NATIONAL
SPACE ACADEMY

Mars as the abode of life

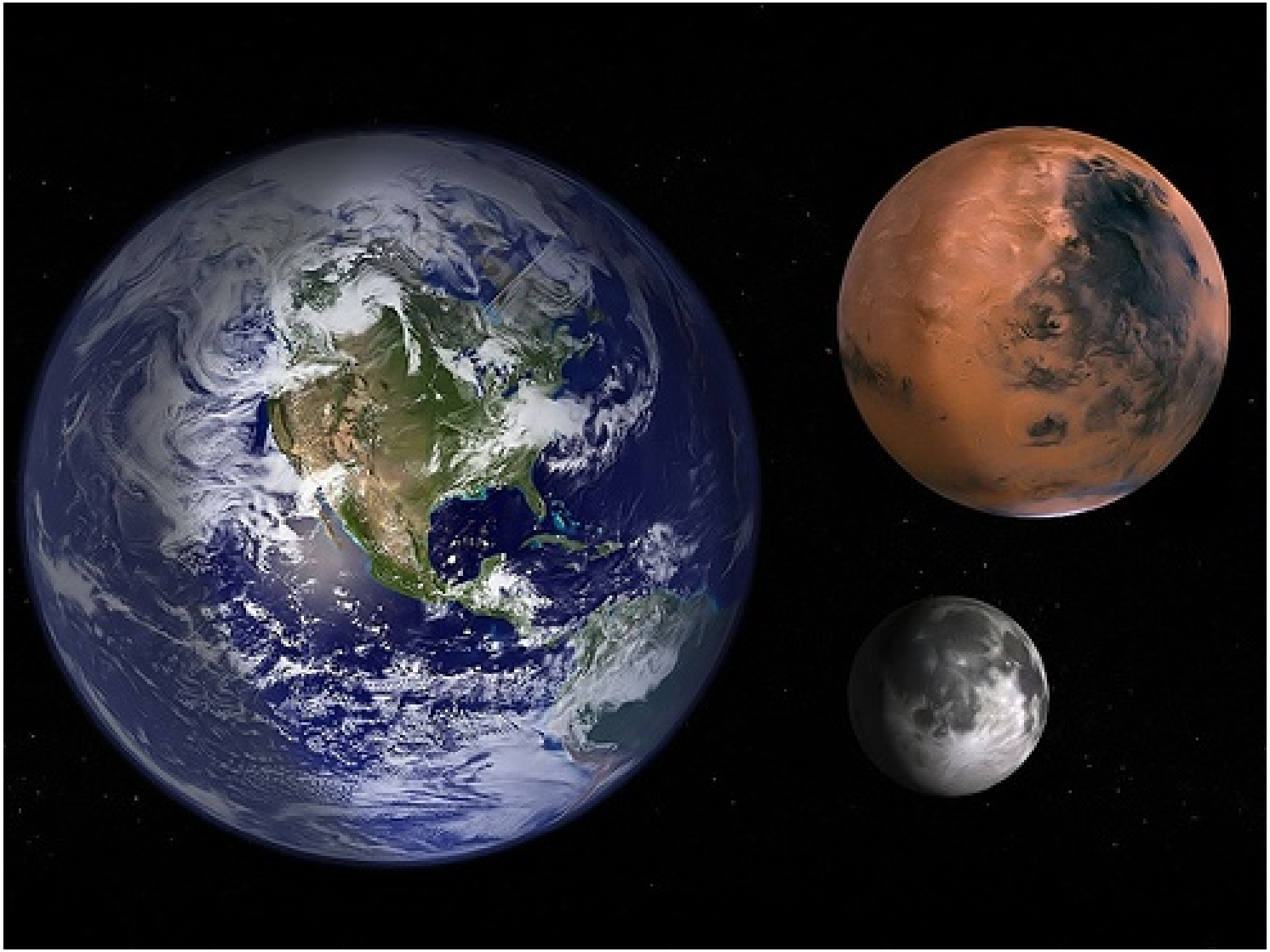
Anu Ojha
Director – UK National Space Academy programme
anuo@spacecentre.co.uk

NATIONAL SPACE CENTRE
Science & Technology Facilities Council
UK SPACE AGENCY
esa
CATAPULT Satellite Applications
Lloyd's Register Foundation

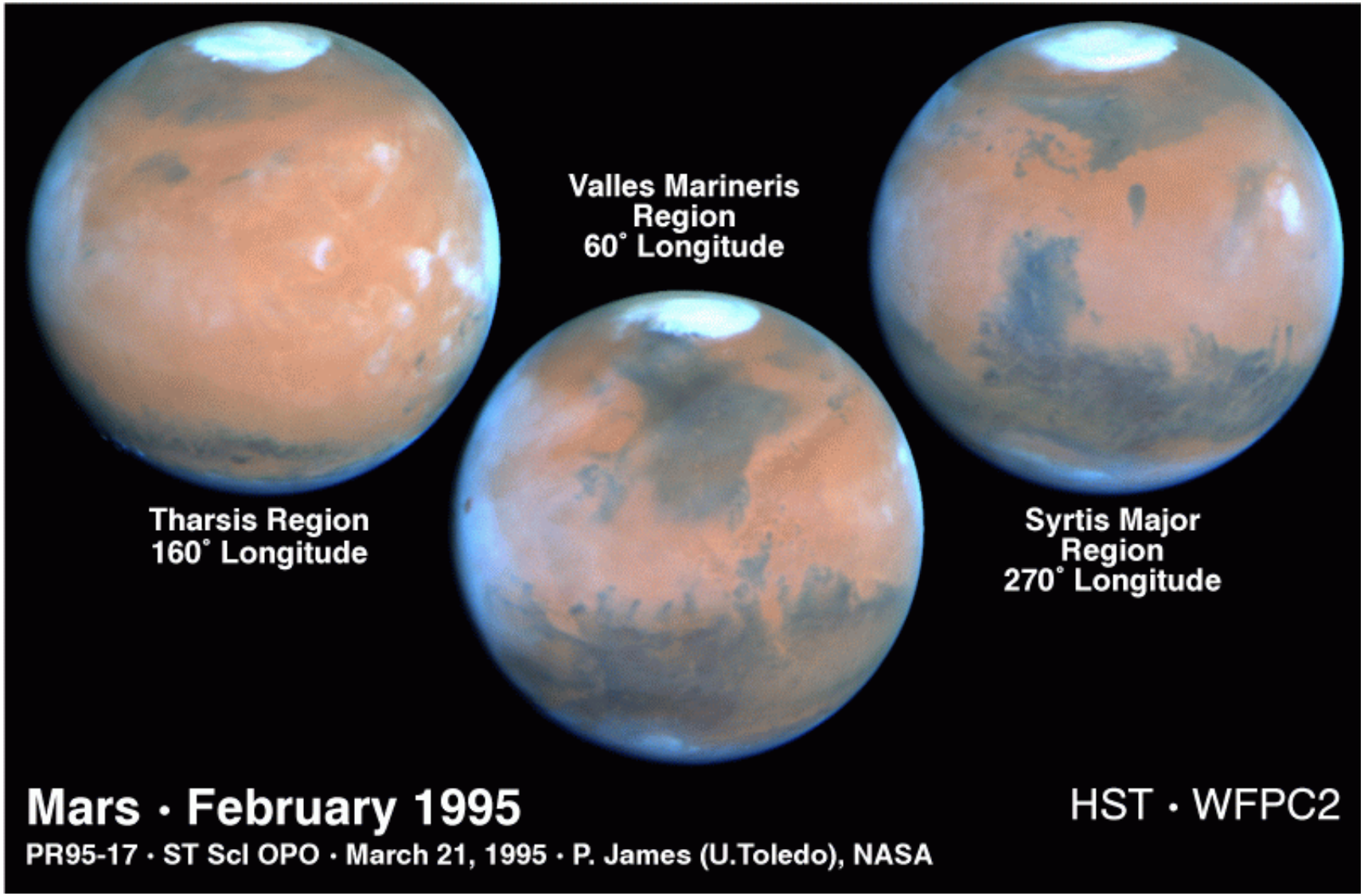
Objectives

- History of our understanding of Mars
- Mars in the Space Age – and the future
- Ideas for teaching contexts/activities – up to/including University level
- Enquiry-based learning/critical thinking skills – “science CSI”

