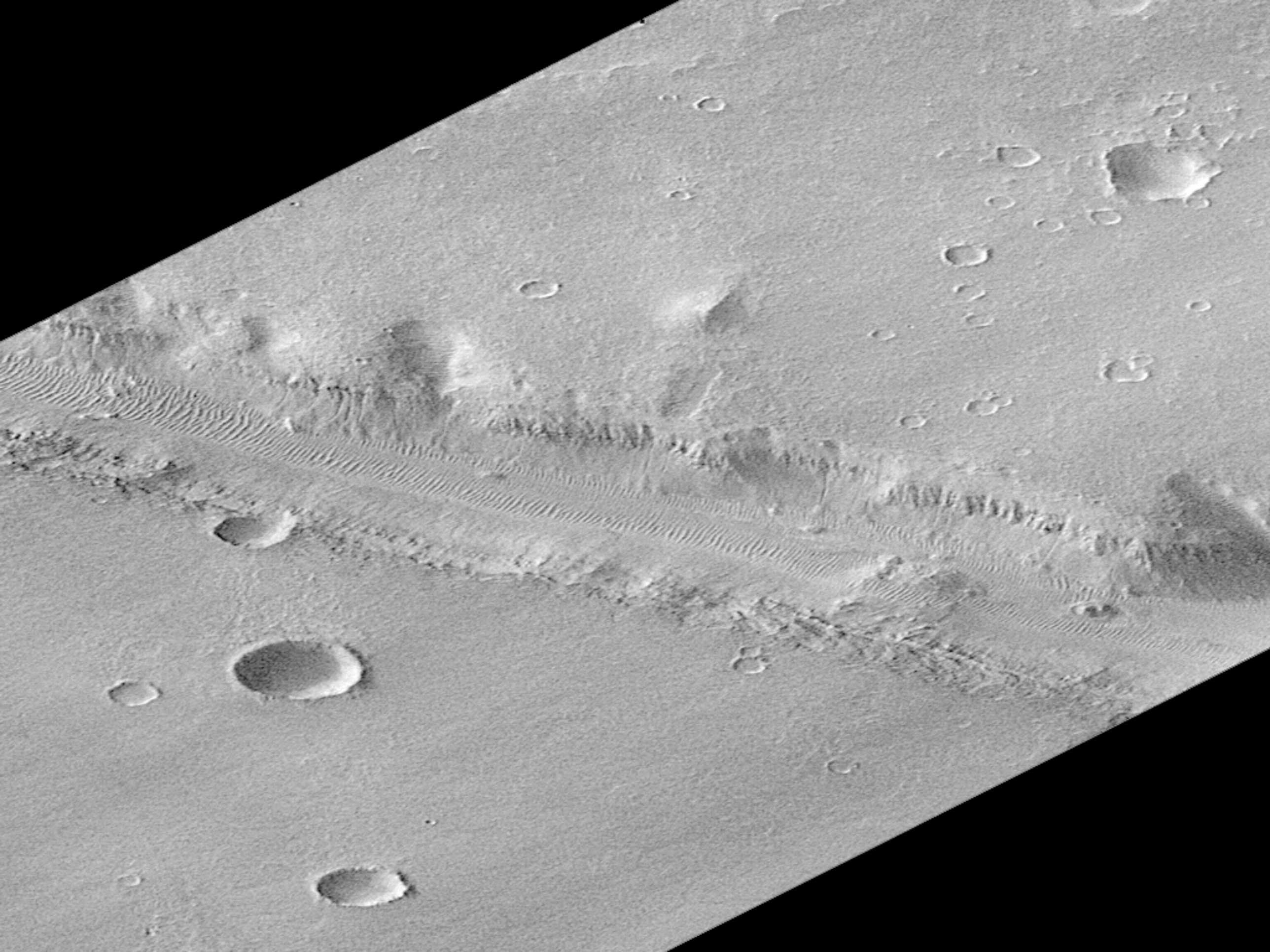




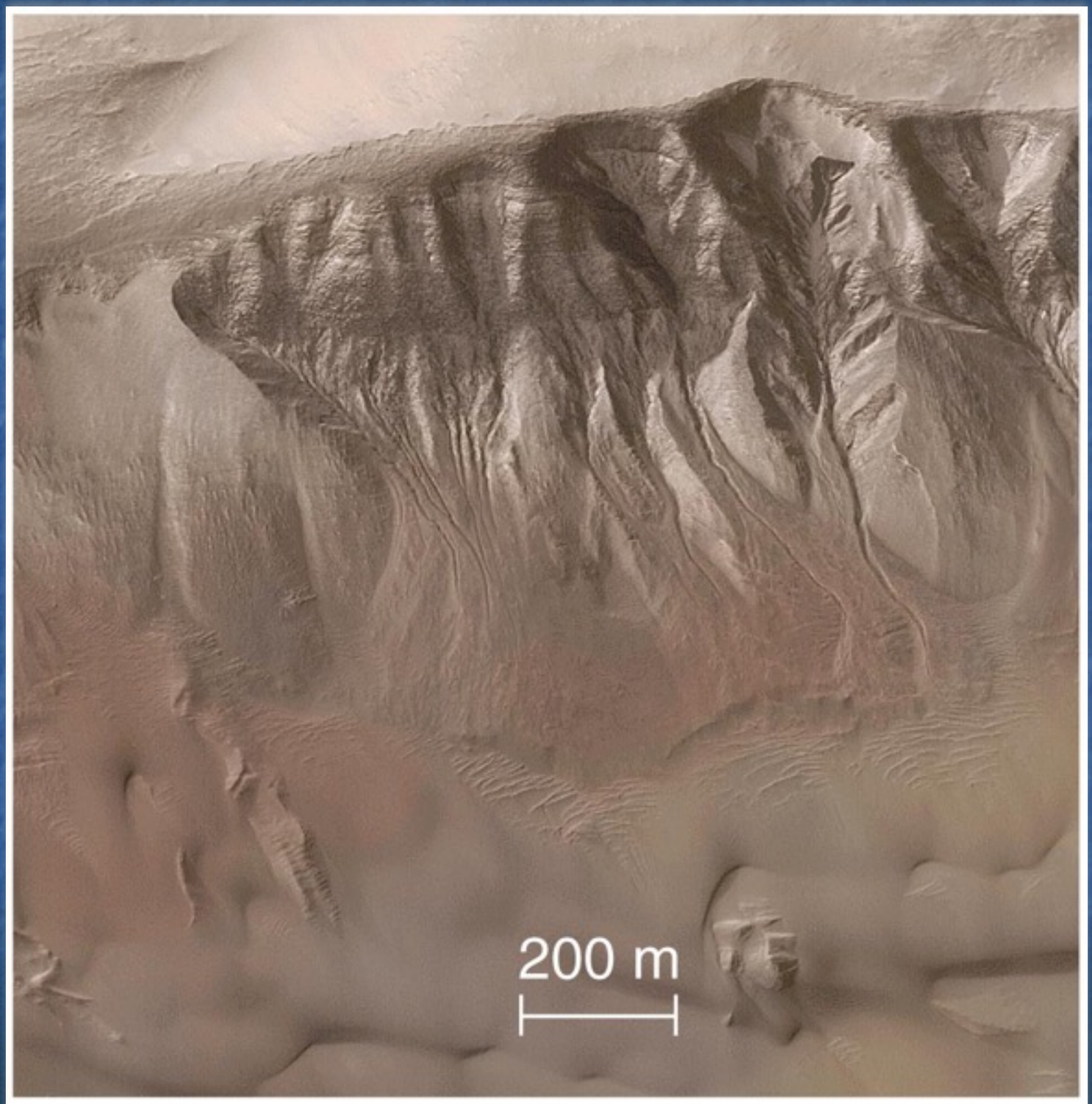
A Dry Riverbed on Mars?