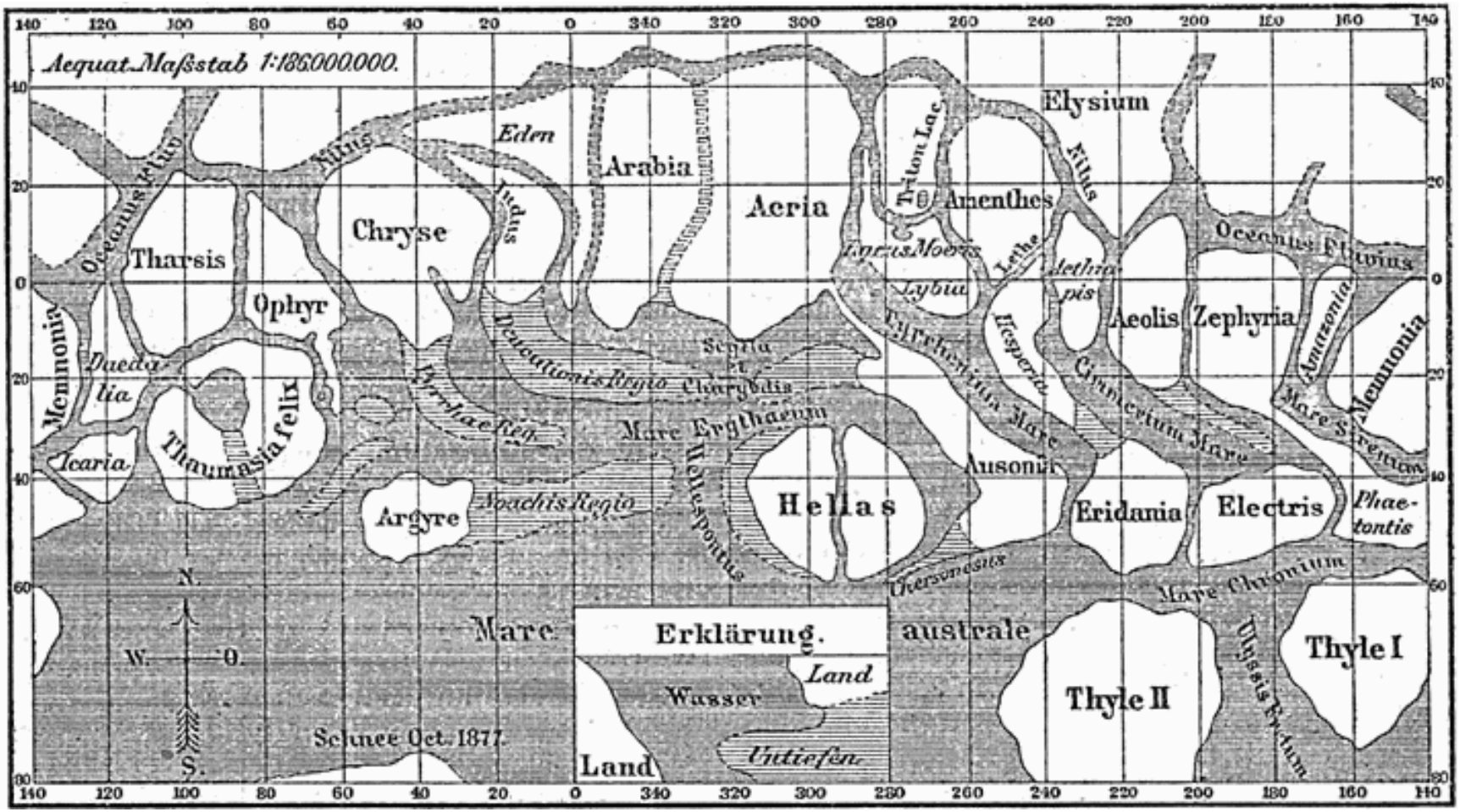
Earth and Mars....as different as they are alike



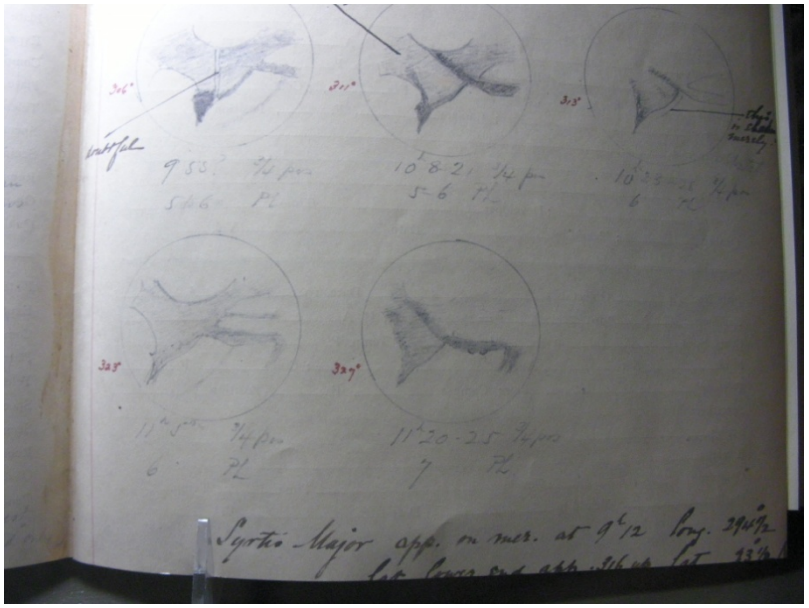
Best possible views from Earth (well, near Earth!)

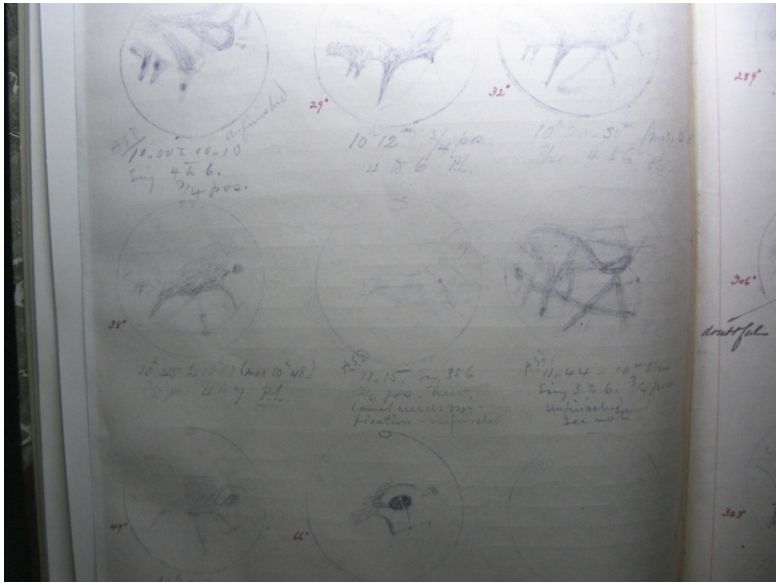


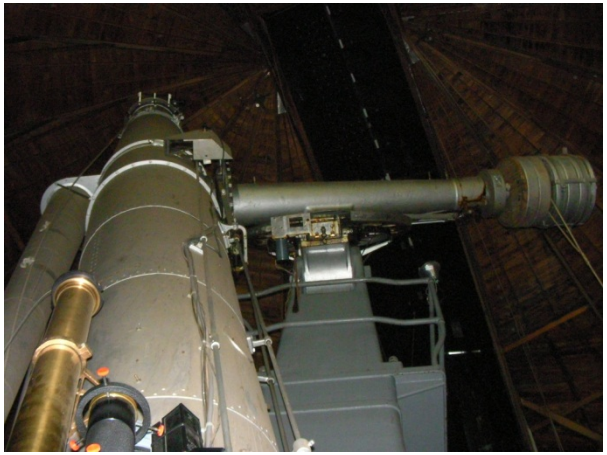
Schiaparelli's map



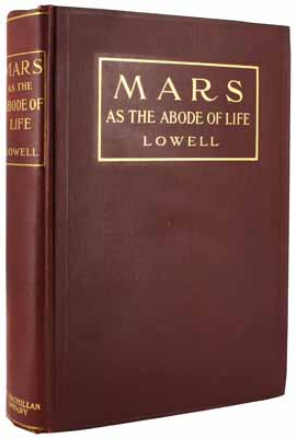
The view from Mars Hill, Flagstaff (Arizona)

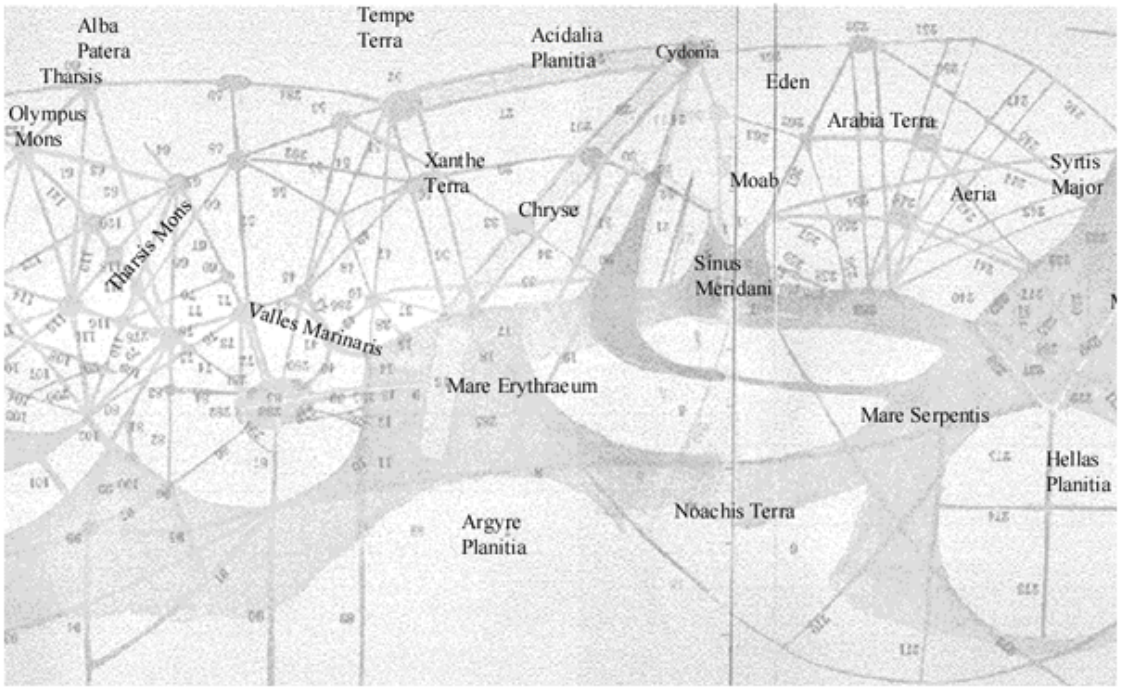




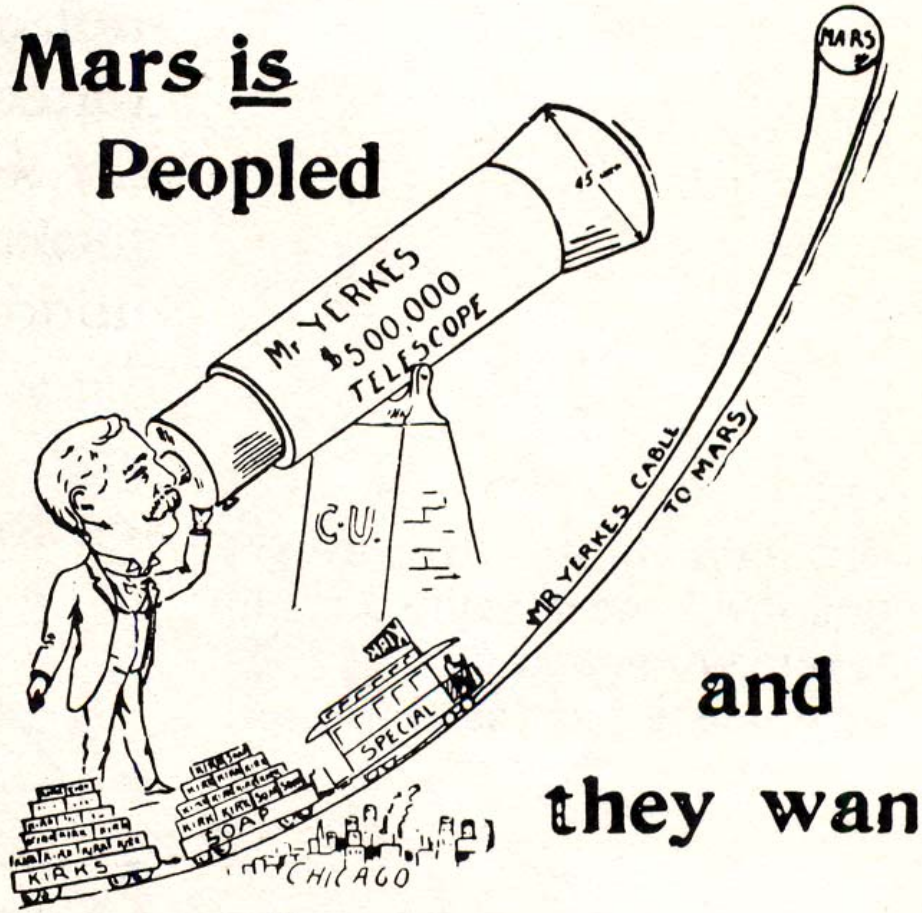


Percival Lowell's vision





Mars is Peopled

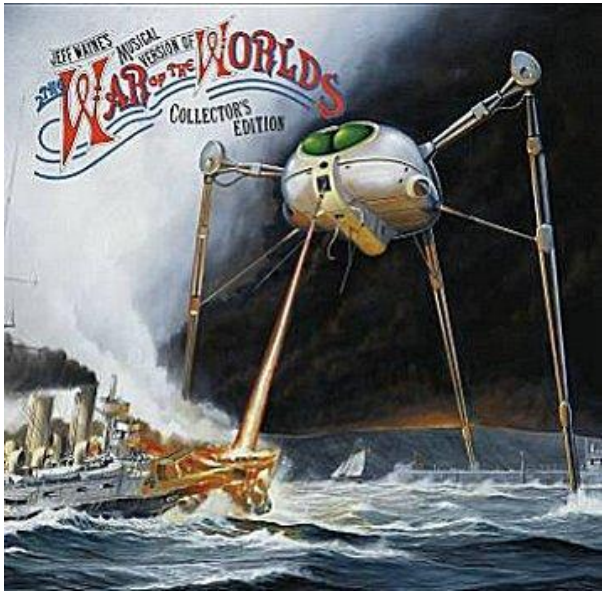


and they want

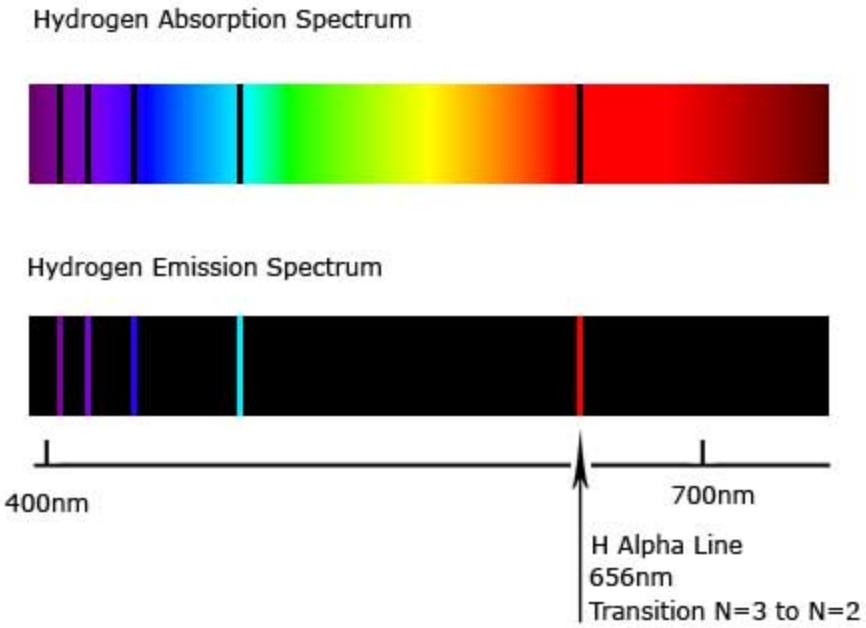
KIRK'S AMERICAN FAMILY SOAP

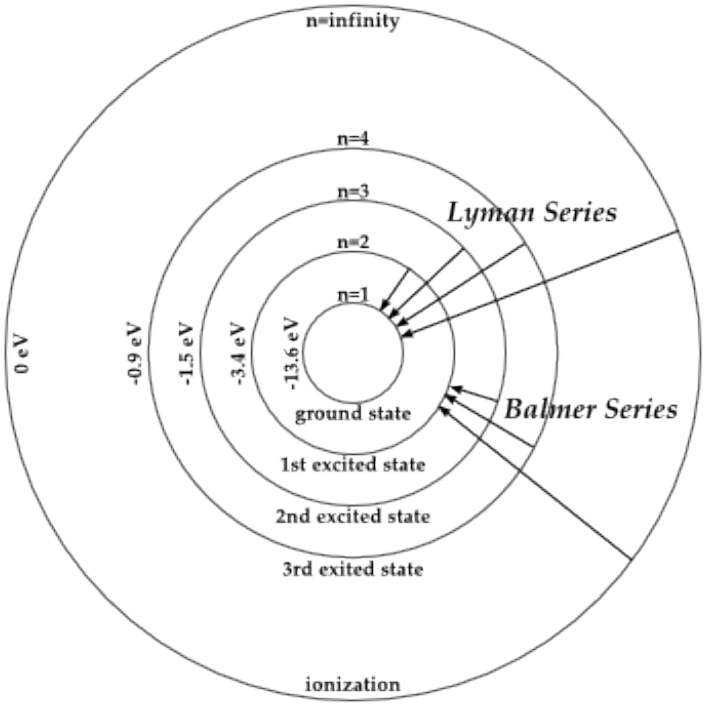