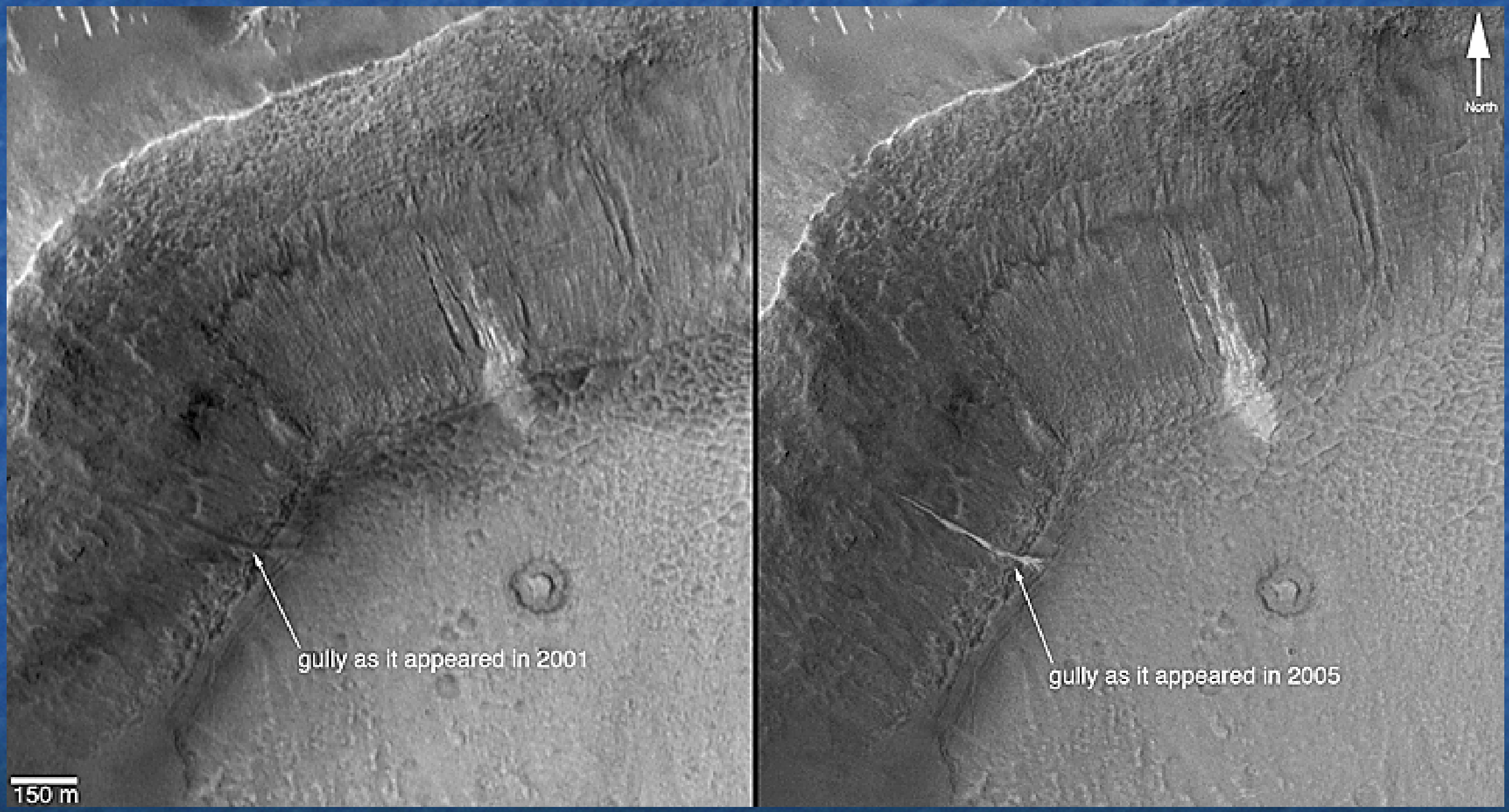




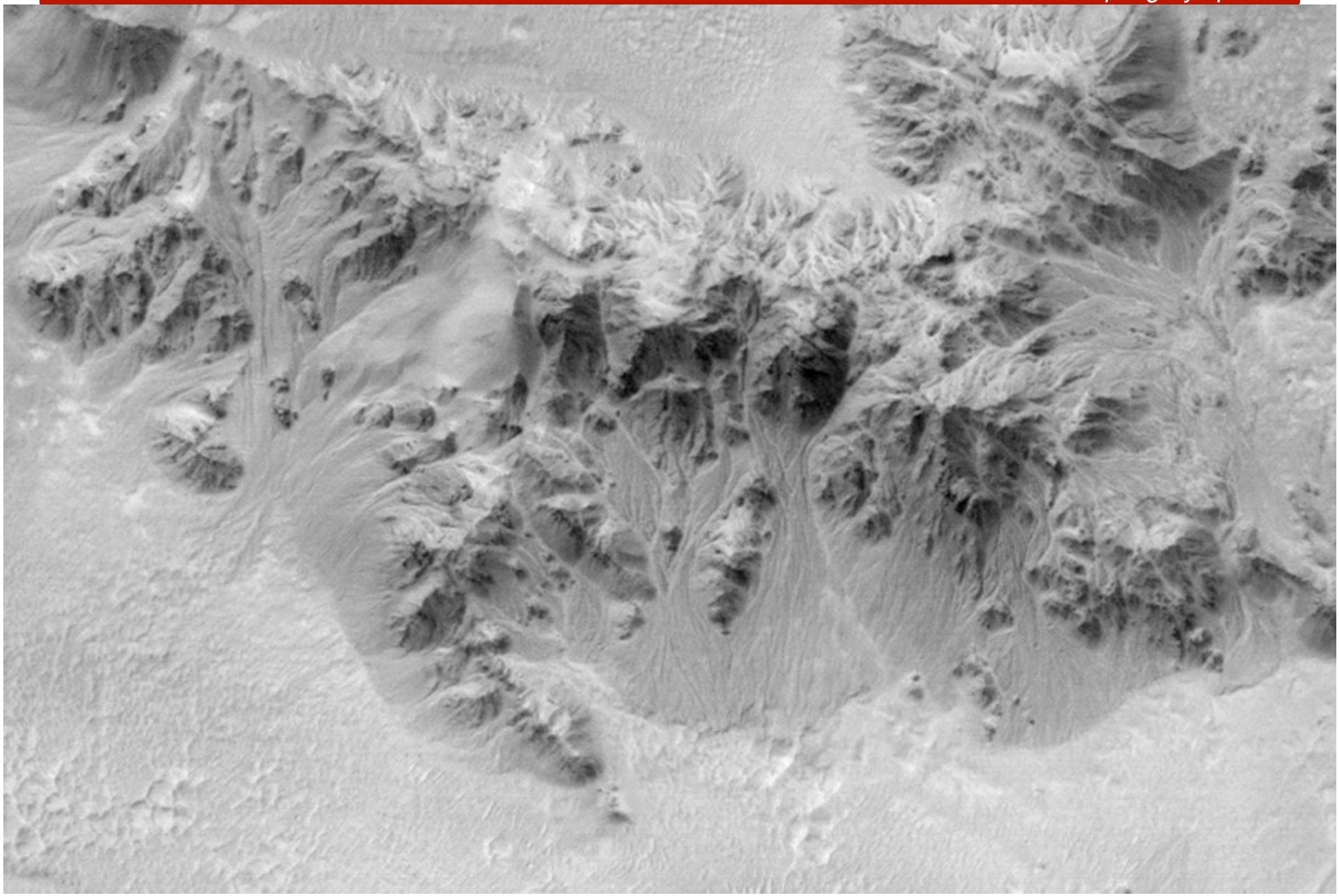
Gullies on Mars



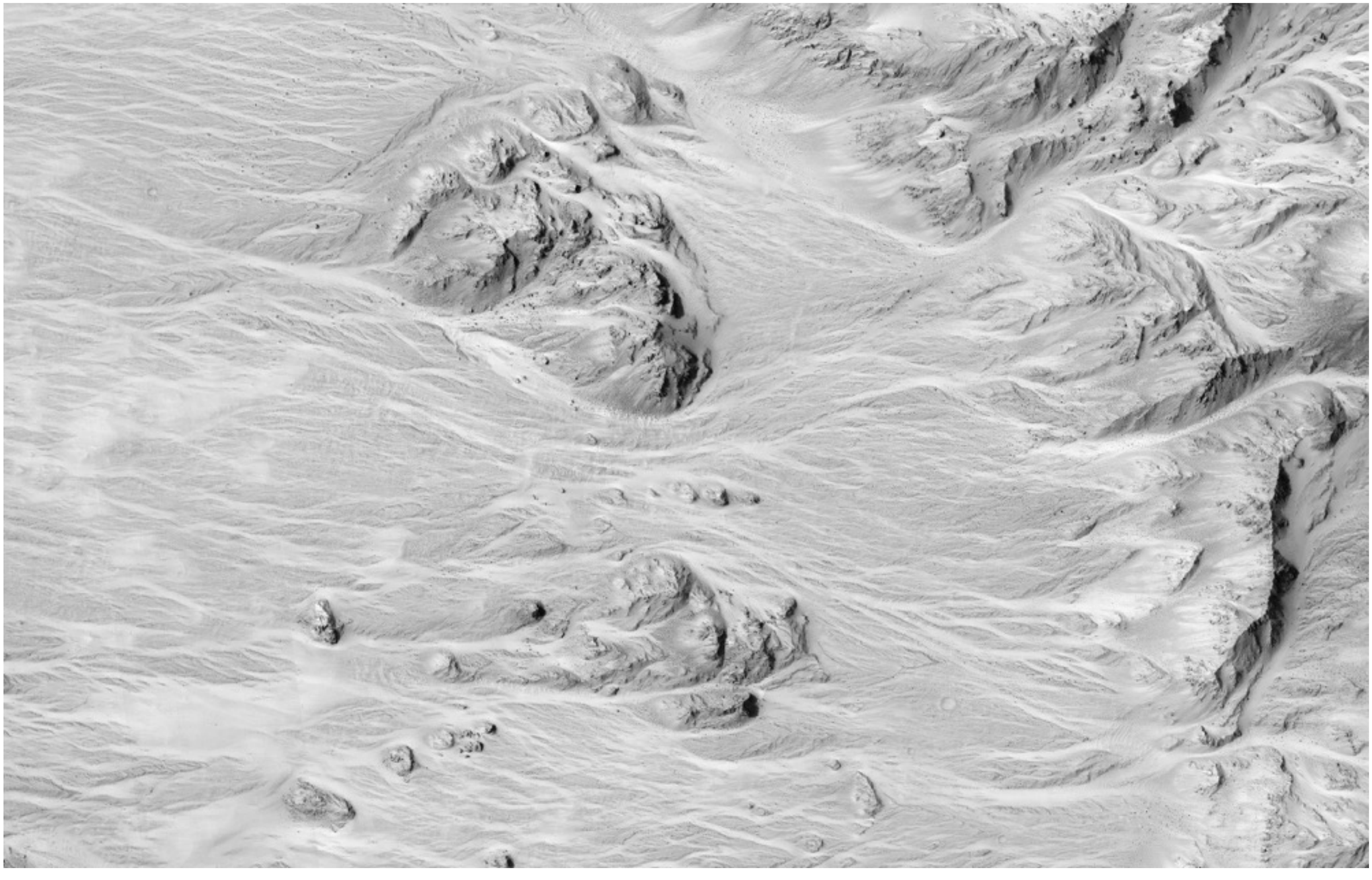
Very Recent Gully Activity (MGS)



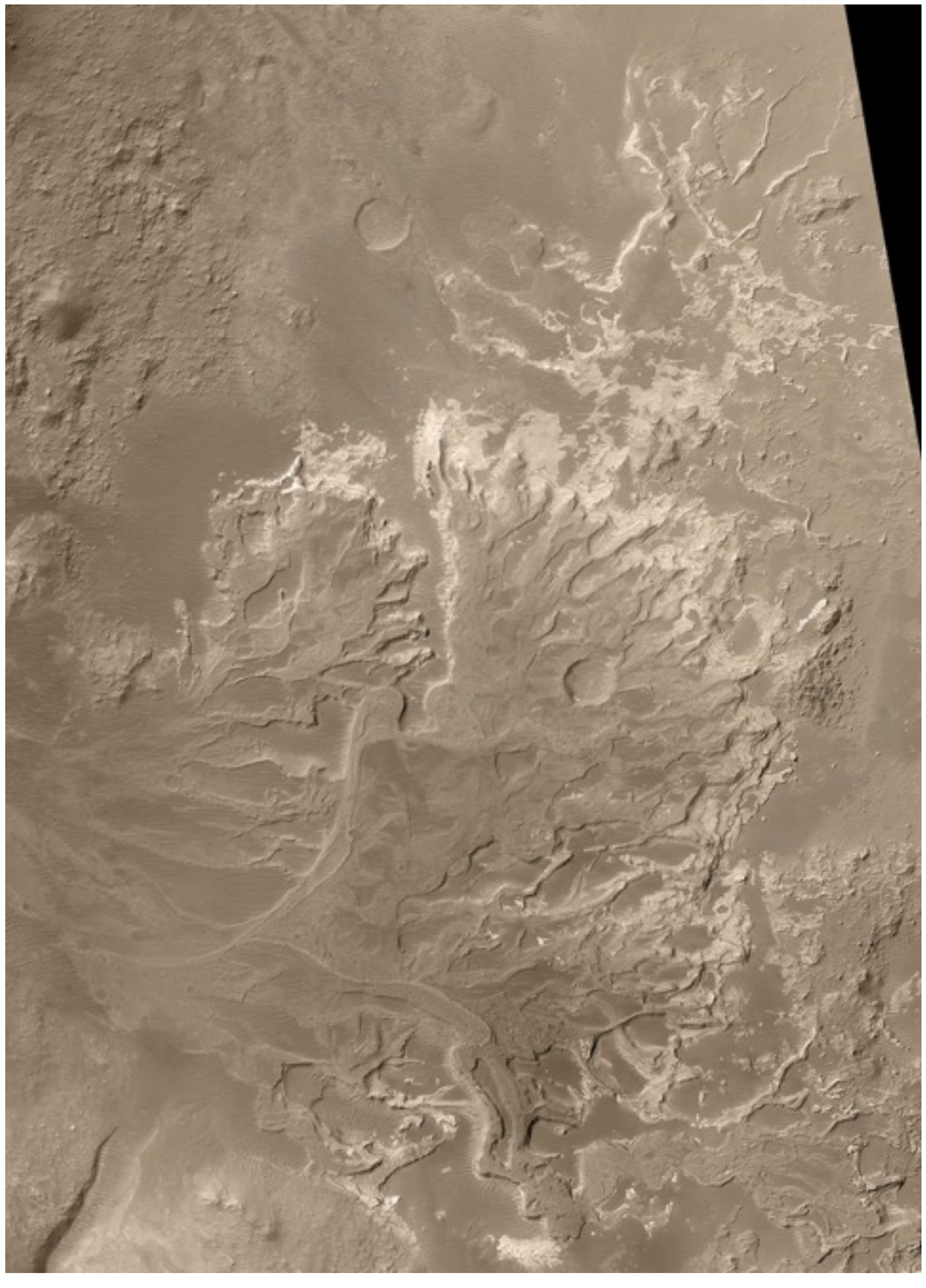
Alluvial Fans at Mojave Crater



MRO HiRISE



A Distributary Fan in Eberswalde Crater



http://beamartian.jpl.nasa.gov/welcome

http://beamartian.jpl.nasa.gov/welcome

Google

Jon Willis's Homepage | UVic webmail | BBC News | UVic Homepage | ADS | Google Maps | Gmaps Pedometer

Be A Martian!

Age of Virtual Exploration & the Human-Robotic Partnership

I want to be a Martian Citizen. > Account Set Up
I just want to look around. > Anonymous Tourist Visa

I am a Martian Citizen.

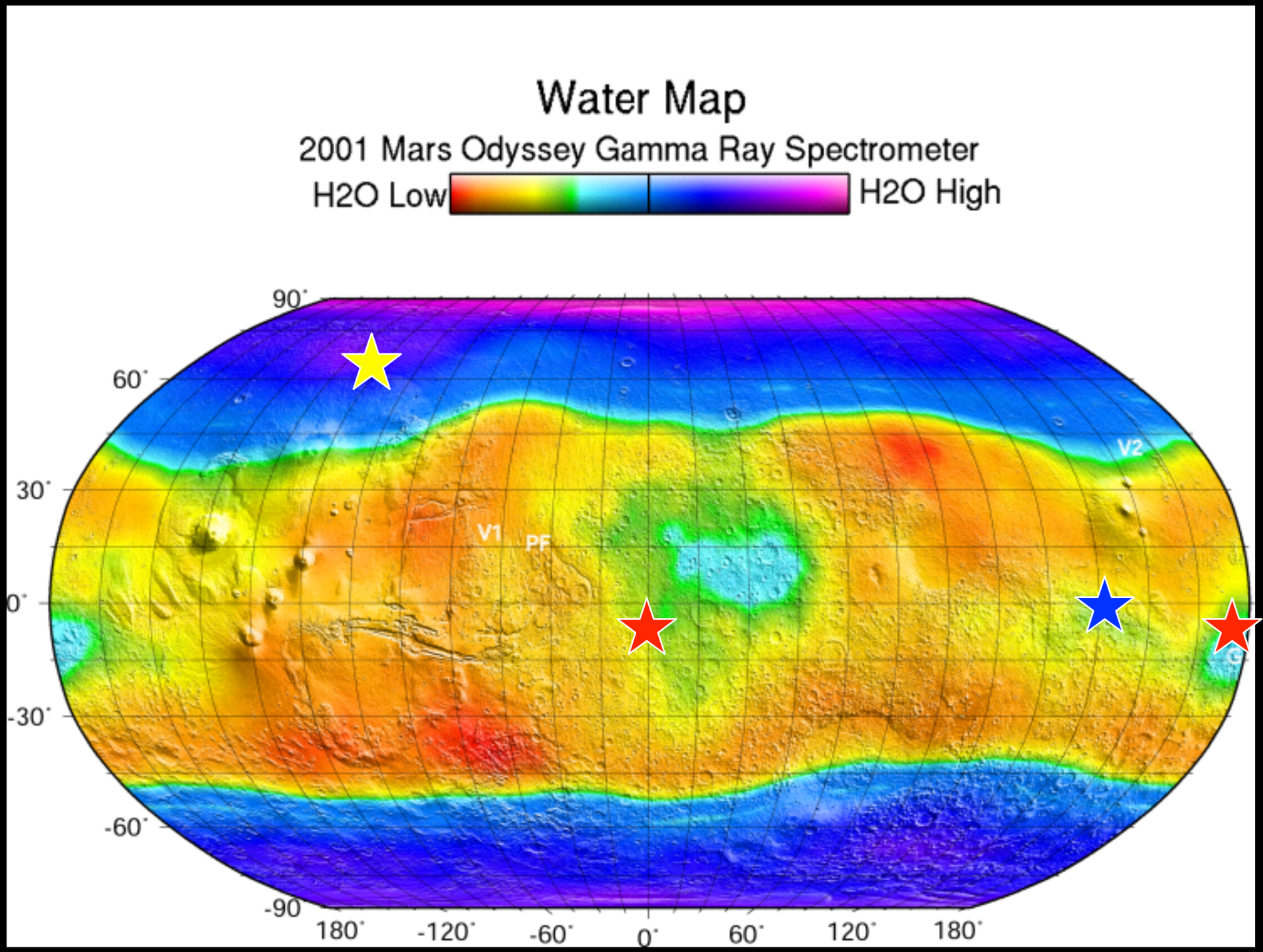
Martian Username | Martian Password | FORGOT?

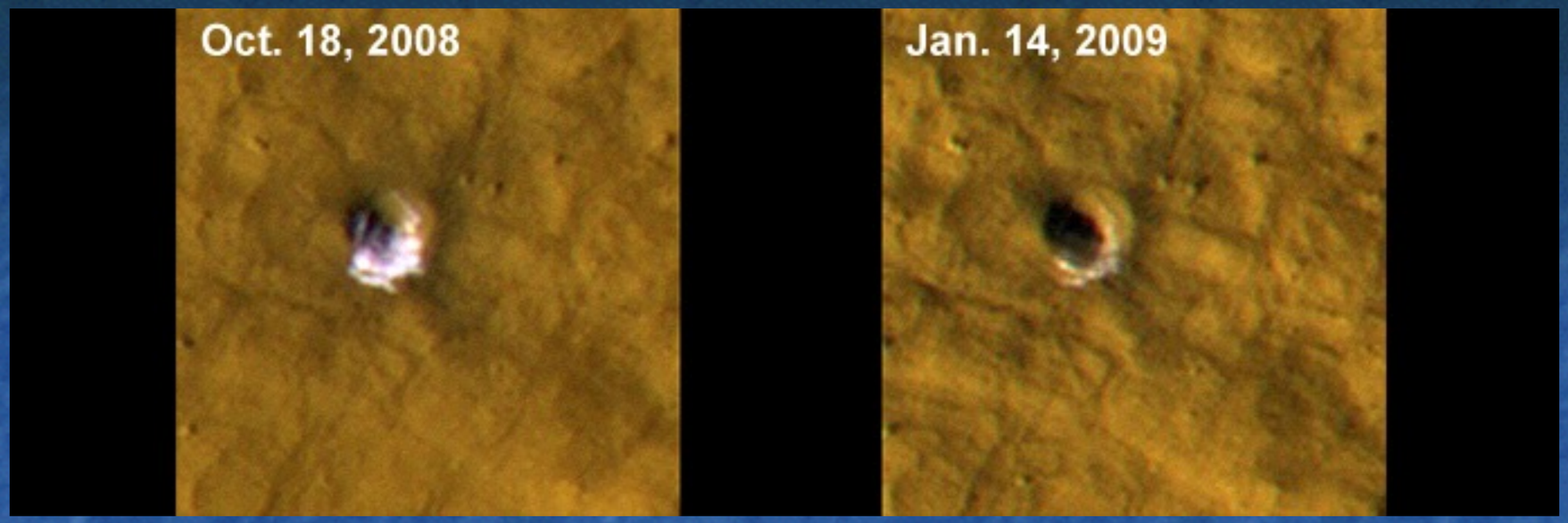
Log In

Mars Exploration Program
Pathfinder Innovation Challenge

Stay Connected

Hydrogen Content (from Mars Odyssey)