Kirk's Dusky Diamond Soap, best for Ladies Toilet.

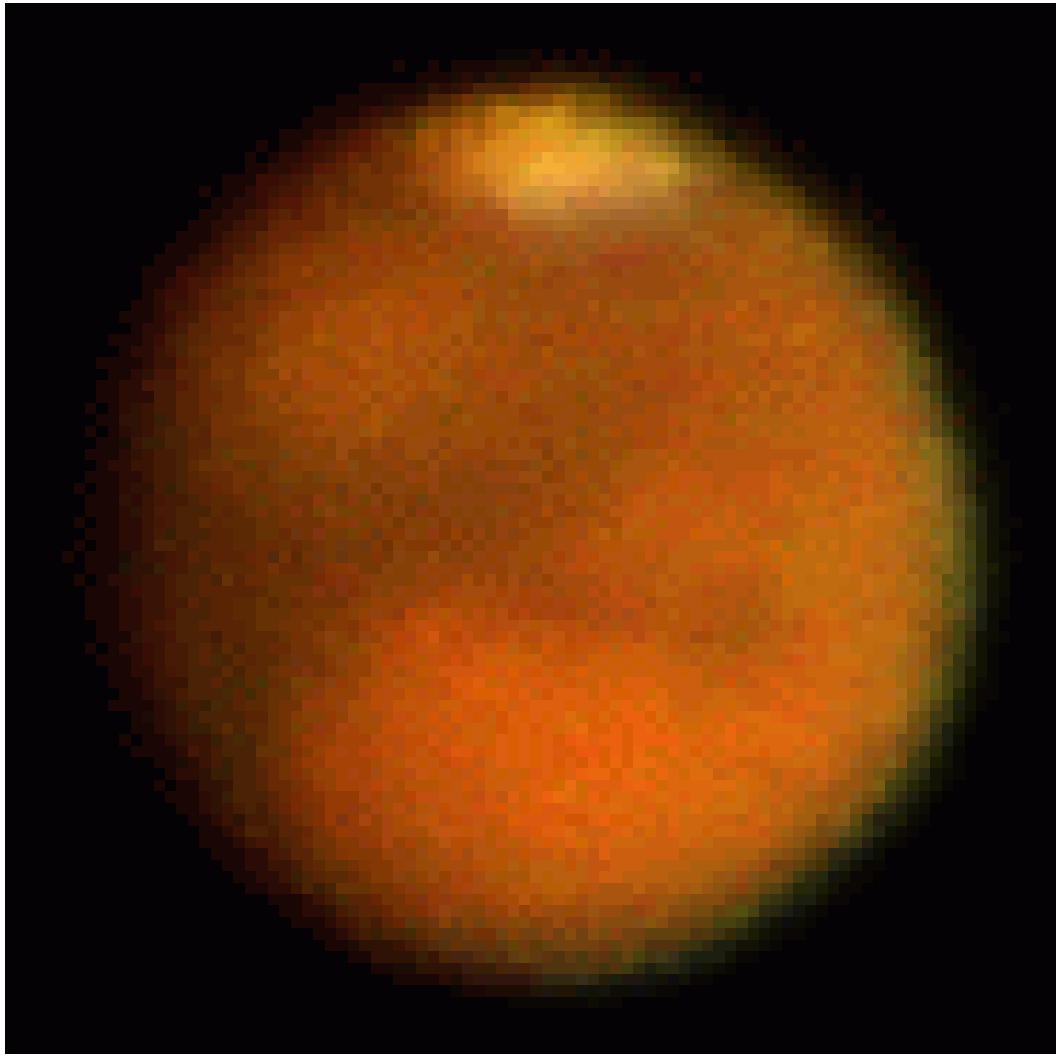

Santa Claus
CONQUERS THE MARTIANS
DVD
ALIENS ATTACK THE NORTH POLE!
WHO WILL SAVE CHRISTMAS?


JEFF WAYNE'S MUSICAL VERSION OF
THE WAR OF THE WORLDS
COLLECTOR'S EDITION

1947….. what did spectroscopy tell us about Mars' atmosphere?