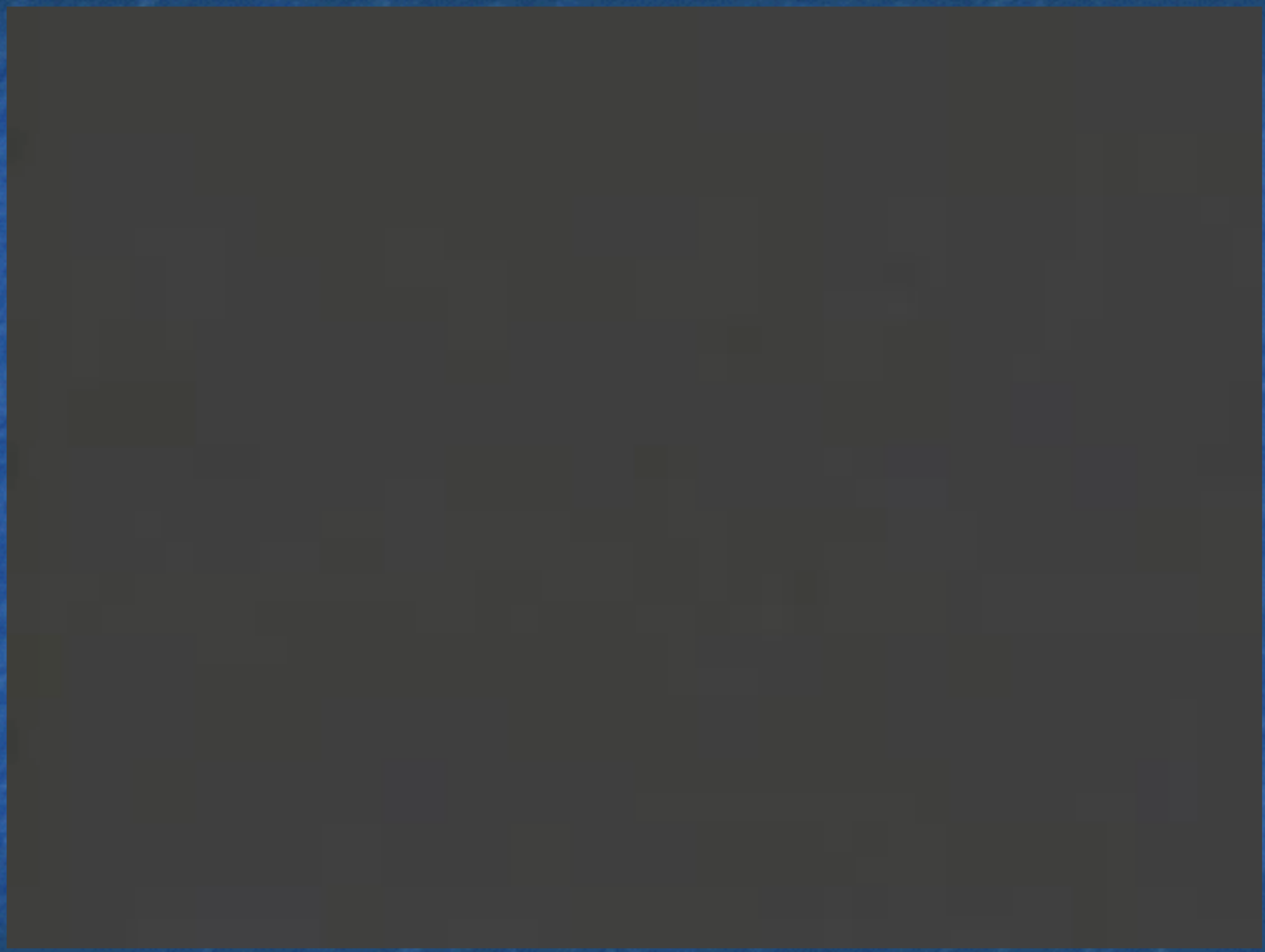

Oct. 18, 2008
Jan. 14, 2009


4 June 2008
500 m


10 August 2008
500 m

A New Emphasis: Habitability

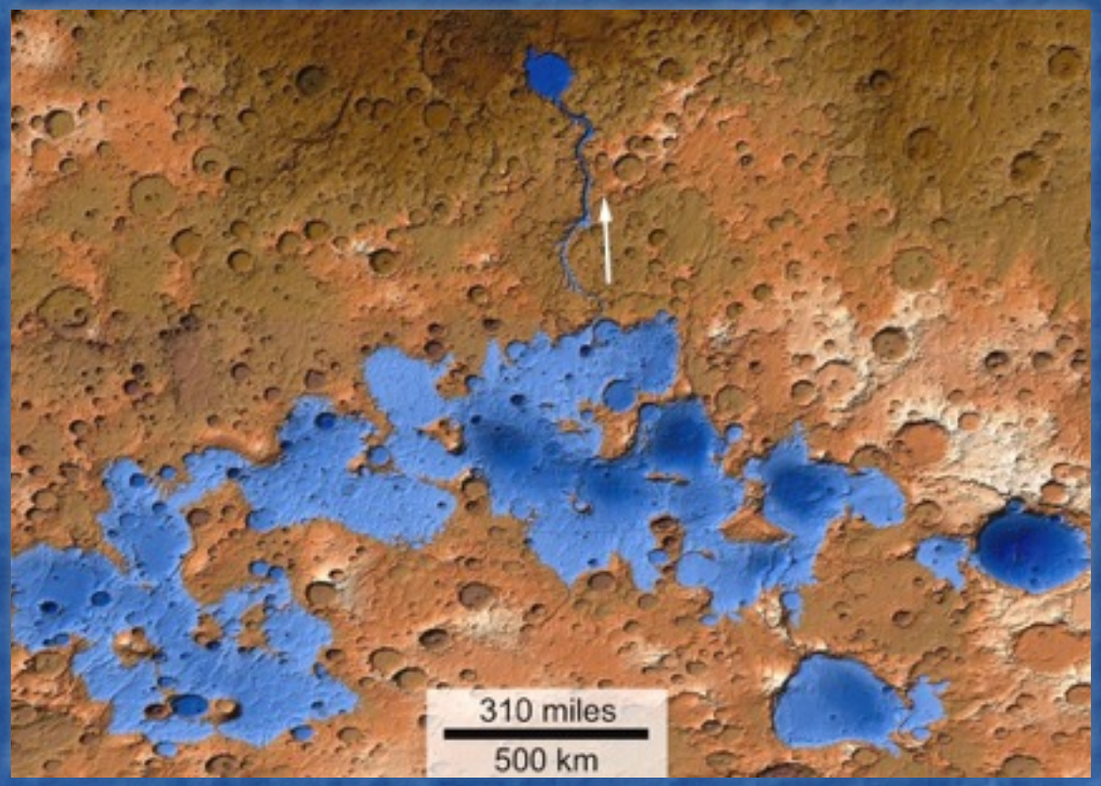
Rover Family Tree

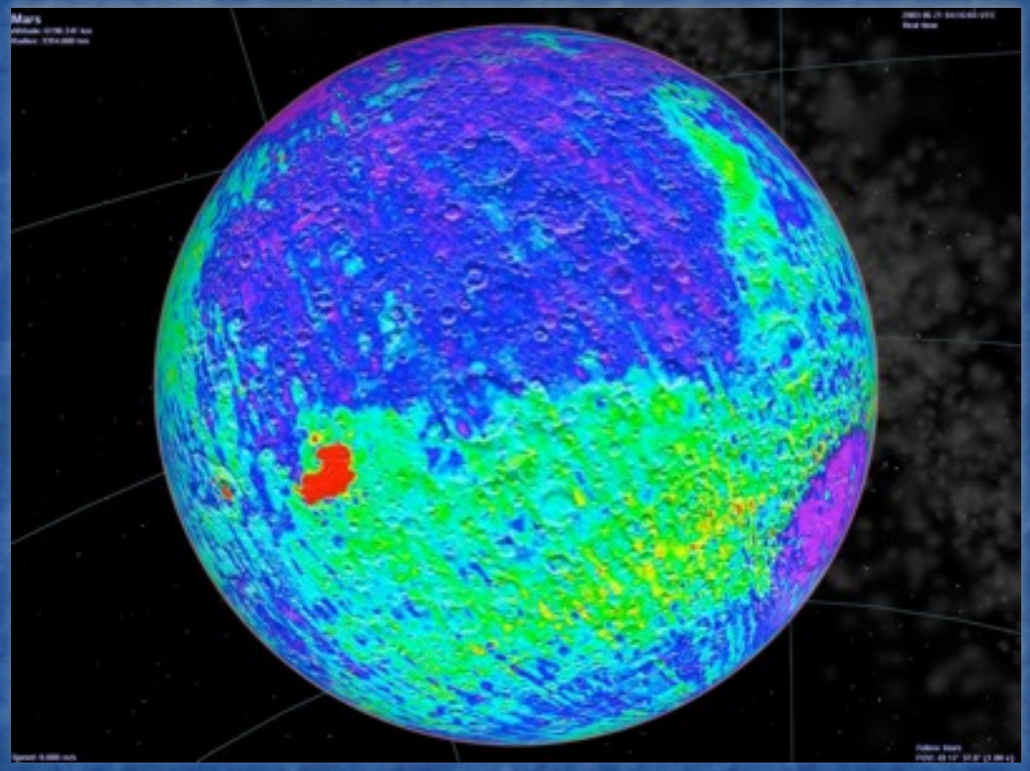


Mars Rovers

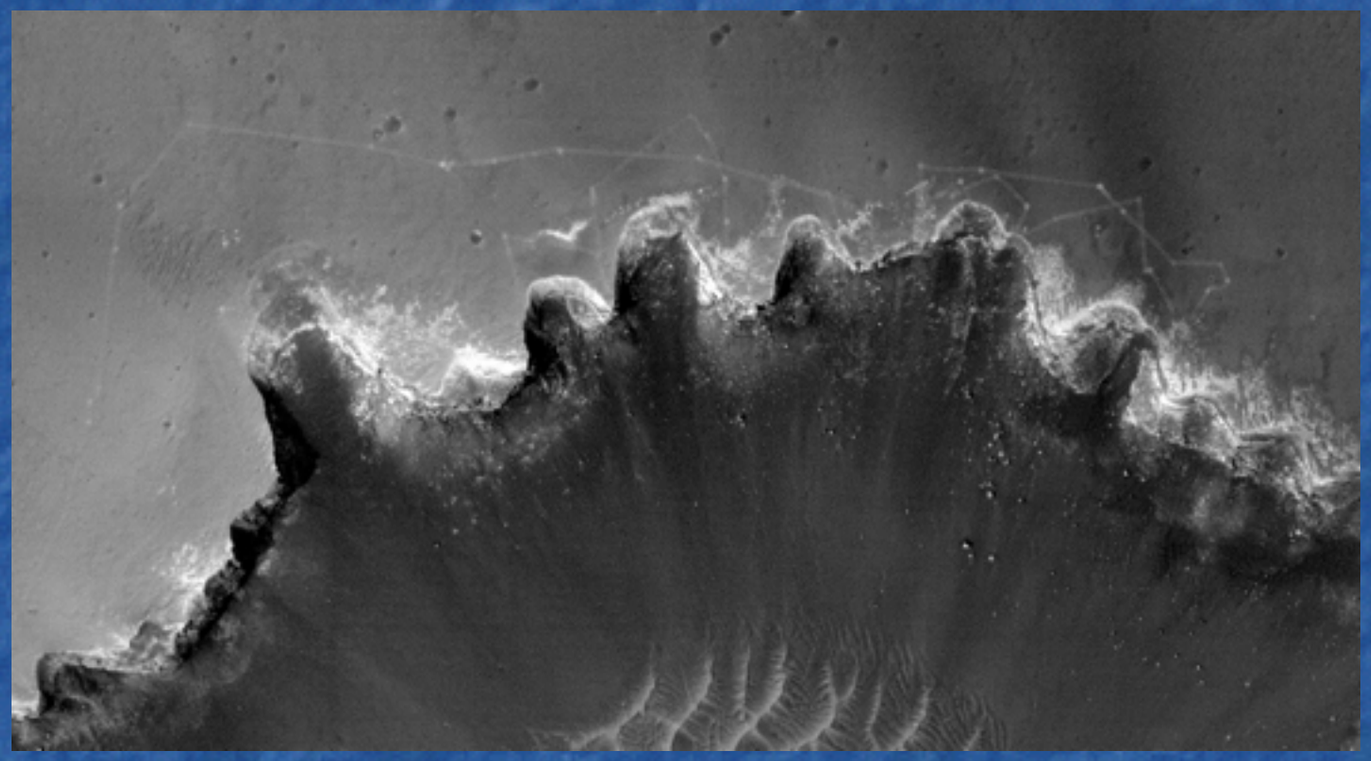
- Spirit rover landed in Gusev Crater on Jan. 4, 2004
- Opportunity rover landed in tiny Eagle Crater in Meridiani Planum on Jan. 24, 2004
- Mars rovers are mobile geology platforms.
- Water driven geology.
- Panoramic cameras + thermal emission spectrometer.
- Two mineral analysis spectrometers and a microscopic imager.

Rover Landing Sites



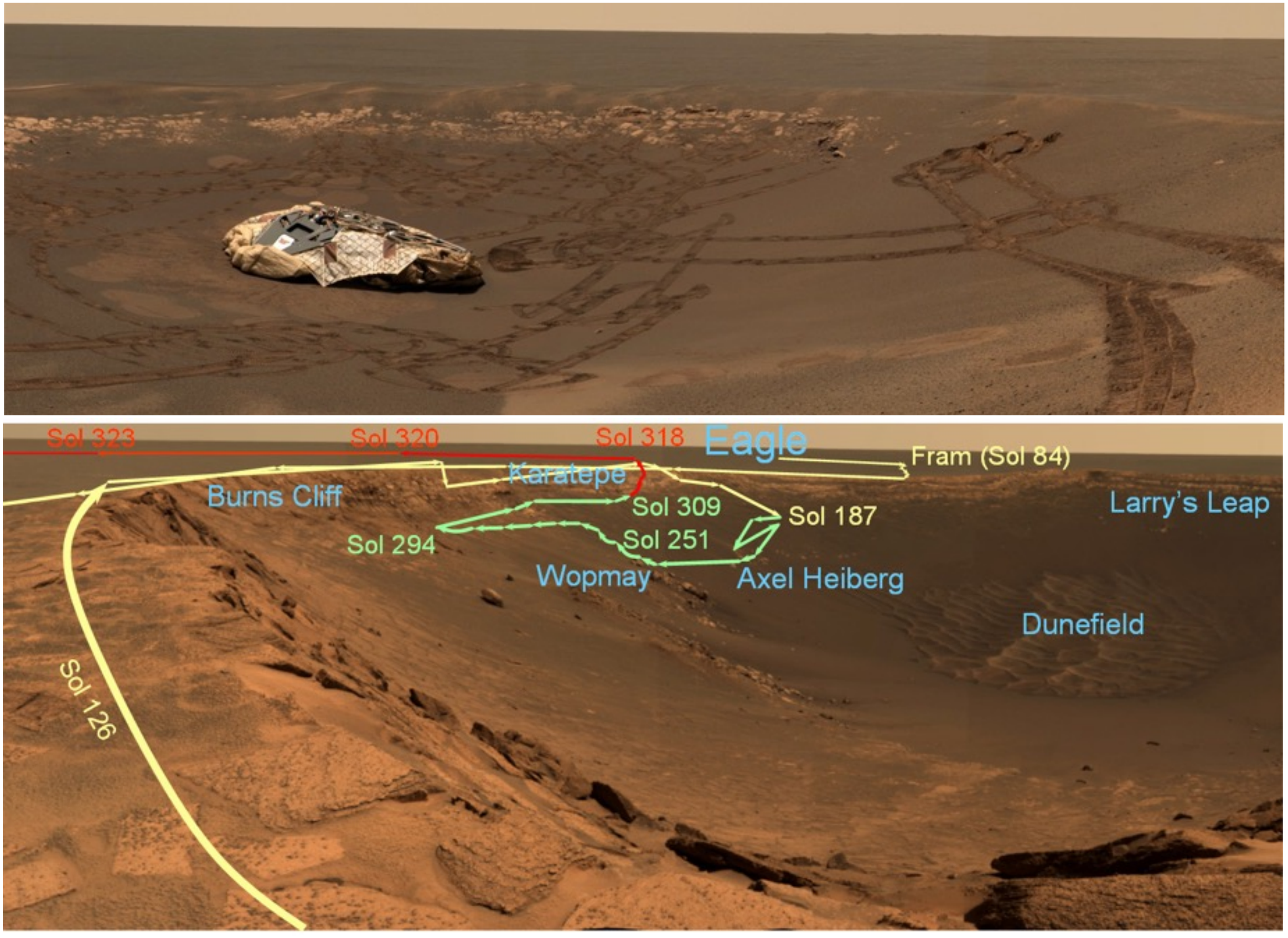


- Gusev Crater may have been a crater lake in the past
- Meridiani Planum has an unusually high concentration of the mineral hematite