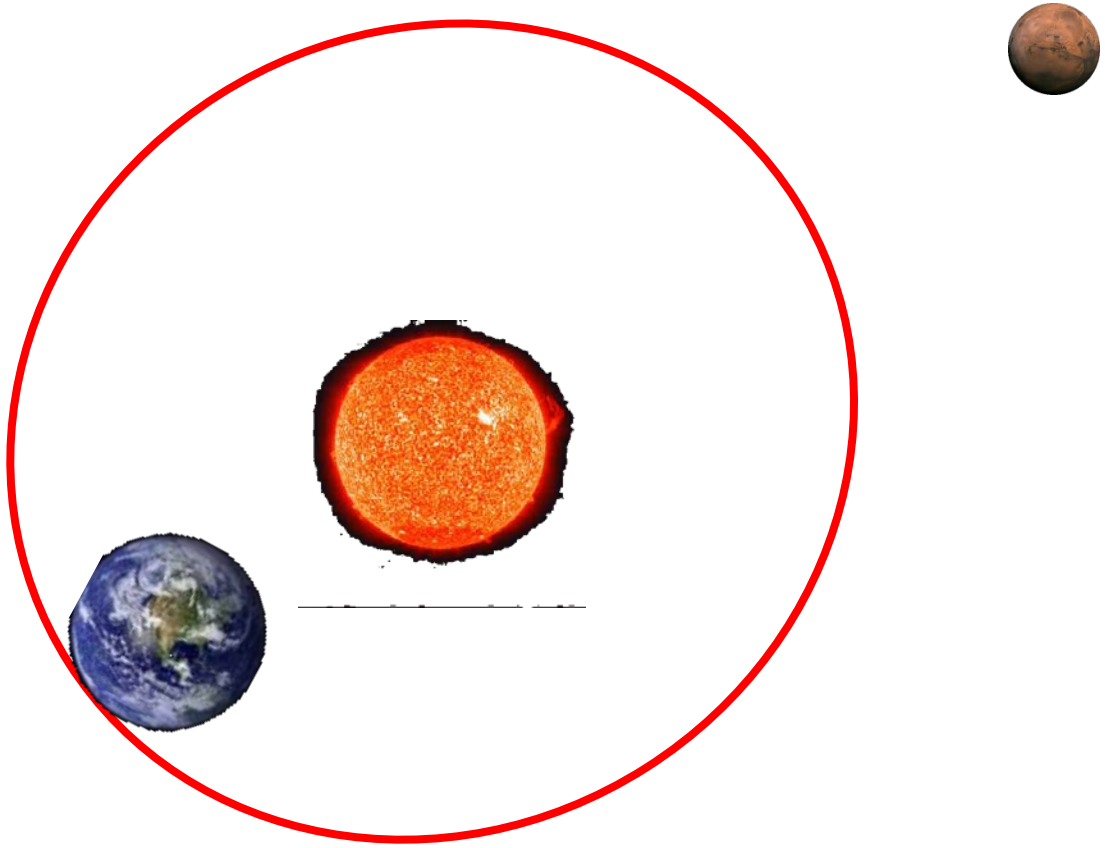
Carbon dioxide – but what pressure?

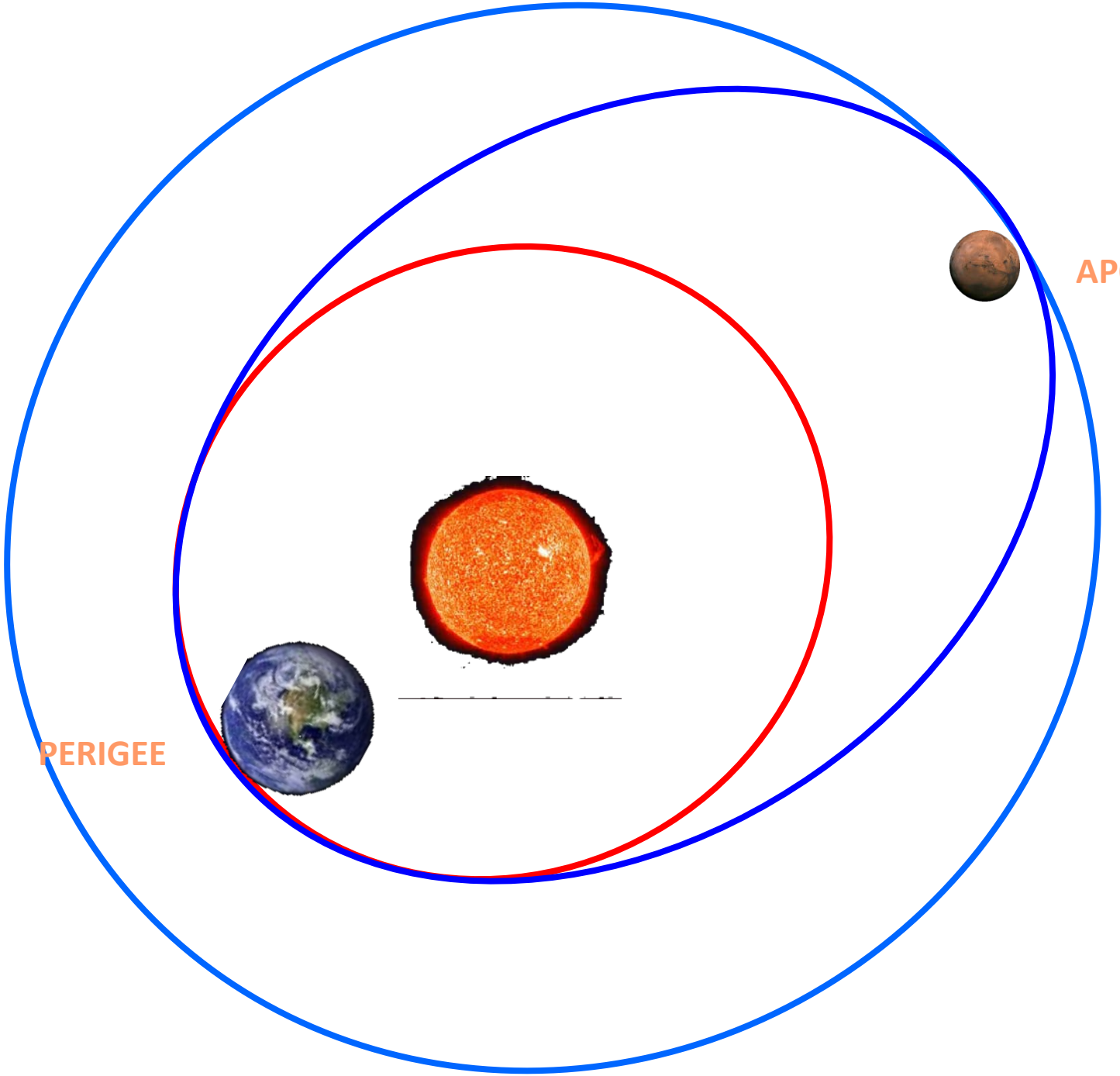
Temperature range?

Water?

Life?

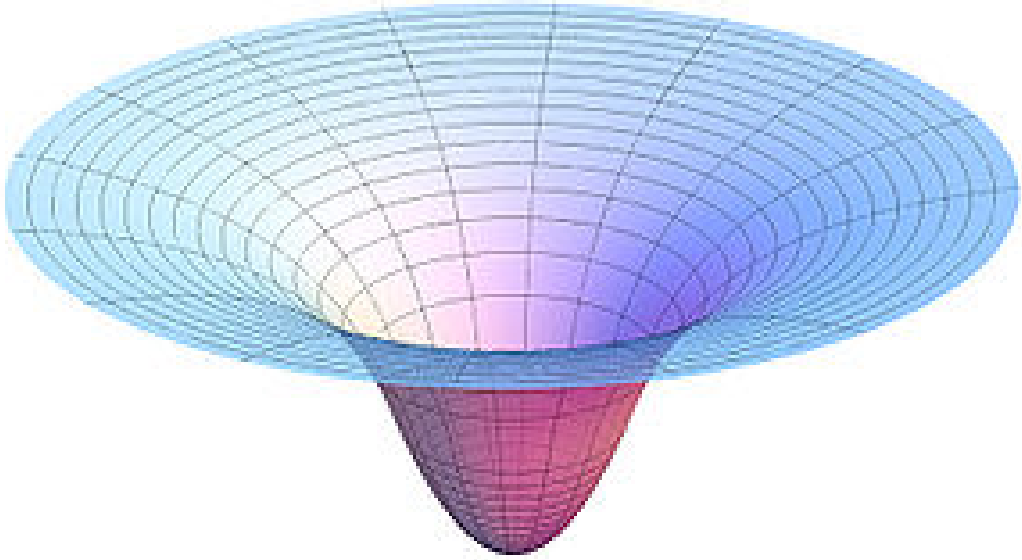
Hohmann transfer orbit from Earth to Mars – every two years