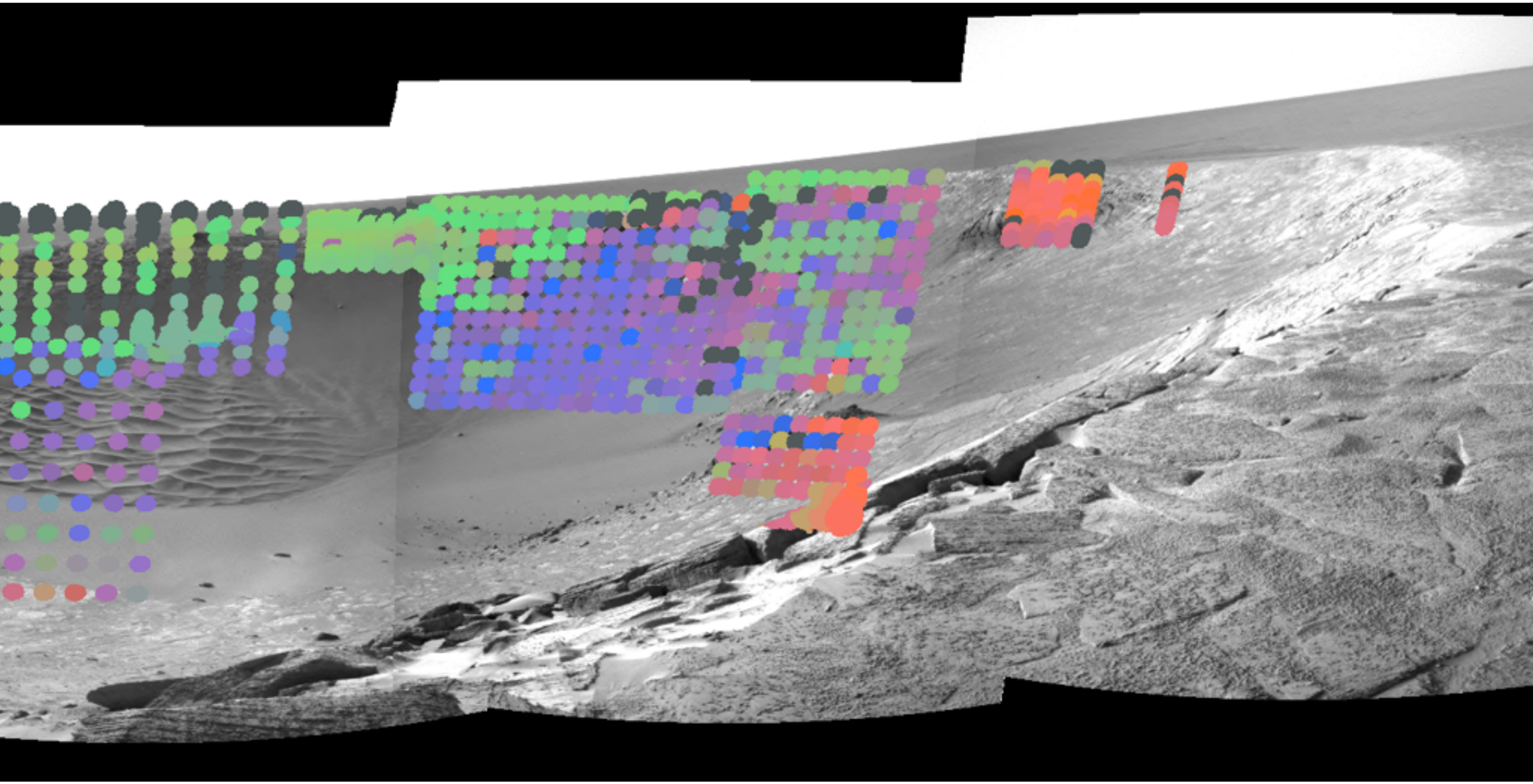


Opportunity looks back to its backshell and parachute

Eagle and Endurance Craters



Mini-TES Mineralogy

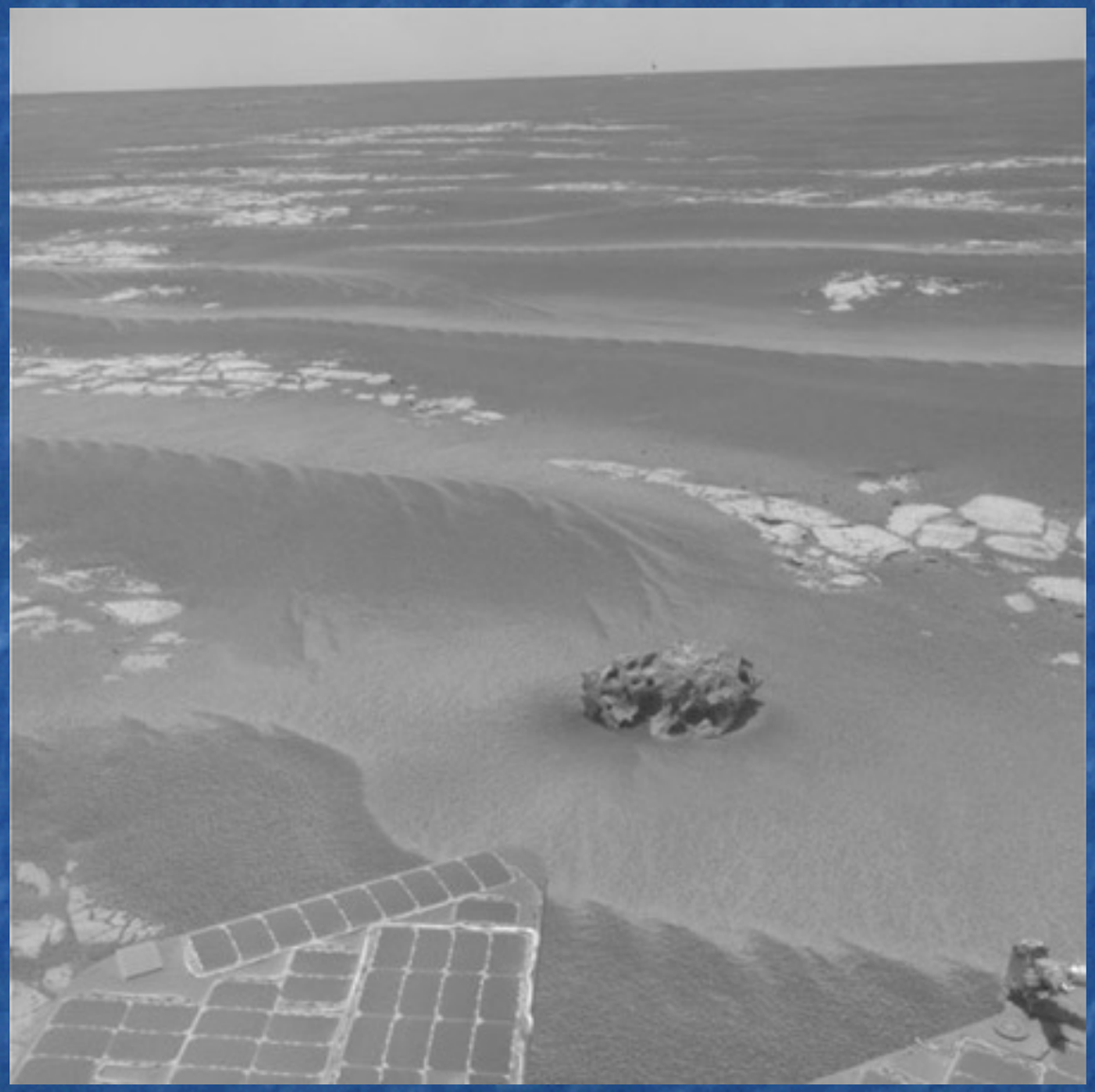


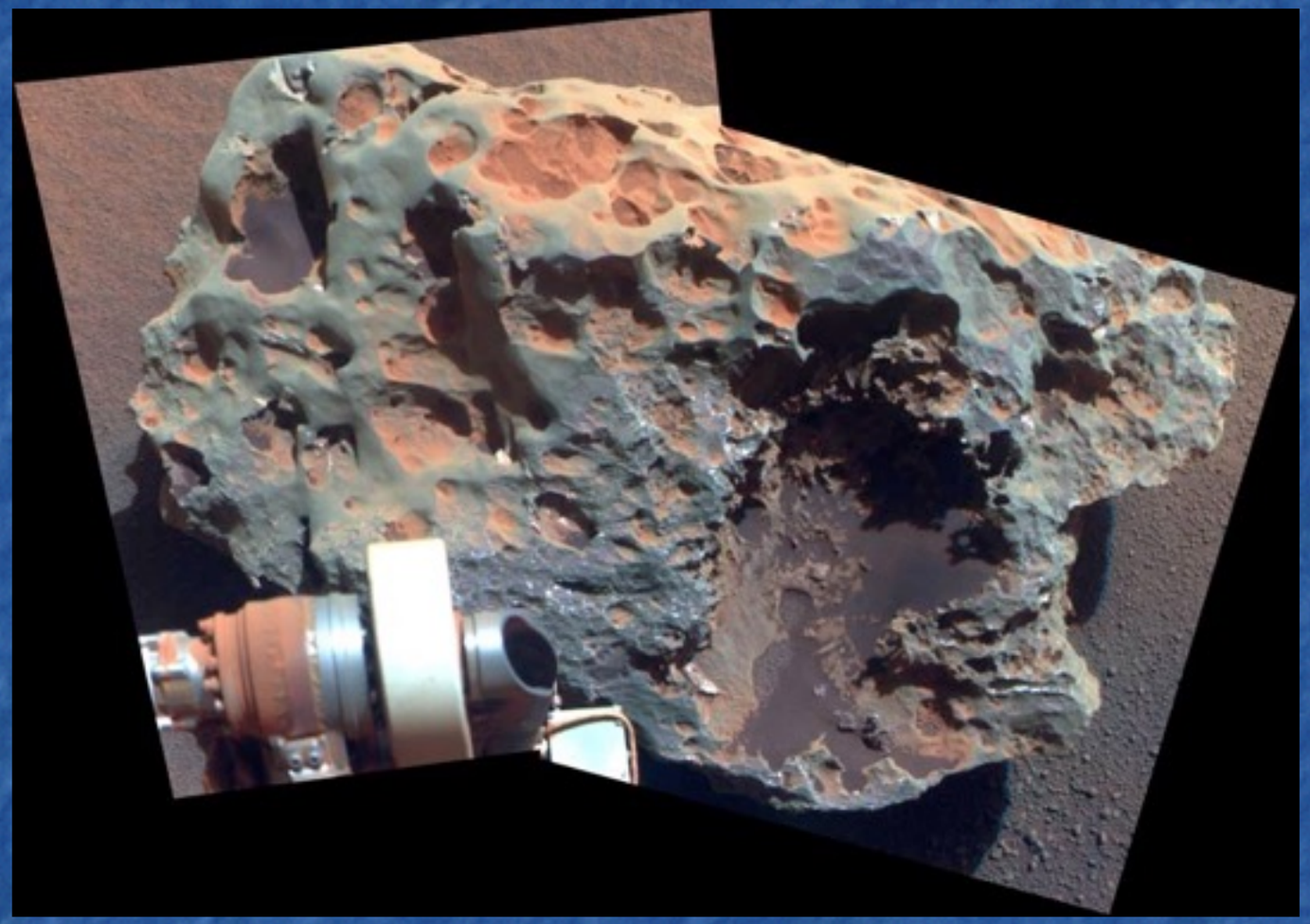
Red = Dust + Sulfate Unit

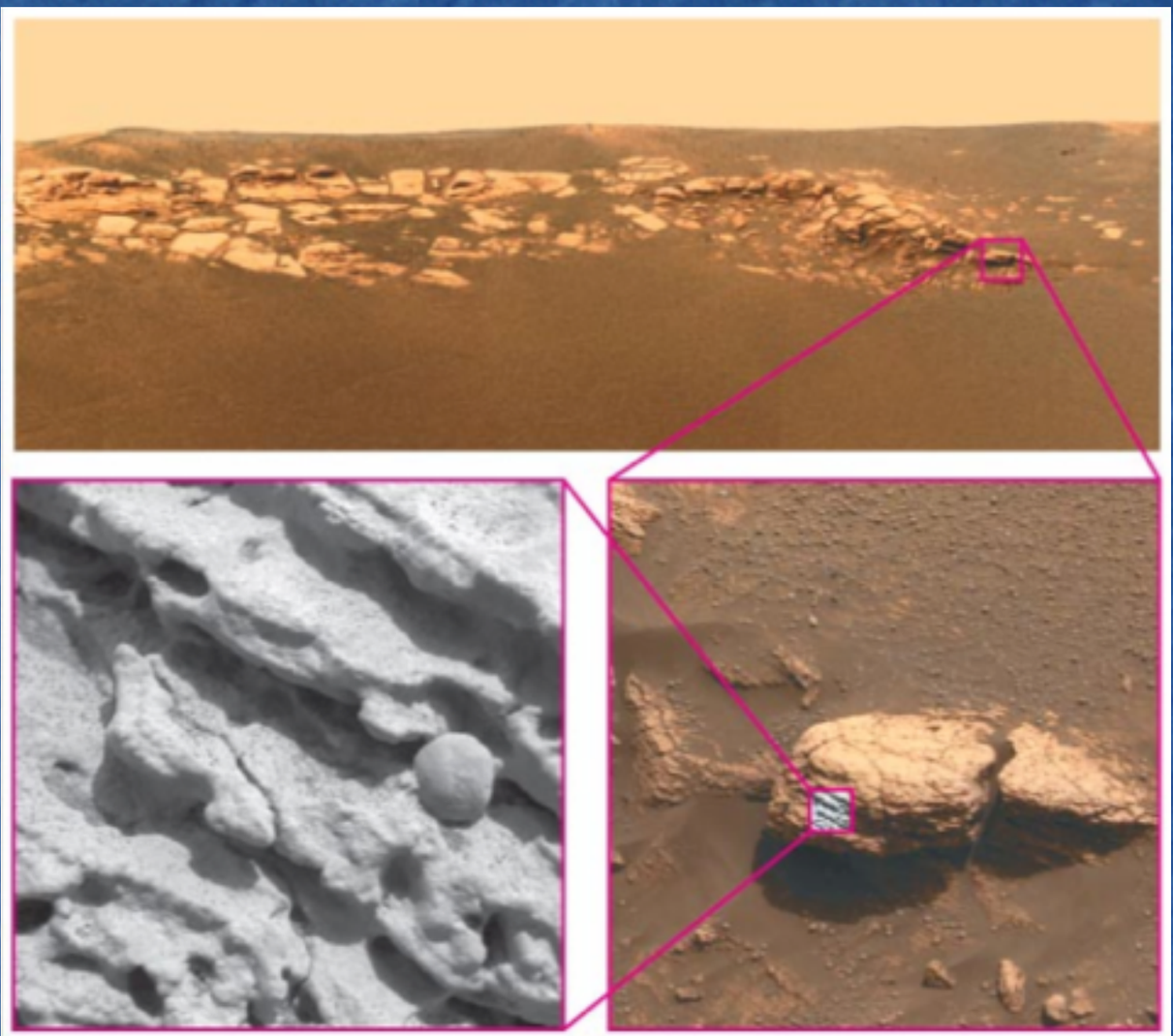
Green = Hematite + Basalt + Dust

Blue/Purple = Basalt (Plagioclase>Pyroxene>>Olivine) + Dust

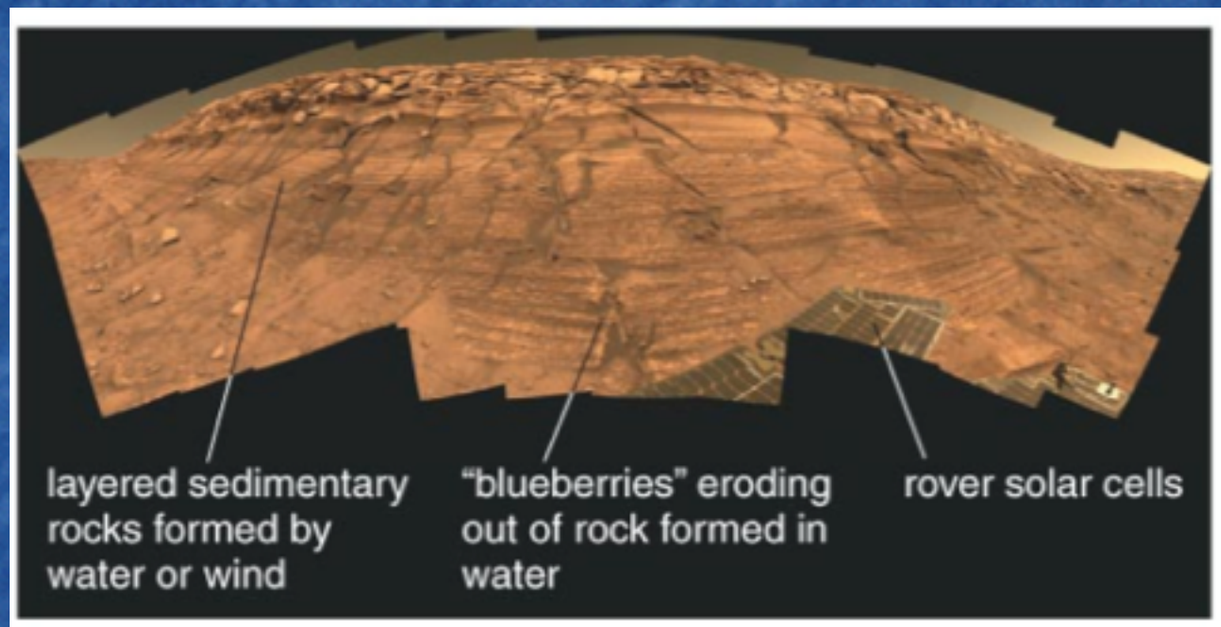
Meteorites on Mars





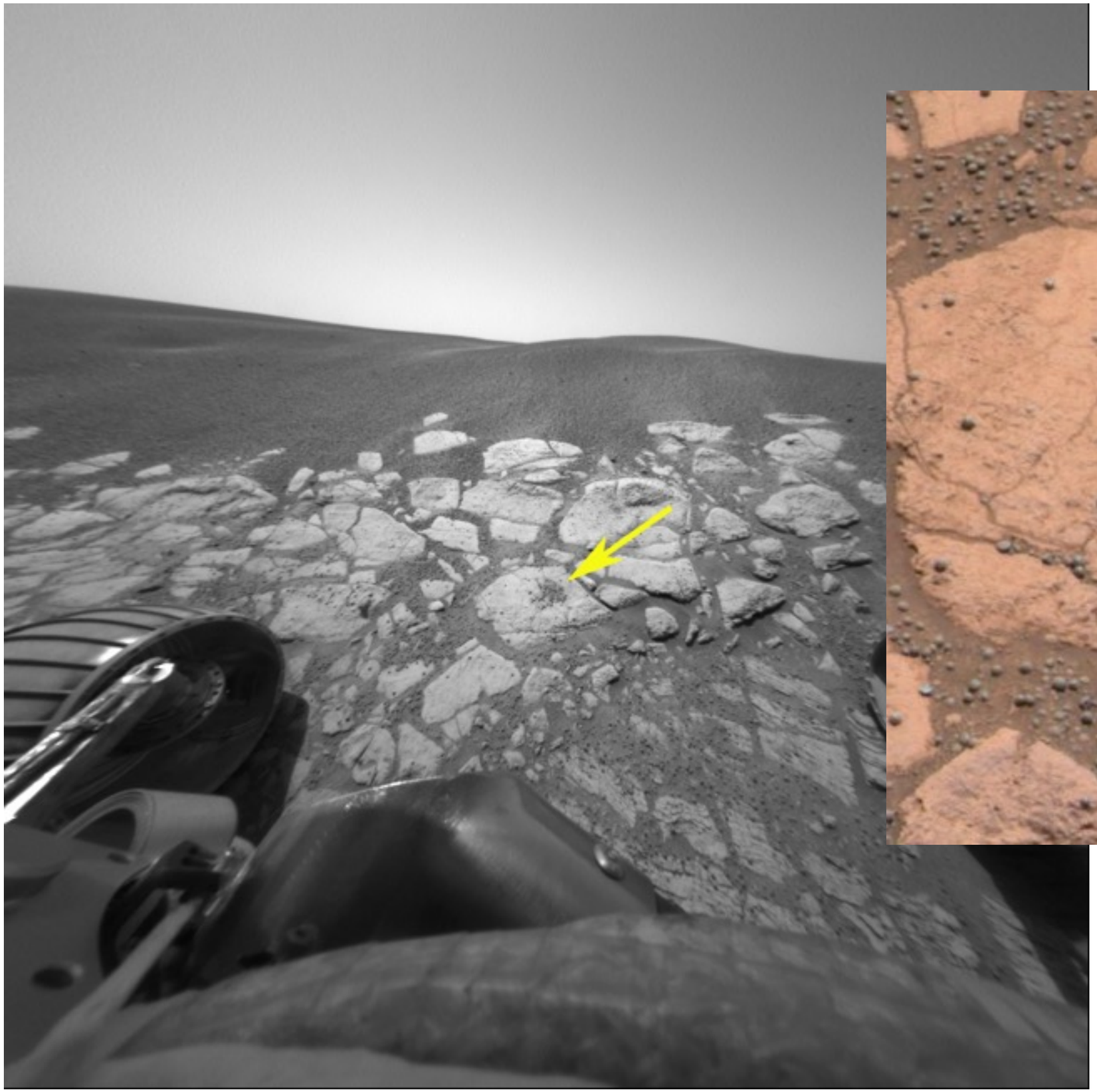


a Zooming in on a knee-high rock outcrop near the rover's landing site. The close-up shows a piece of the rock about 3 cm across. The layered structure, odd indentations, and small sphere all support the idea that the rock formed from sediments in standing water.

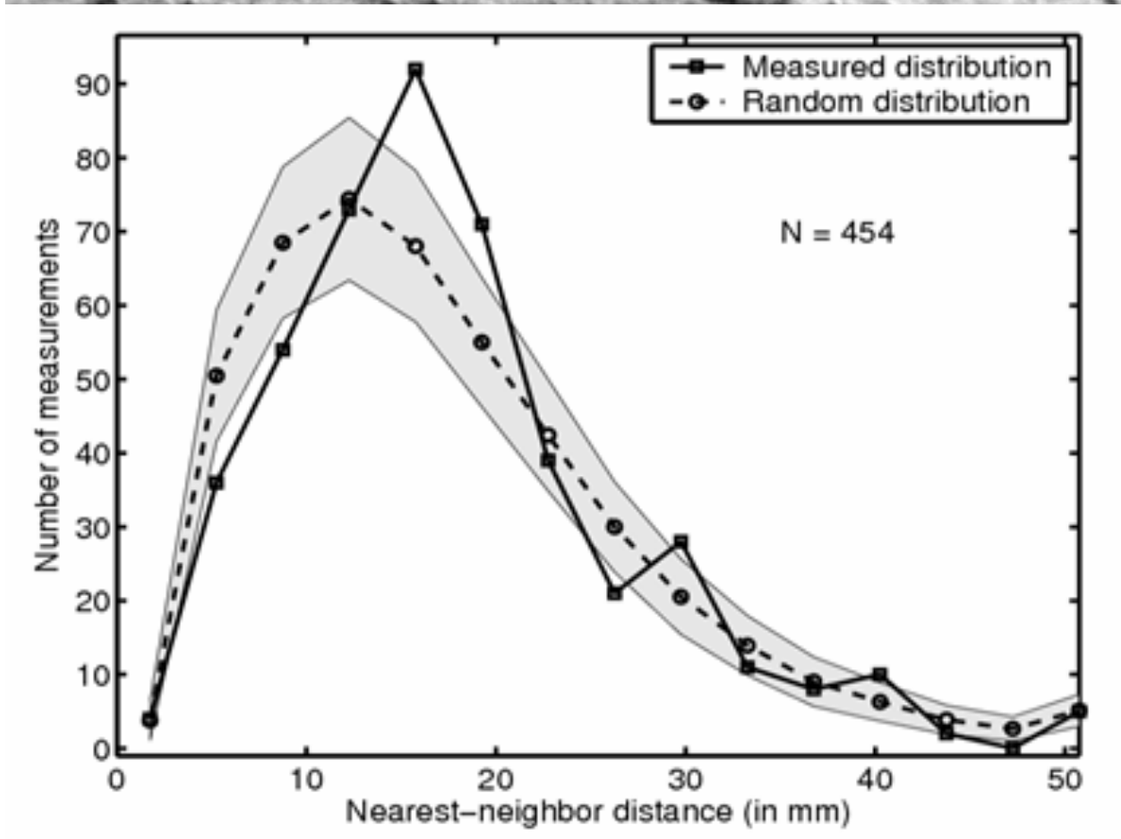


b The wall of Endurance Crater shows bedrock layers altered by water. Close-ups show hematite "blueberries" eroding out of the rock. The changing tilts of the rock layers hint at changing wind or waves during deposition.

Measuring Spherule Mineralogy



Spherule Distribution



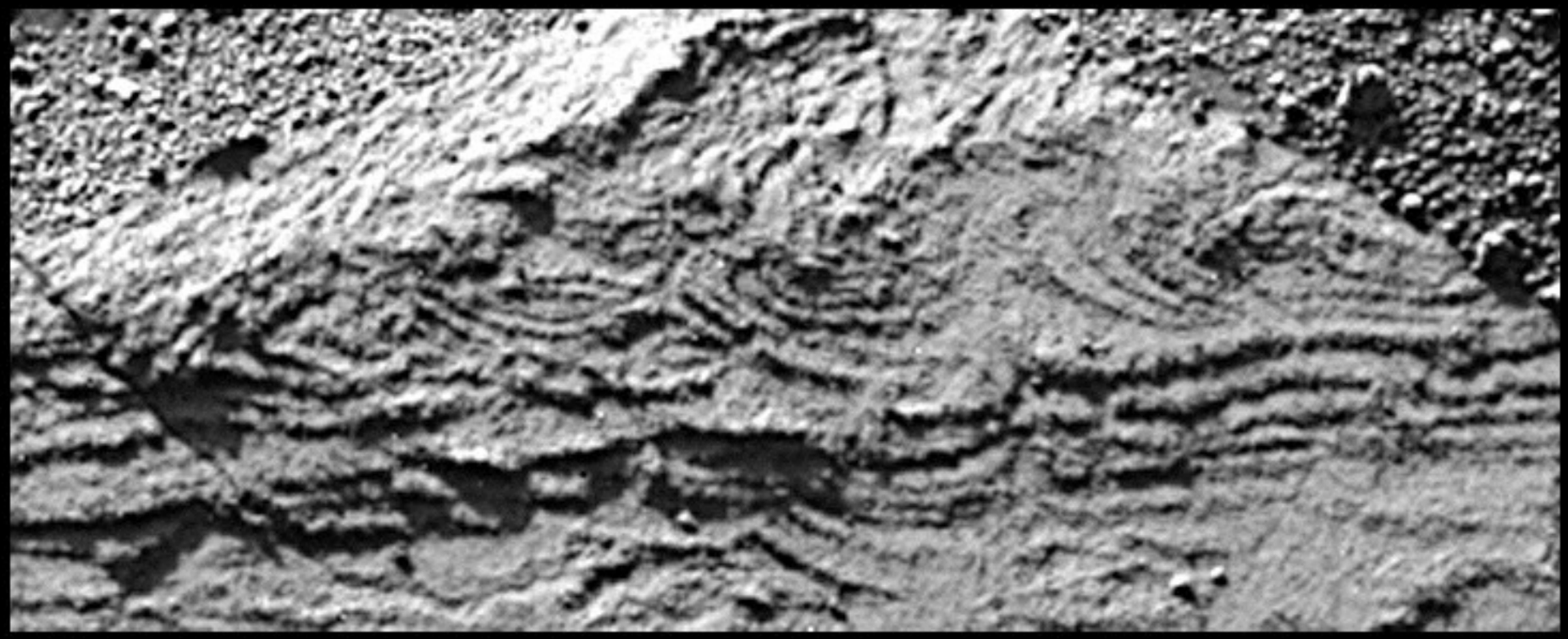
Volume distribution is more uniform than random, as expected for concretions

Current Ripples On Earth

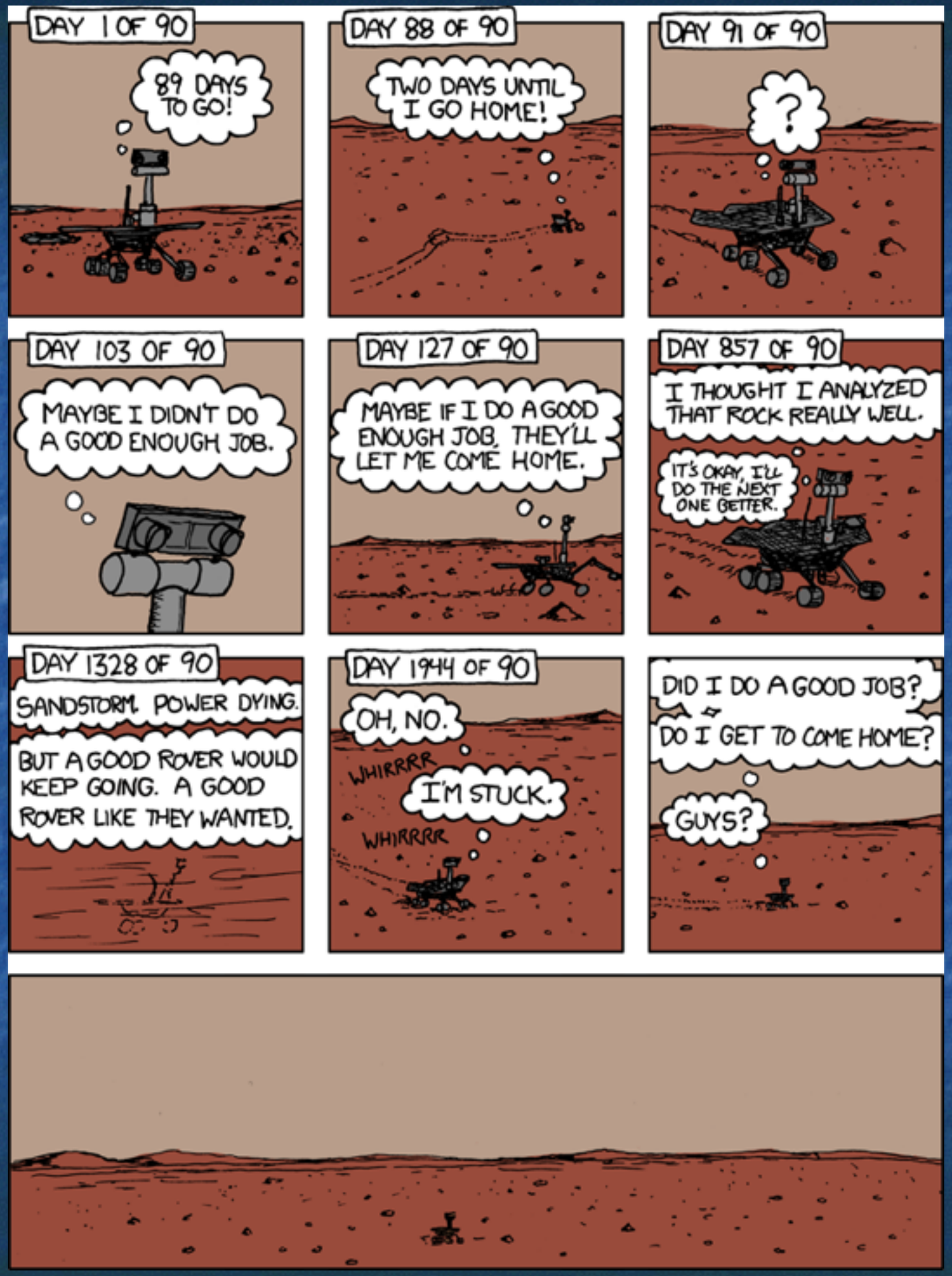
Courtesy of Dave Rubin, USGS

Opportunity Pancam
"Overgaard" rock
Sol 690 (Jan. 2, 2006)
430 nm image

2x
enlarged
portion



Full original image


DAY 1 OF 90
89 DAYS TO GO!
DAY 88 OF 90
TWO DAYS UNTIL I GO HOME!
DAY 91 OF 90
?
DAY 103 OF 90
MAYBE I DIDN'T DO A GOOD ENOUGH JOB.
DAY 127 OF 90
MAYBE IF I DO A GOOD ENOUGH JOB, THEY'LL LET ME COME HOME.
DAY 857 OF 90
I THOUGHT I ANALYZED THAT ROCK REALLY WELL.
IT'S OKAY, I'LL DO THE NEXT ONE BETTER.
DAY 1328 OF 90
SANDSTORM. POWER DYING.
BUT A GOOD ROVER WOULD KEEP GOING. A GOOD ROVER LIKE THEY WANTED.
DAY 1944 OF 90
OH, NO.
WHIRRRR
I'M STUCK.
WHIRRRR
DID I DO A GOOD JOB?
DO I GET TO COME HOME?
GUYS?

OUT-OF-THIS-WORLD RECORDS!