APOGEE
PERIGEE

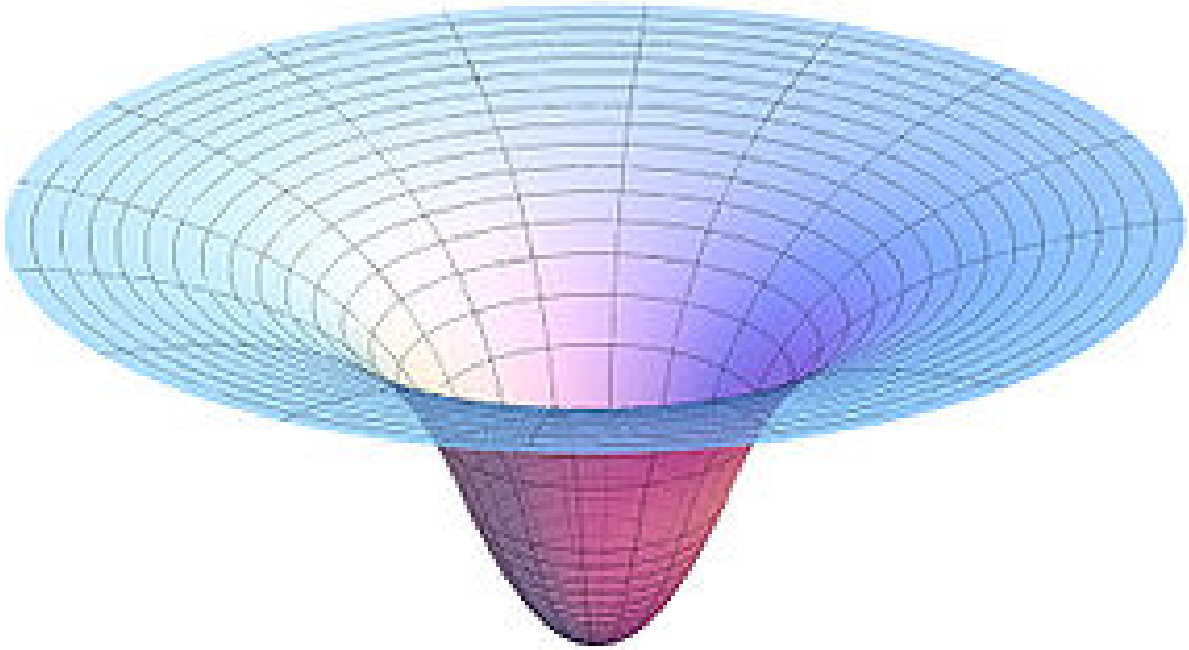
Potential energy wells

- Gravitational field of a unipolar source?
- Newton's Laws?
- Binary star system? (equal masses/ unequal?)
- As a PE model, how is Gravitational Field Strength represented on the model?
- What real orbital phenomena do we see modelled?
- Other force fields/A level topics that can be modelled this way?



http://www.esa.int/spaceinvideos/Videos/2014/07/Gravity_wells_-_classroom_demonstration_video_VP04