DRIVING DISTANCES ON MARS AND THE MOON

(AS OF JULY 28, 2014)
MARS — MOON —

0 10 20 KILOMETERS 30 40 50

Opportunity
(USA)
[2004-present]
40.25 KM

Lunokhod 2
(USSR)
[1973]
39 KM

Apollo 17
Lunar Rover
(USA)
[1972]
35.74 KM

Apollo 15
Lunar Rover
(USA)
[1971]
27.8 KM

Apollo 16
Lunar Rover
(USA)
[1972]
27.1 KM

Lunokhod 1
(USSR)
[1970-1971]
10.5 KM

Curiosity
(USA)
[2012-present]
8.6 KM

Spirit
(USA)
[2004-2010]
7.7 KM

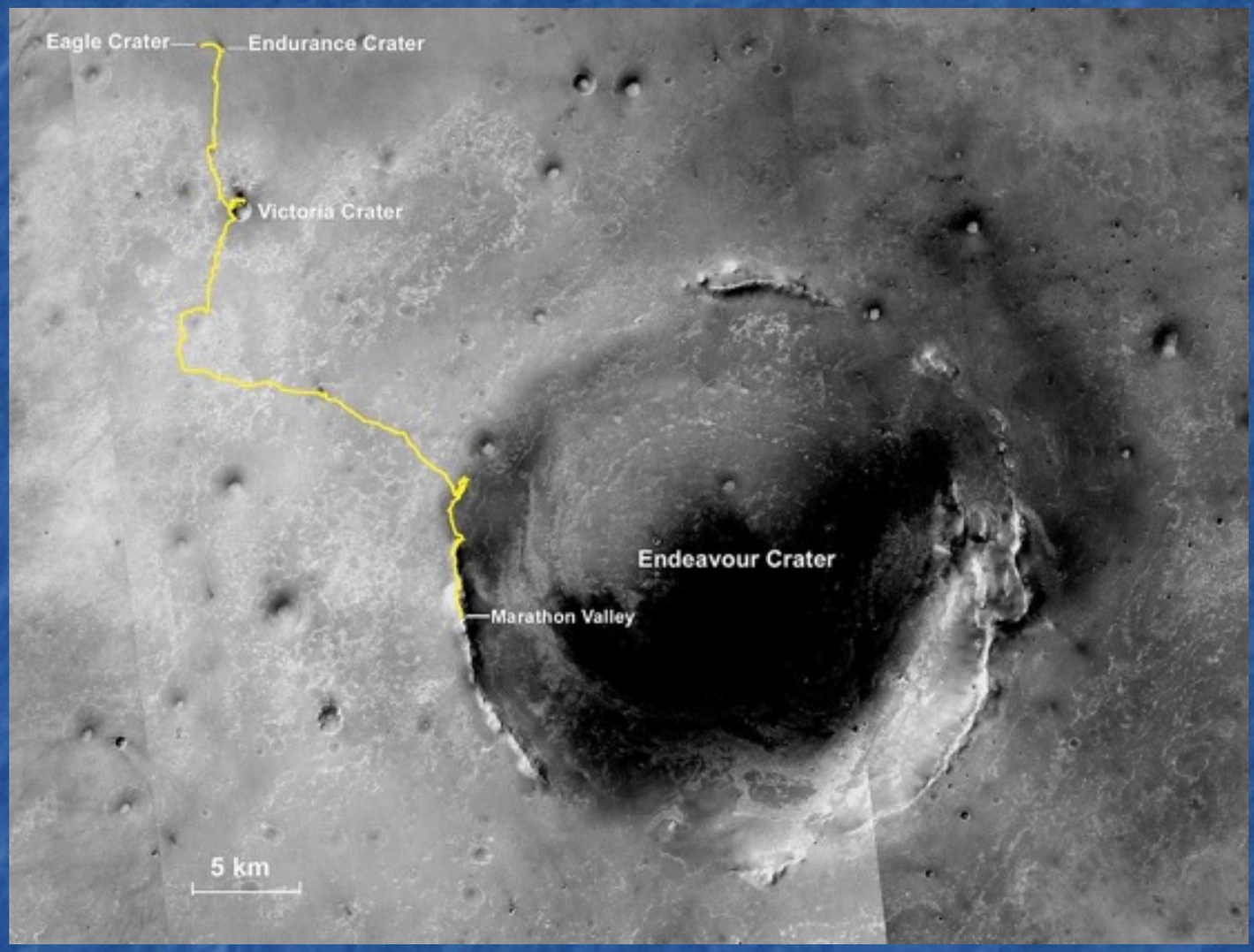
Marathon race distance
(42.195 km / 26.22 miles)

Yutu
(China)
[2013-2014]
0.12 KM

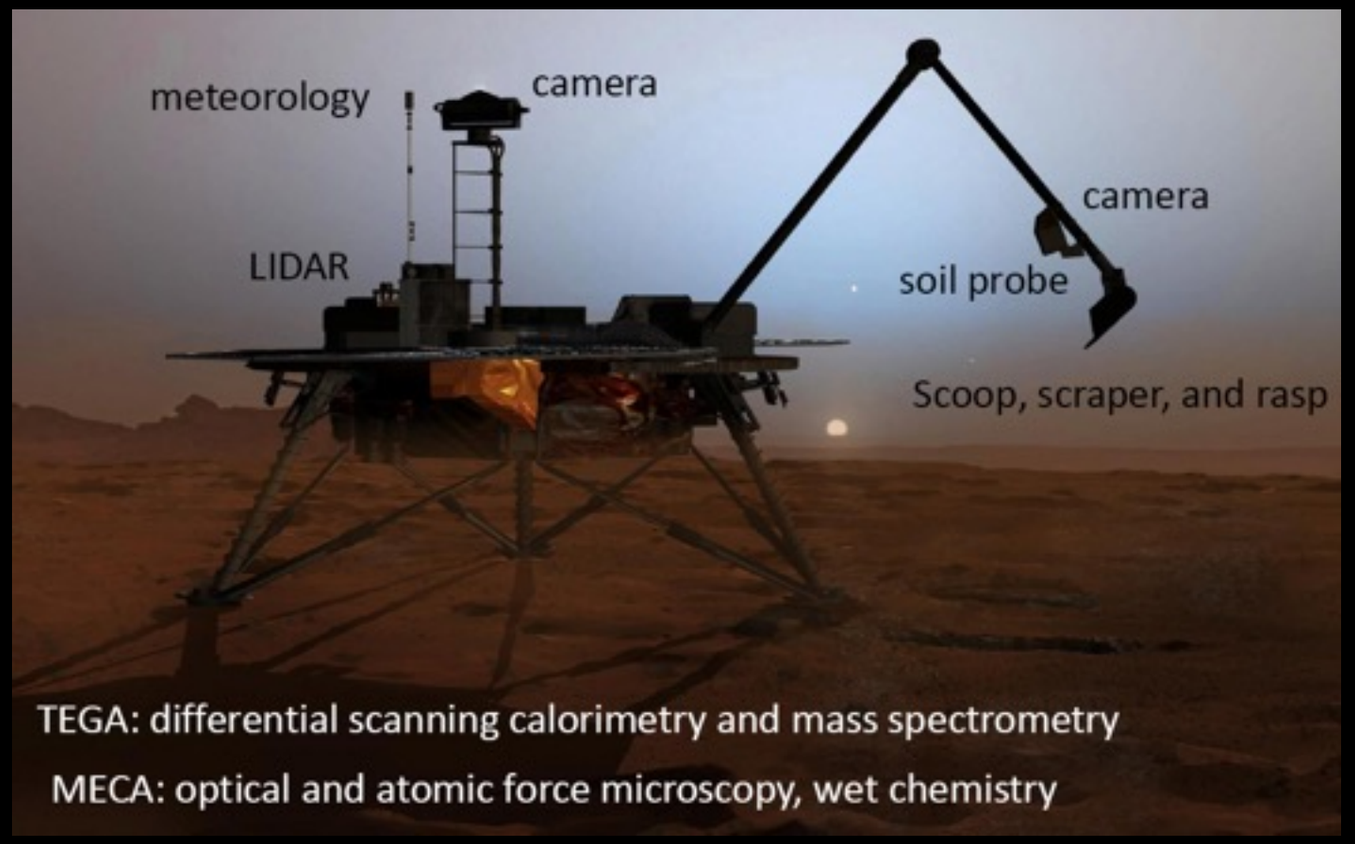
Sojourner
(USA)
[1997]
0.10 KM

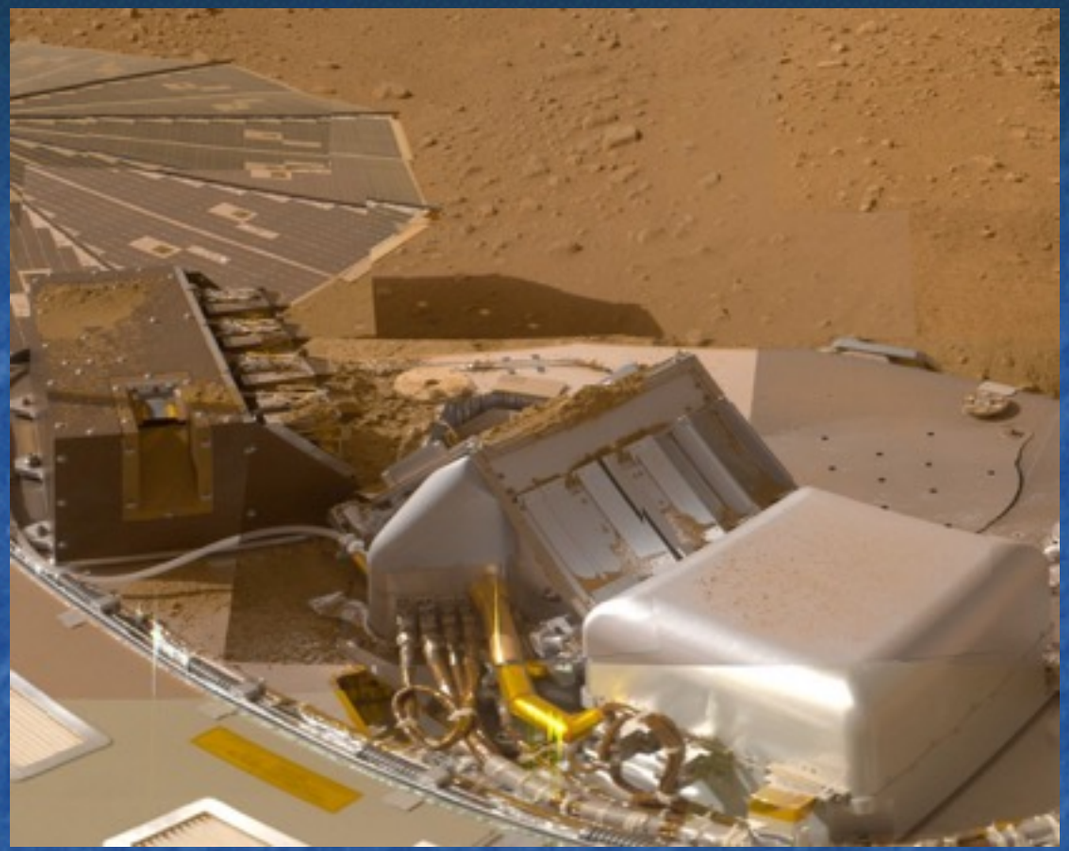
0 10 MILES 20 30

FOR MORE INFO VISIT
MARS.NASA.GOV



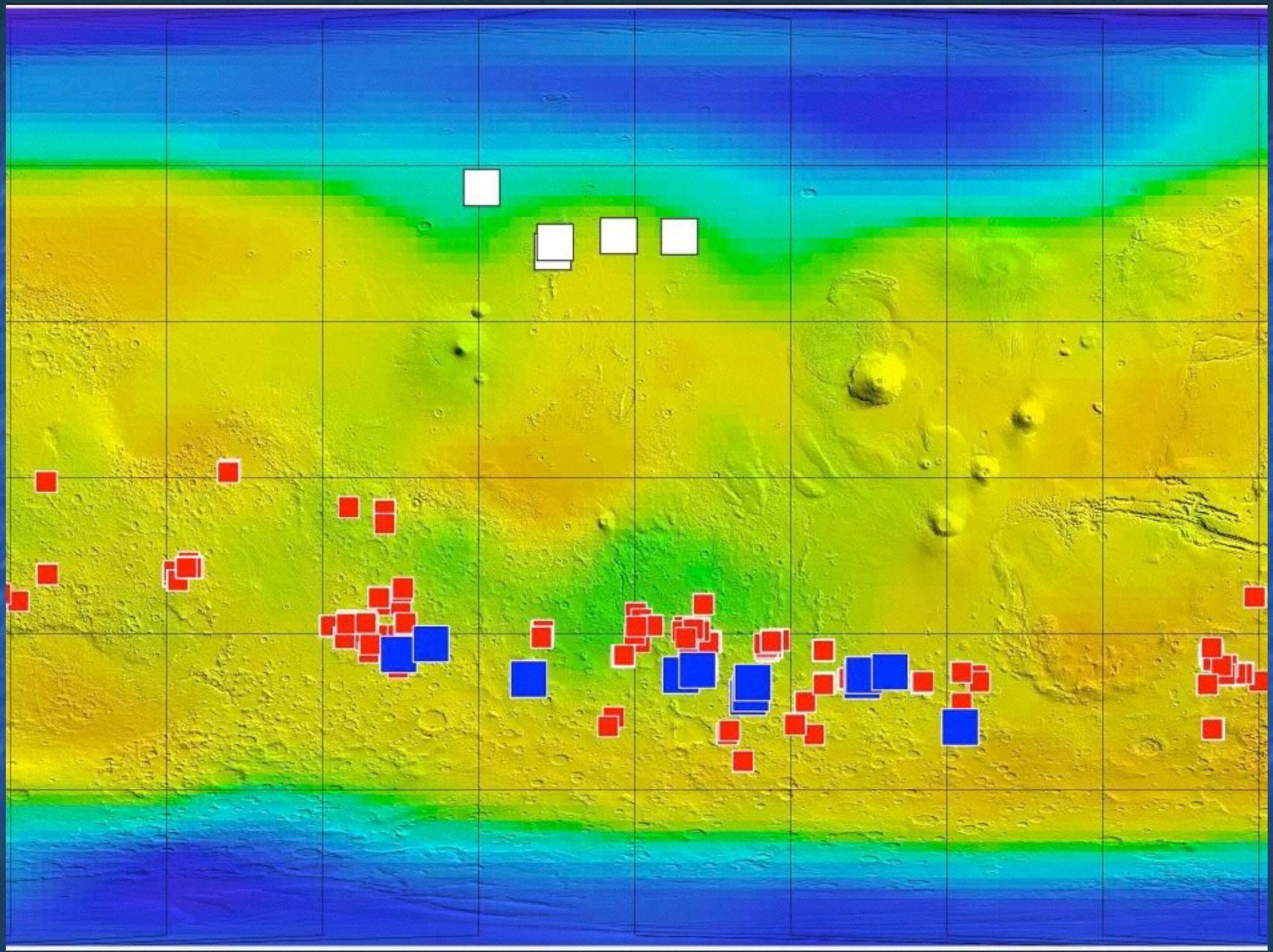
Mars Phoenix



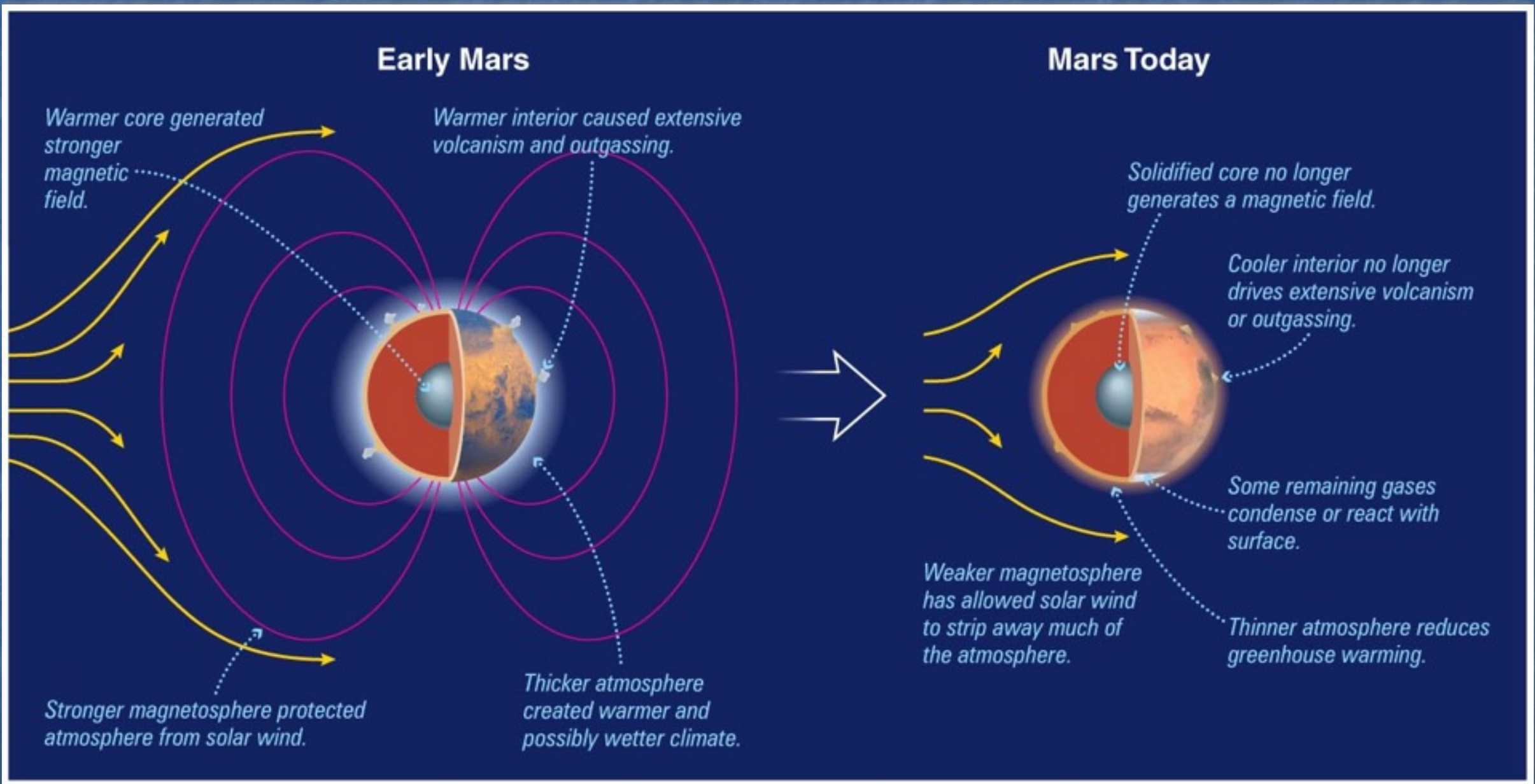


Mars Phoenix results:

- Water ice in sub-soil
- Perchlorate in soil: sucks humidity from atmosphere, could form a low-T salty brine with water, used by Earth-based microbes as energy source.
- Water-ice clouds and snow detected in atmosphere. Seasonal snow dustings expected.
- Calcium-carbonate detected in soil: C02 + H20 + surface.