Gravitational field modelling



$F = (GMm) / r^2$

$E = GM / r^2$

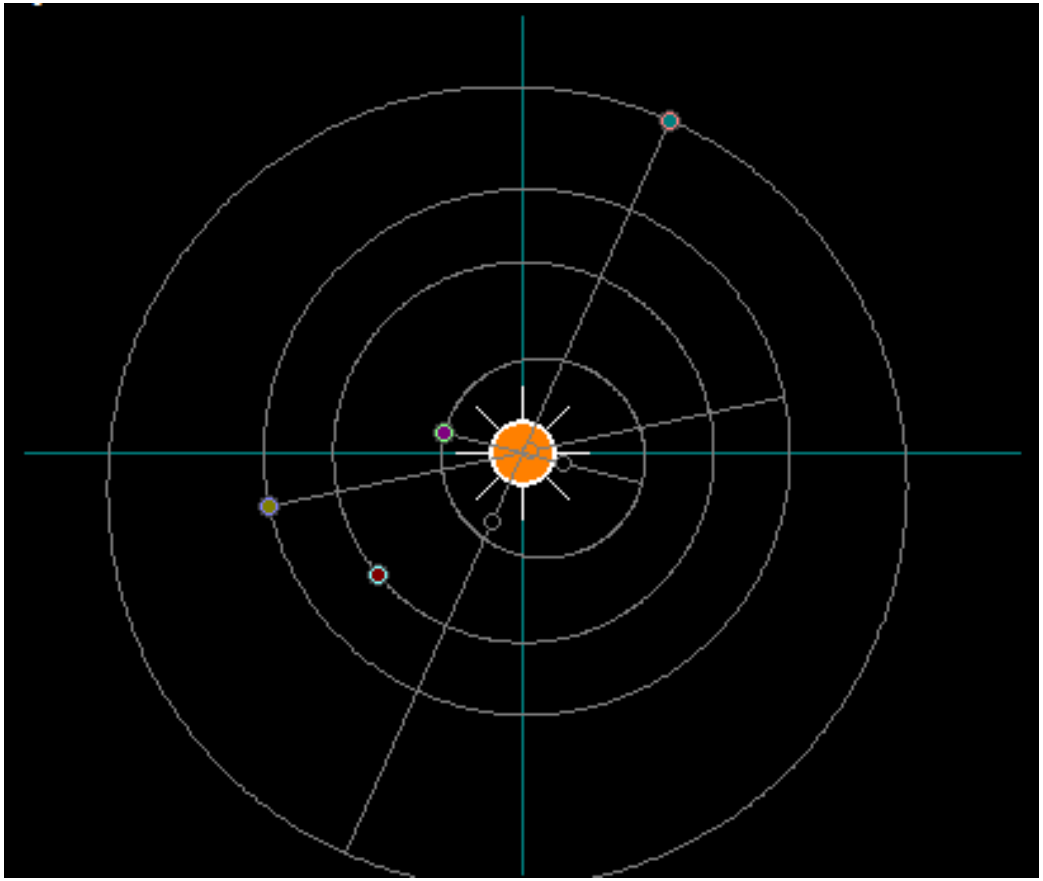
$PE = - GMm/r$

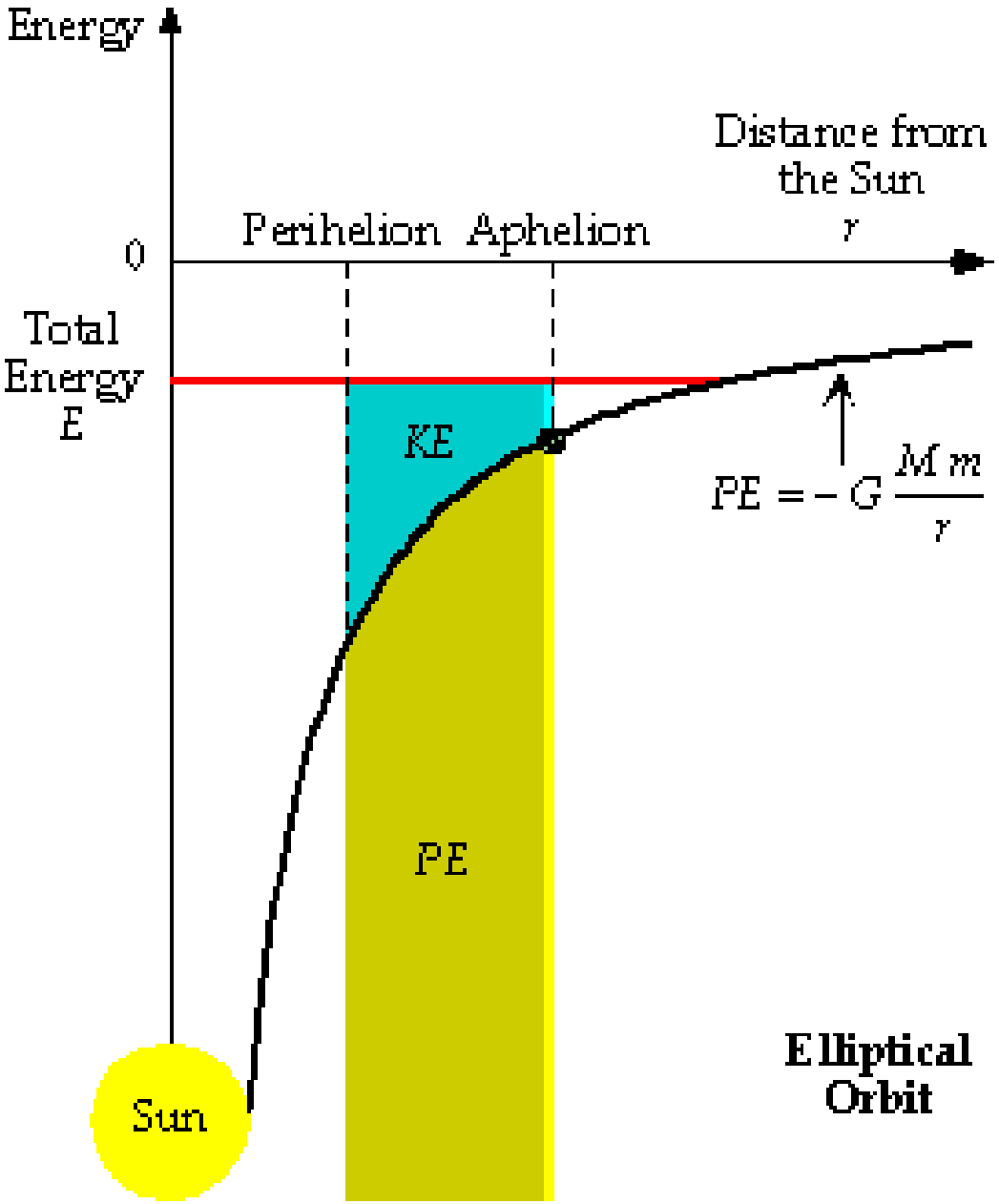
$V = - GM/r$

$E = -\text{grad}V$

Kepler's Third Law

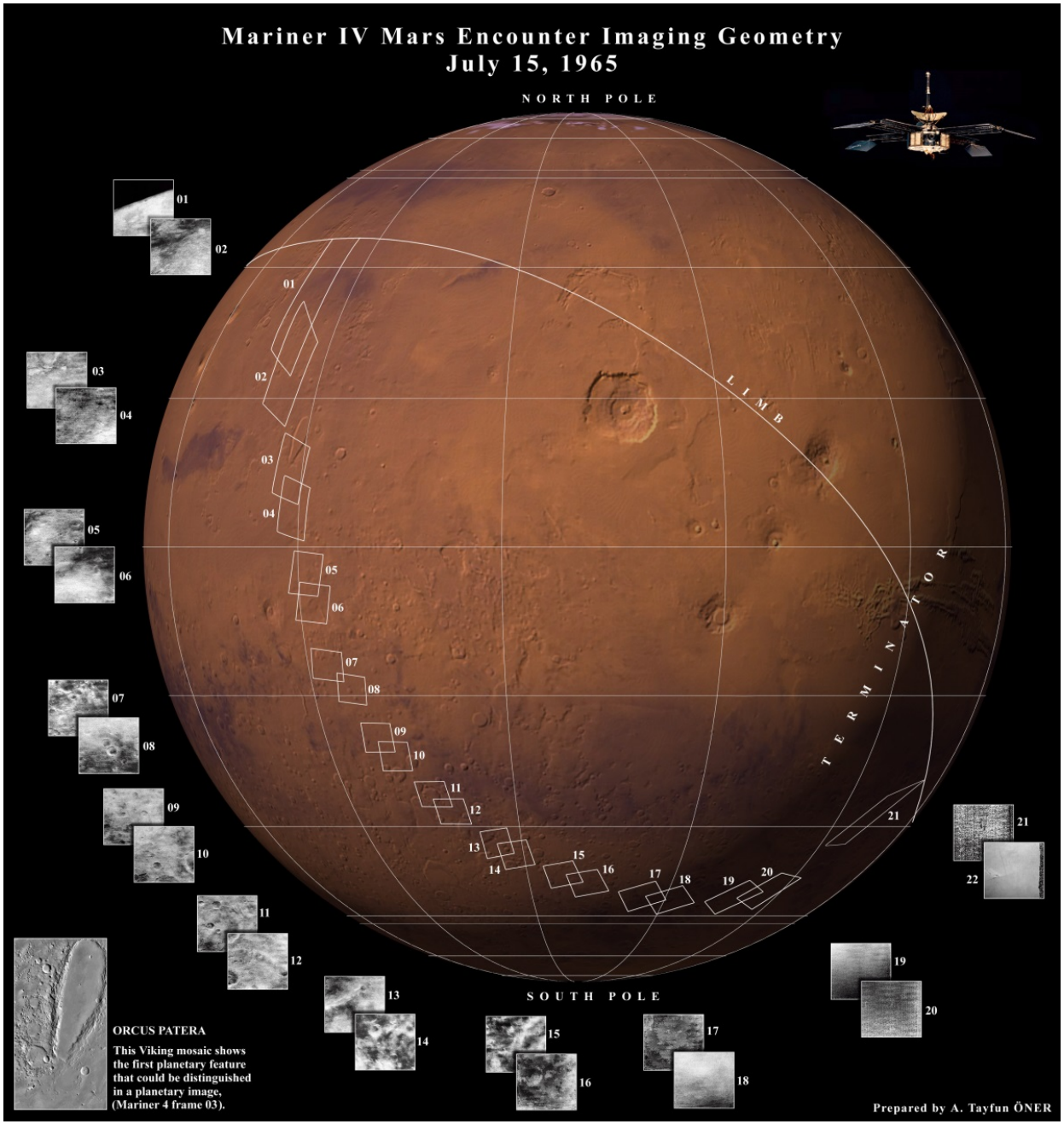
- "Period squared is proportional to radius of semi-major axis of orbit cubed"
- Angular velocities are less for the planets farther out – they don't keep in step




Energy
Distance from the Sun
r
Perihelion
Aphelion
0
Total Energy
E
KE
PE
$PE = -G\frac{Mm}{r}$
Sun
Elliptical Orbit

Kepler's laws and Mars: e=nearly 10%!

- Southern Hemisphere – short hot summer, long cold winter
- Northern Hemisphere – long temperate summer, short temperate winter
- Planet-wide drop in atmospheric pressure during Southern winter