Climate Change on Mars



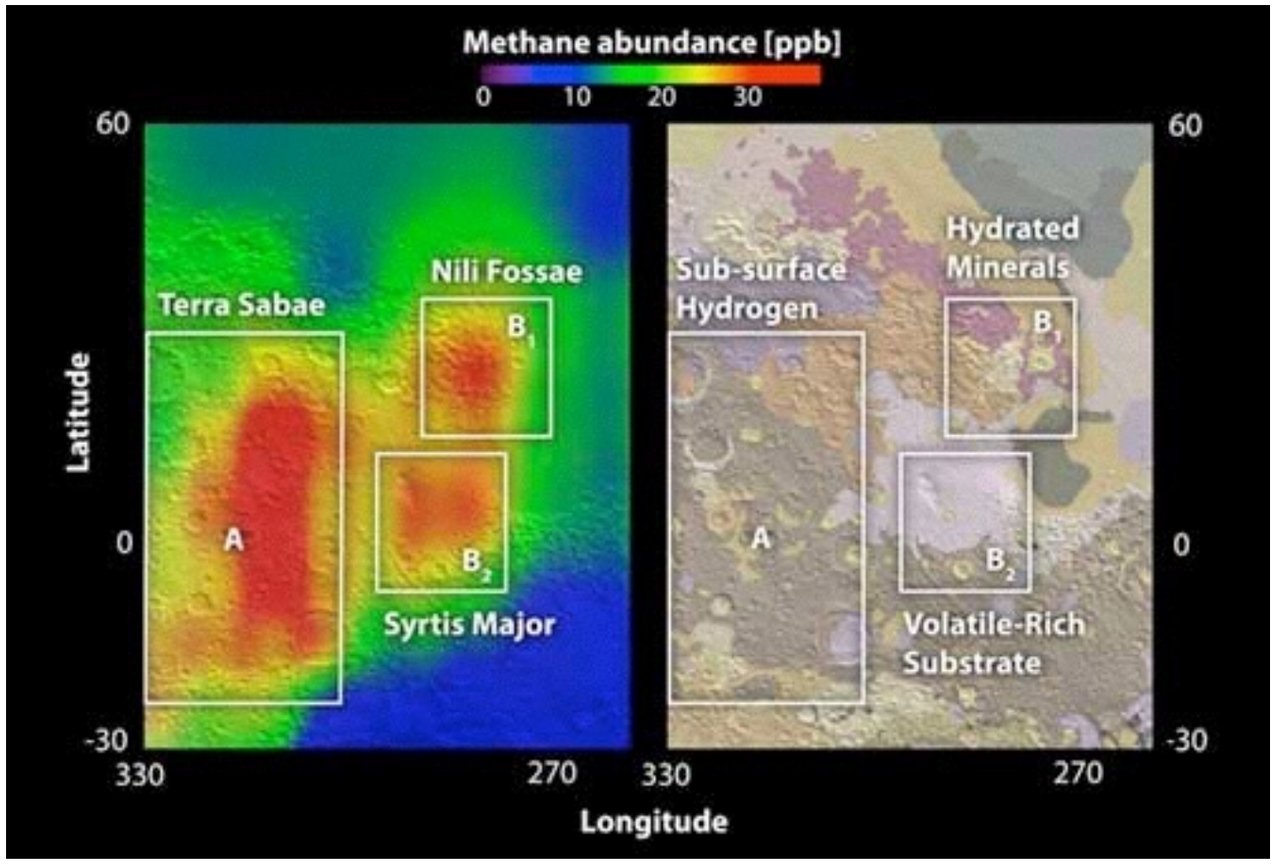
Water on Mars

- Ancient water-driven surface features imaged from orbit.
- Surface distribution of water ice detected from orbit.
- Water-driven mineralogy detected by rovers.
- Small-scale water features detected by rovers.
- Internal heat loss led to a decrease in geological activity.
- No atmospheric recycling.
- Photolysis of H20 used up the atmospheric water vapour.
- Hydrogen was lost to space. Oxygen oxidised the surface rocks.

Ancient Mars?

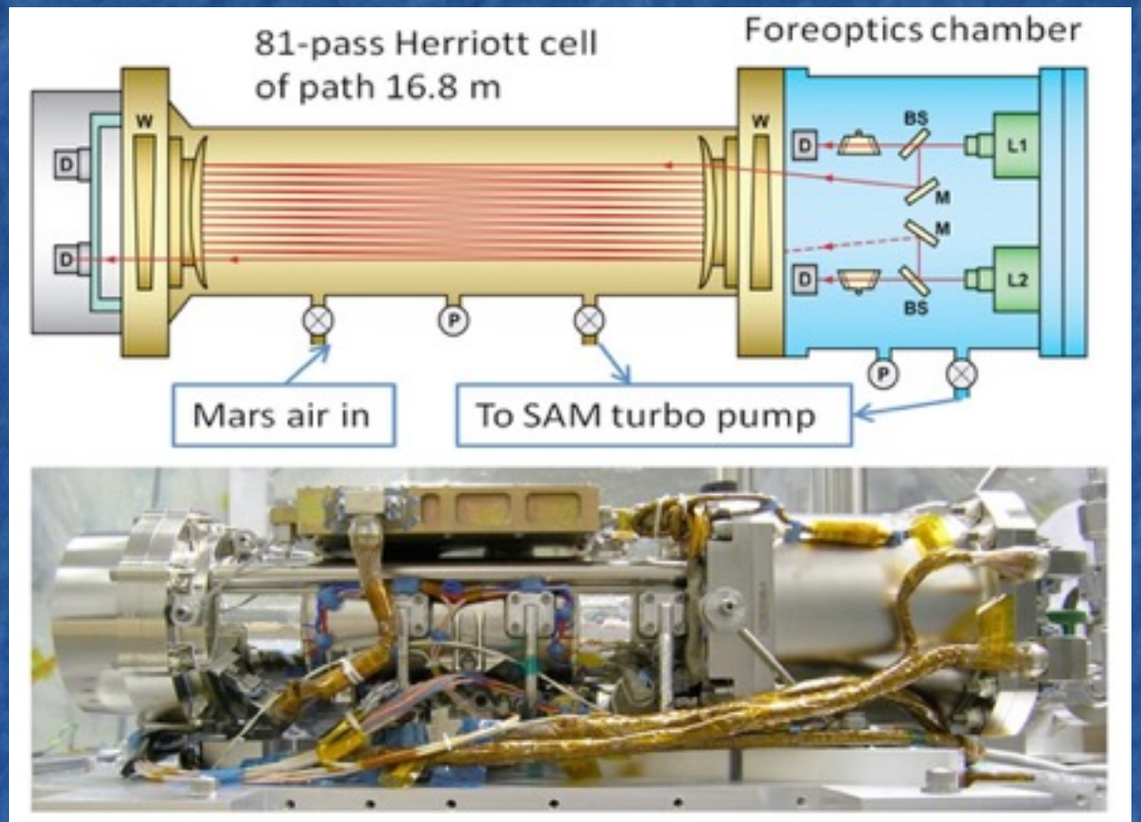
Image Courtesy of Kees Veenenbos

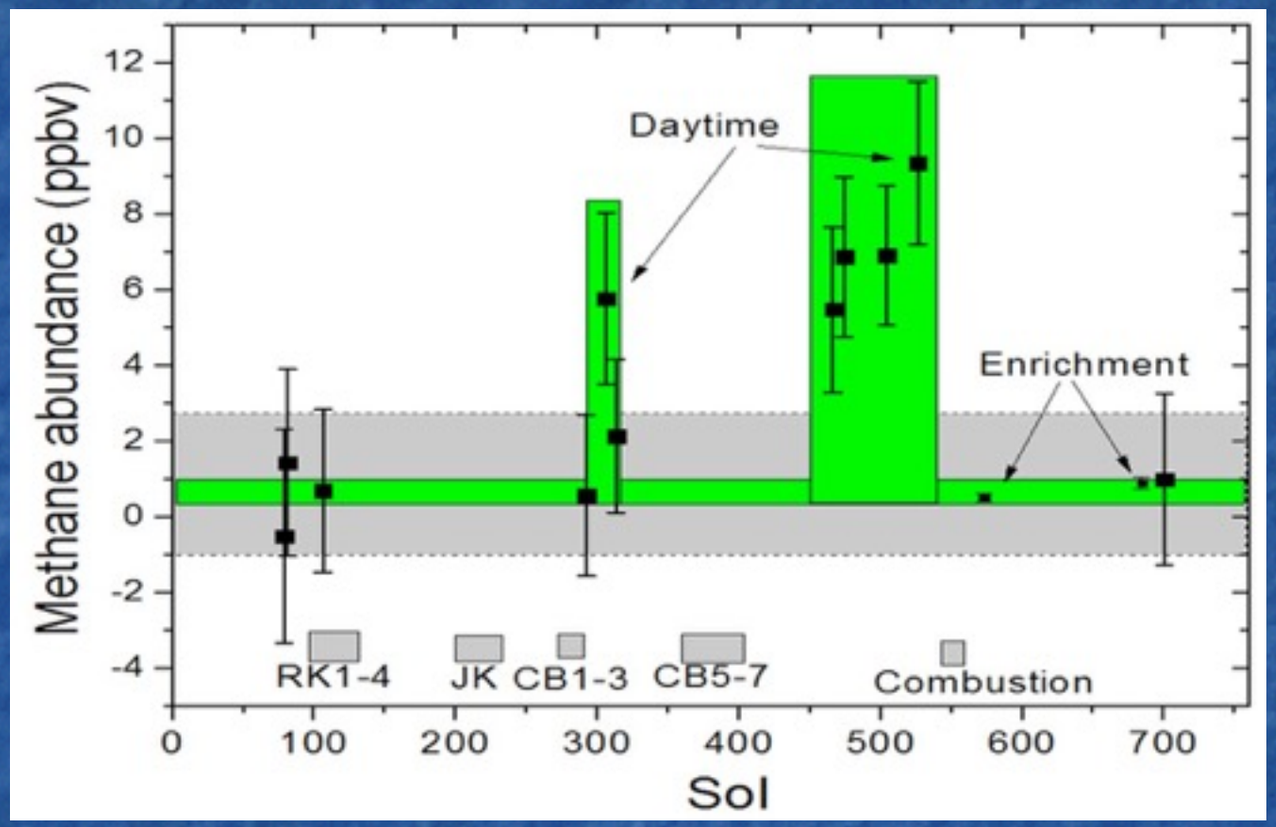
Methane In The Martian Atmosphere!



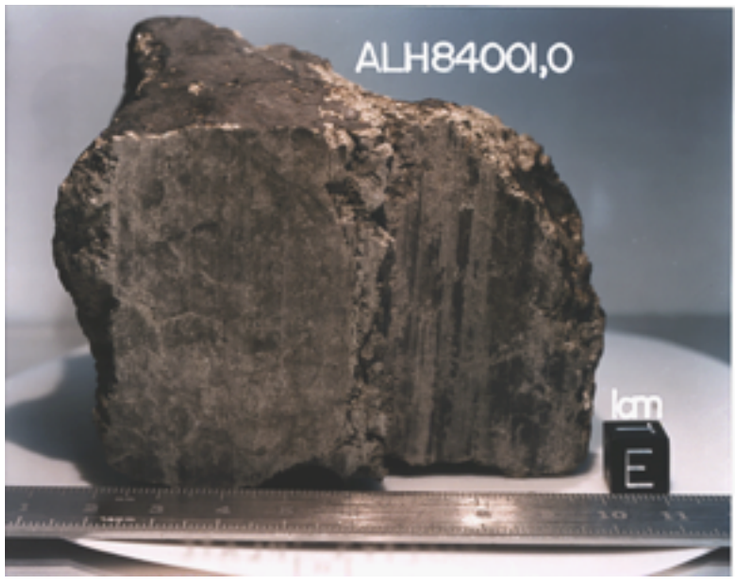
- Methane has been detected in the martian atmosphere
- Distribution is temporally and spatially variable
- UV photodissociation time for methane is very short, so there must be an active source.
- Methane can be produced both biologically (*e.g.*, bacteria) and abiologically (*e.g.*, volcanism).
- Implication: Mars is biologically or volcanically active.

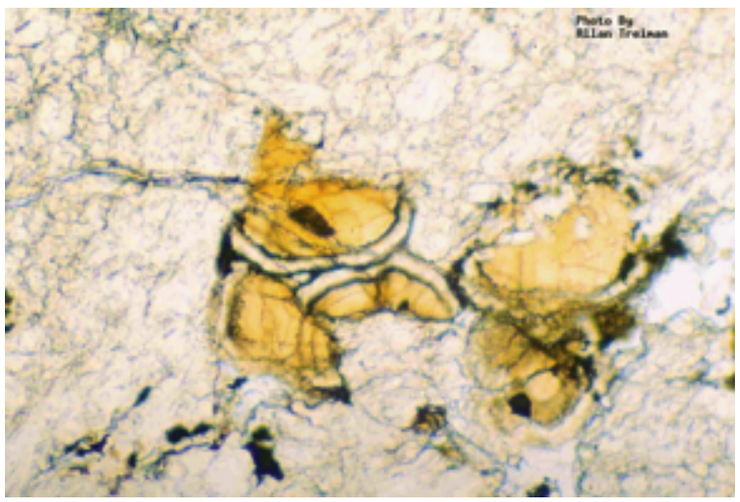
Methane Measurements by NASA's Curiosity in Mars' Gale Crater

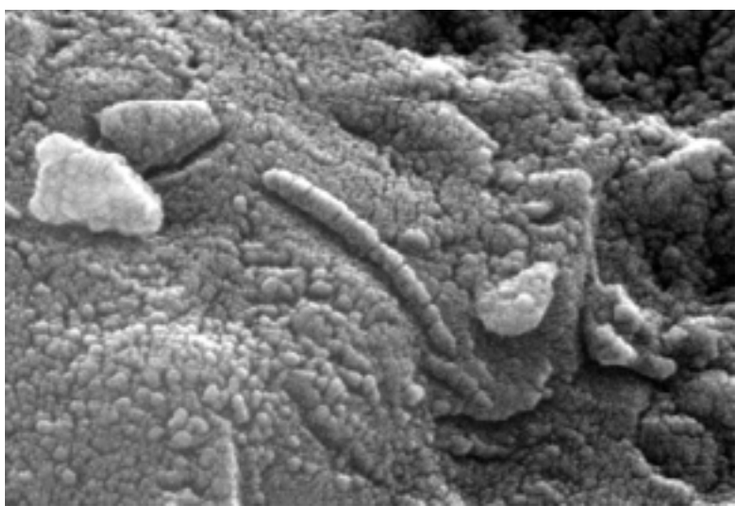




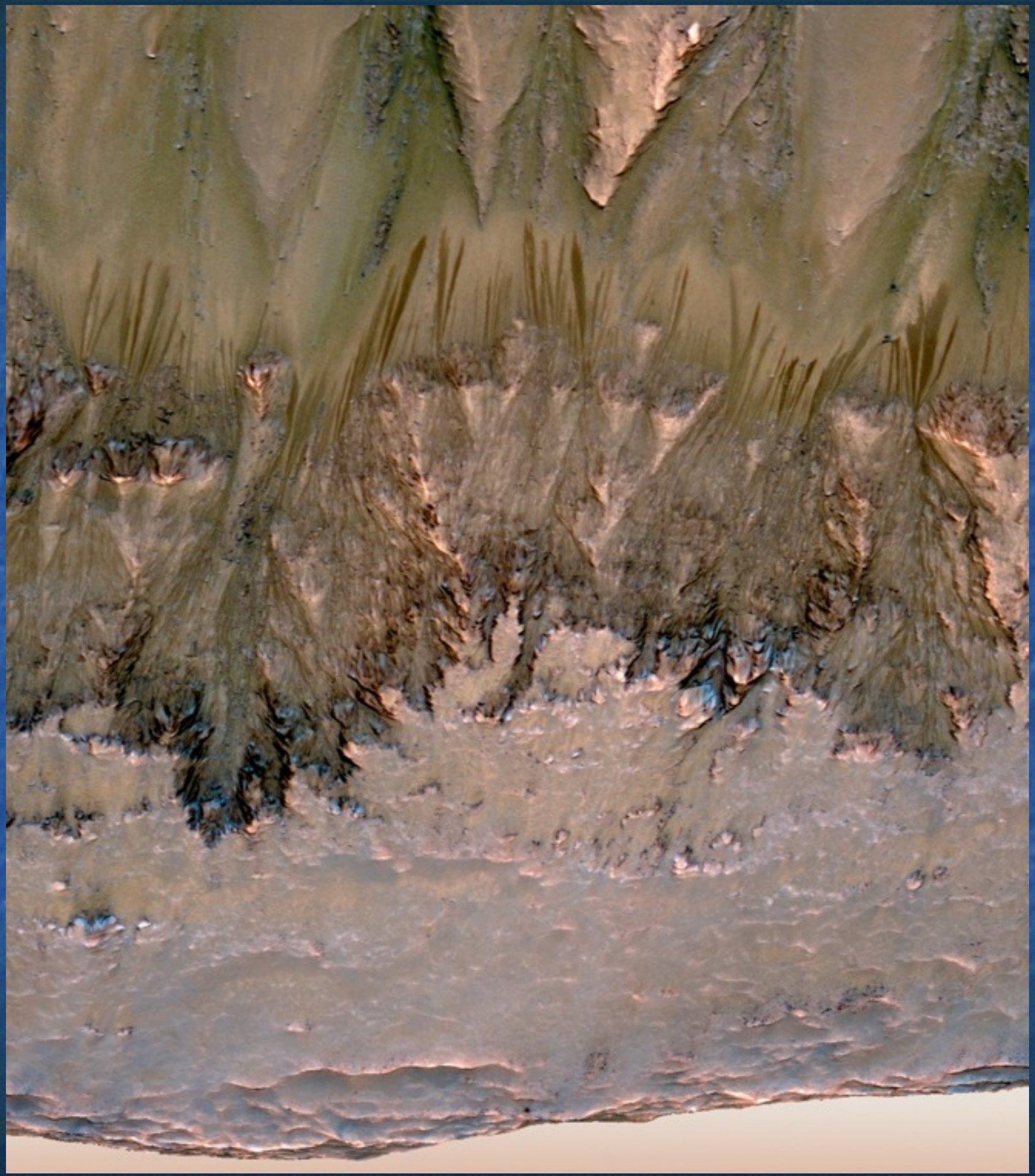
ALH84001







- Very ancient (>4 Gyr) martian meteorite that contains:
  - Carbonate globules
  - Polycyclic aromatic hydrocarbons
  - Magnetite crystals similar to those formed by some terrestrial bacteria
  - Very small shapes that resemble bacteria
- All these observations could be compatible with ancient martian life, but all could also have non-biological explanations



Key Challenges of Human Exploration of Mars

1 EARTH VICINITY

- Multiple launches of large payloads
- Automated rendezvous & docking
- Long-term storage of systems in orbit

2 TRANSIT TO MARS

- Human health and performance in space (200 days to Mars) including radiation & zero-g
- Long-term system reliability, maintenance and operations of systems for long-periods
- Landing large payloads on Mars (Aero-Entry, and precision landing)
- Mars orbit insertion or aerocapture
- Extended periods of dormancy
- Communication time lag
- Abort to surface

3 SURFACE EXPLORATION

- Human health and performance on Mars (500 days)
- Minimize surface assembly and associated operations
- Long-term system reliability, maintenance and operations of systems for long-periods
- No logistics resupply
- Communication time lag
- Robust exploration including long-range & routine EVA
- Extensive science operations & minimal sample return
- Environment of Mars: dust, dust storms, etc.
- Nuclear surface system operation and reliability
- Extended periods of dormancy
- Ascent & rendezvous
- Planetary protection

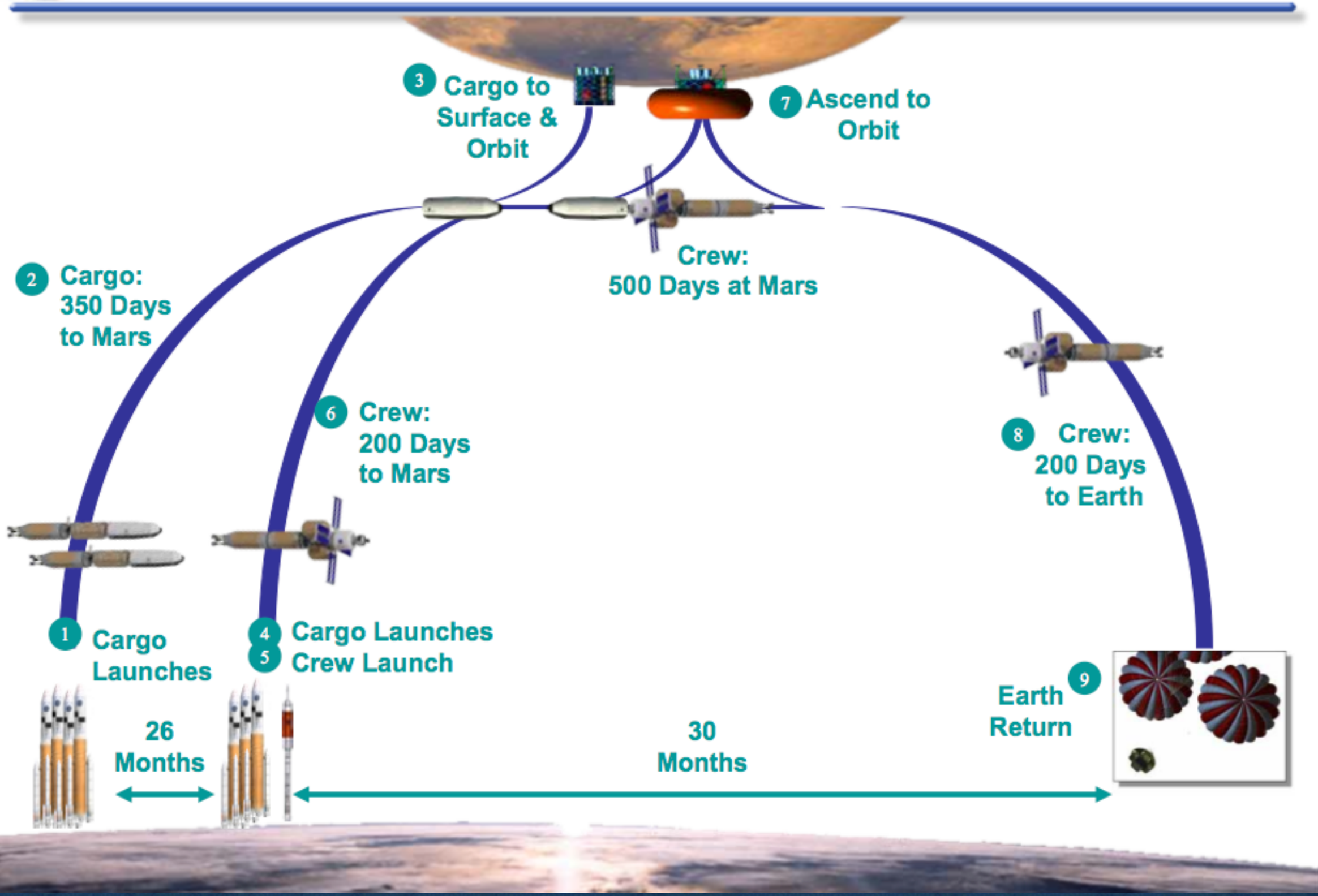
4 TRANSIT FROM MARS

- Human health and performance in space (200 days to Mars)
- Long-term system reliability
- Communication time lag

5 EARTH RETURN

- High-speed direct entry (12+ km/s)

Design Reference Architecture 5.0
Mission Profile



Journal of Cosmology, 2010, Vol 12, 3619-3626.
JournalofCosmology.com, October-November, 2010
The Human Mission to Mars. Colonizing the Red Planet

To Boldly Go: A One-Way Human Mission to Mars

Dirk Schulze-Makuch, Ph.D.[1], and Paul Davies, Ph.D.[2],
[1]School of Earth and Environmental Sciences, Washington State University
[2]Beyond Center, Arizona State University

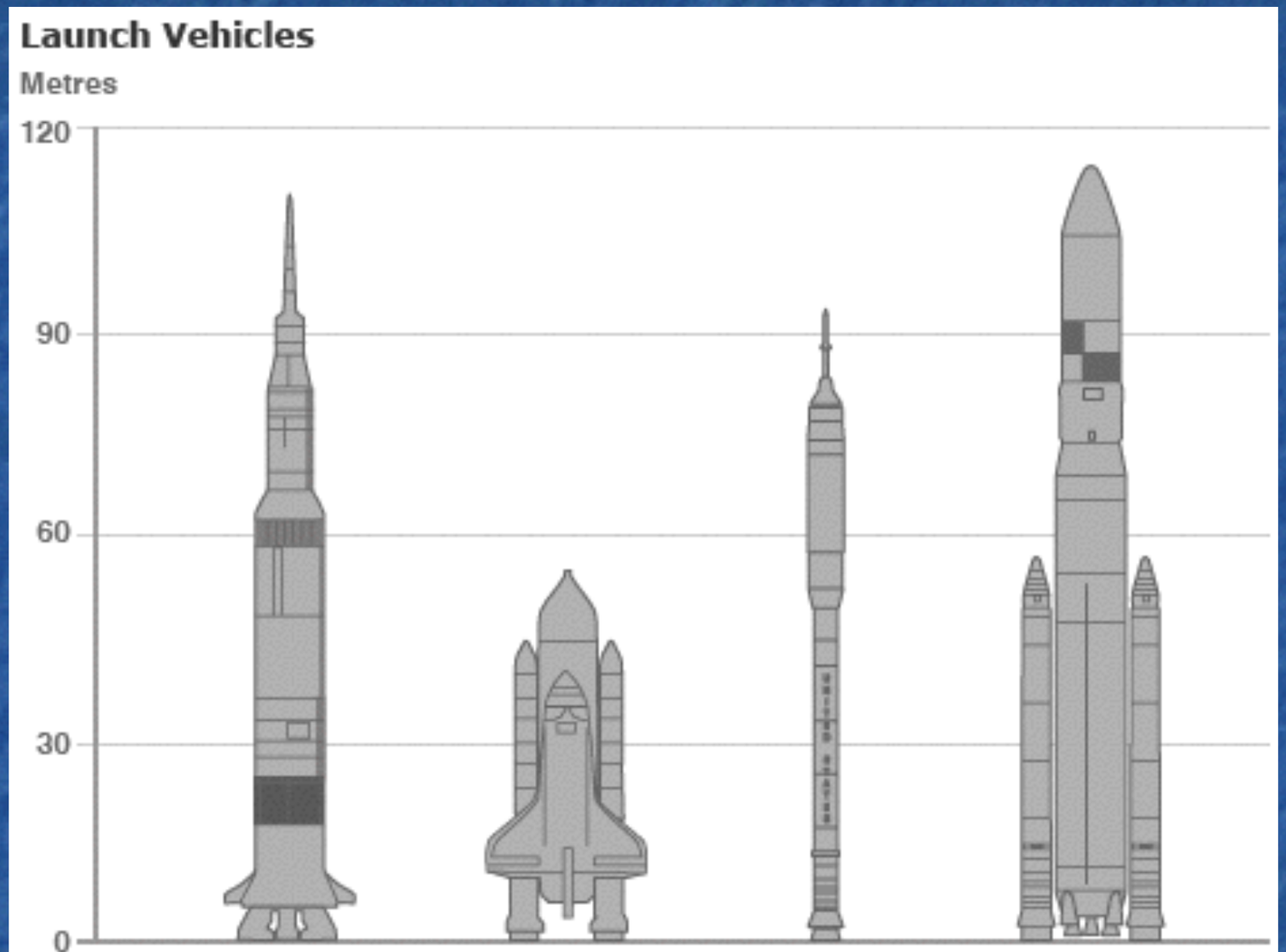
POLL: Would you sign up for a one-way trip to Mars?

I'm dying to go!	3767	63%
Maybe when I'm closer to death but not now.	944	16%
Life is too good here.	1305	22%

Total votes : 6016

Submit vote

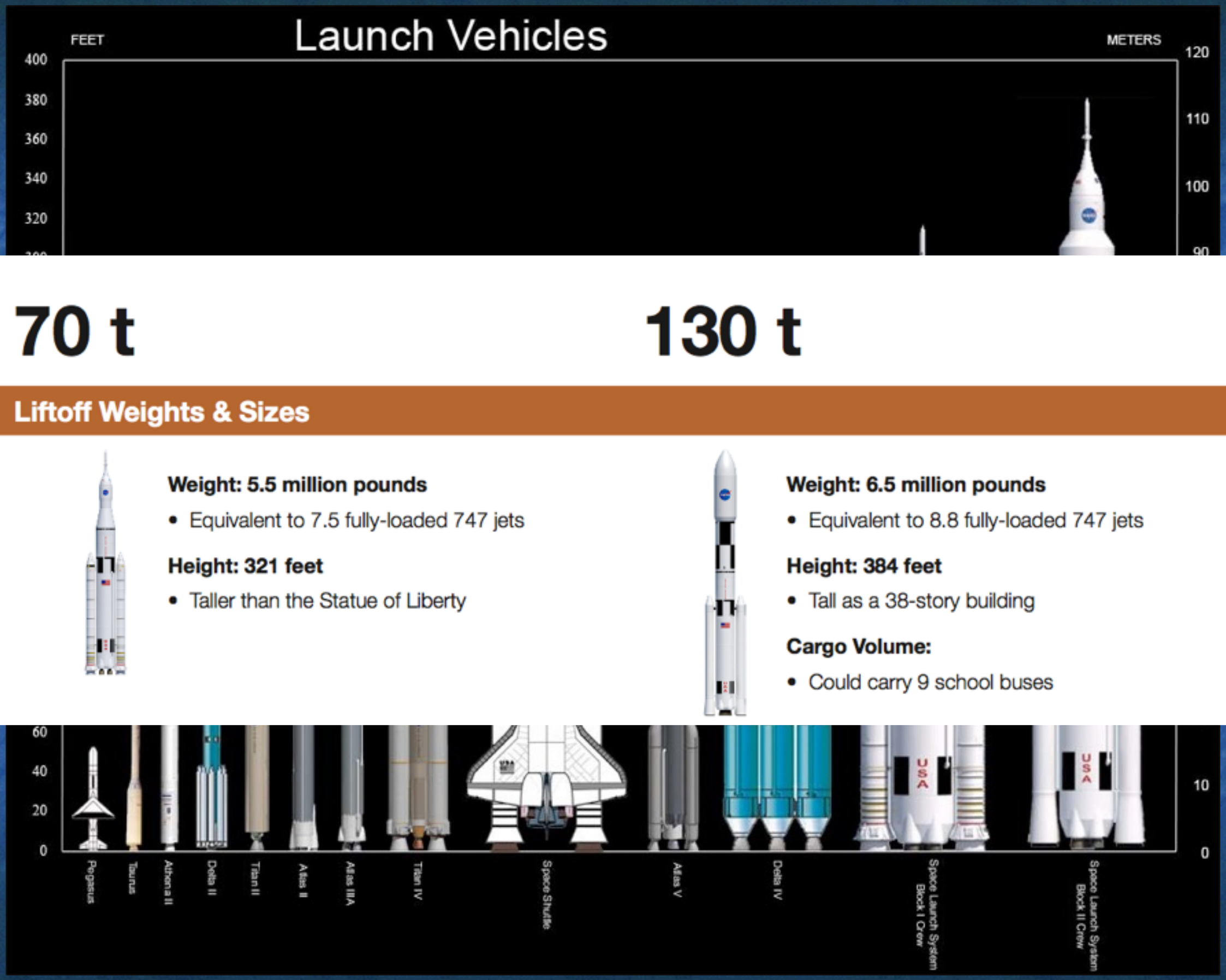
First steps to Mars?



	Saturn 5	Space Shuttle	Ares I	Ares V
Origin:	USA	USA	USA	USA
Height:	111m (364ft)	56m (184ft)	94m (309ft)	116m (381ft)
Payload*:	118,000 kg	25,000 kg	25,000 kg	188,000 kg

* To low-Earth orbit

SOURCE: NASA



70 t

Liftoff Weights & Sizes

Weight: 5.5 million pounds

- Equivalent to 7.5 fully-loaded 747 jets

Height: 321 feet

- Taller than the Statue of Liberty

130 t

Weight: 6.5 million pounds

- Equivalent to 8.8 fully-loaded 747 jets

Height: 384 feet

- Tall as a 38-story building

Cargo Volume:

- Could carry 9 school buses

Summary

- Mars possesses abundant water and sufficient solar energy to power life.
- Several big questions remain:
- Does water exist today in a liquid state - is it stable or short-lived?
- Where are the organics?
- Where is the methane coming from - MAVEN - Exomars?
- Finding fossils is a hit-and-miss process.