Mariner IV Mars Encounter Imaging Geometry
July 15, 1965
NORTH POLE
SOUTH POLE
LIMB
TERMINATOR
01
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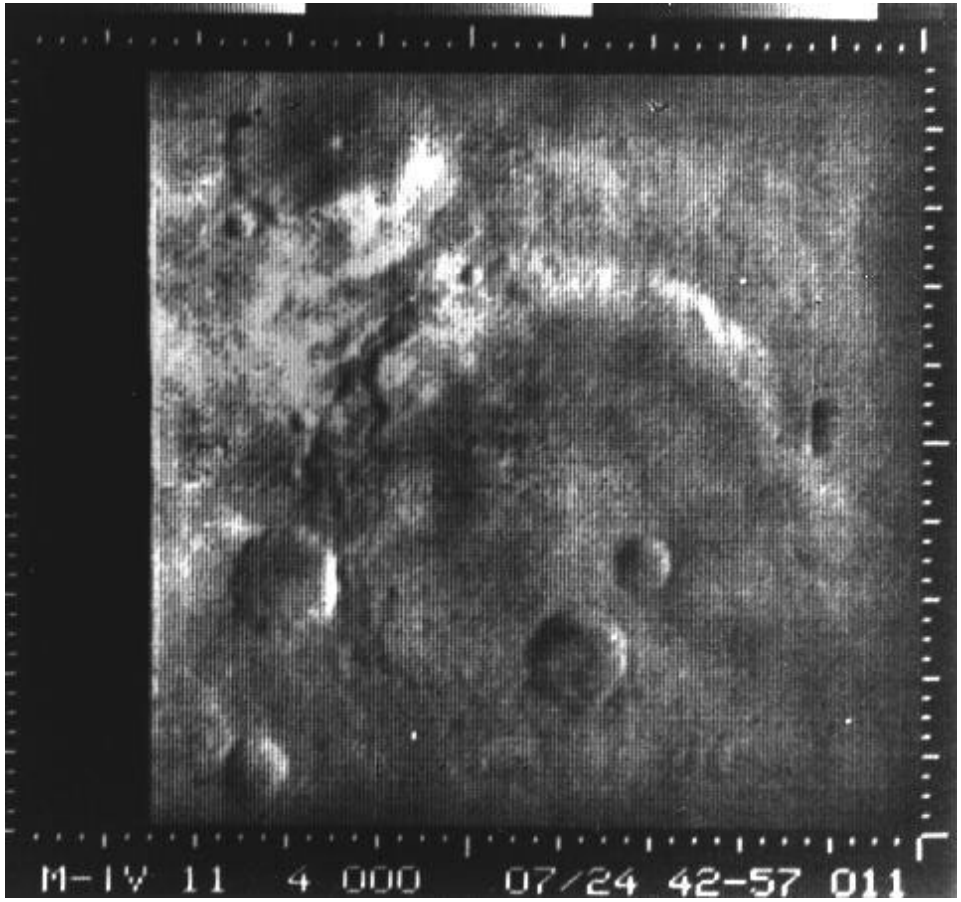
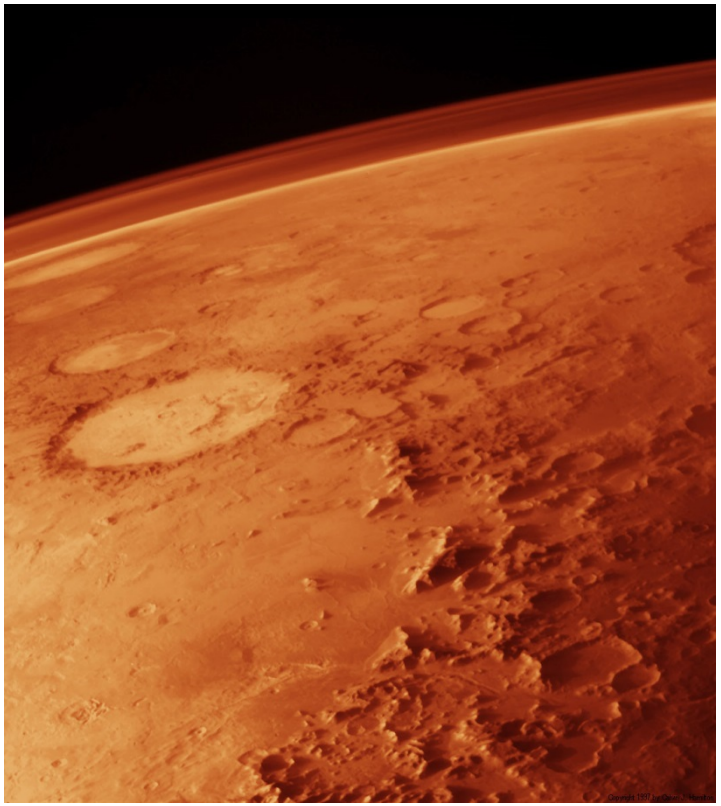
ORCUS PATERA
This Viking mosaic shows the first planetary feature that could be distinguished in a planetary image, (Mariner 4 frame 03).
Prepared by A. Tayfun ÖNER

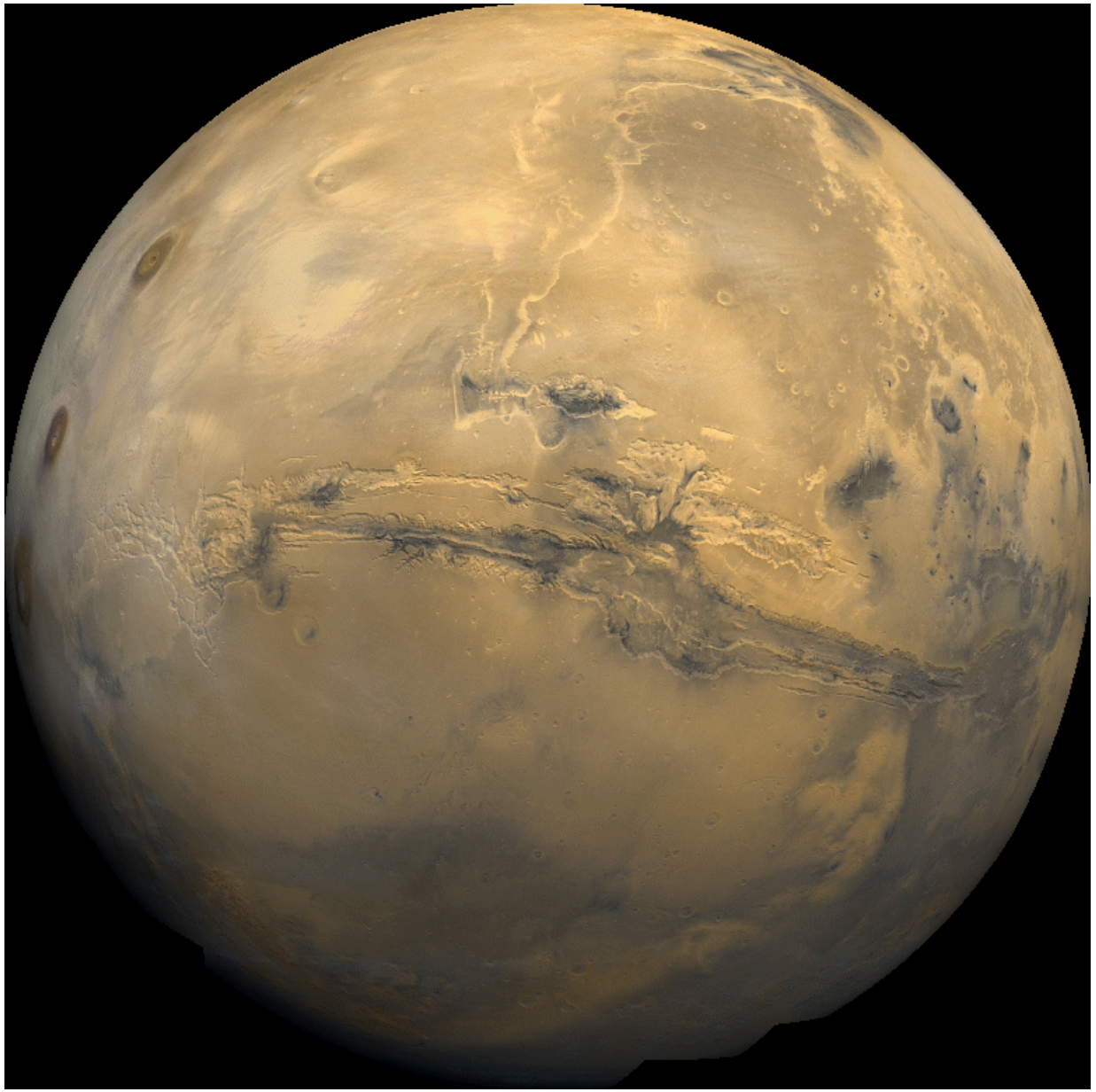




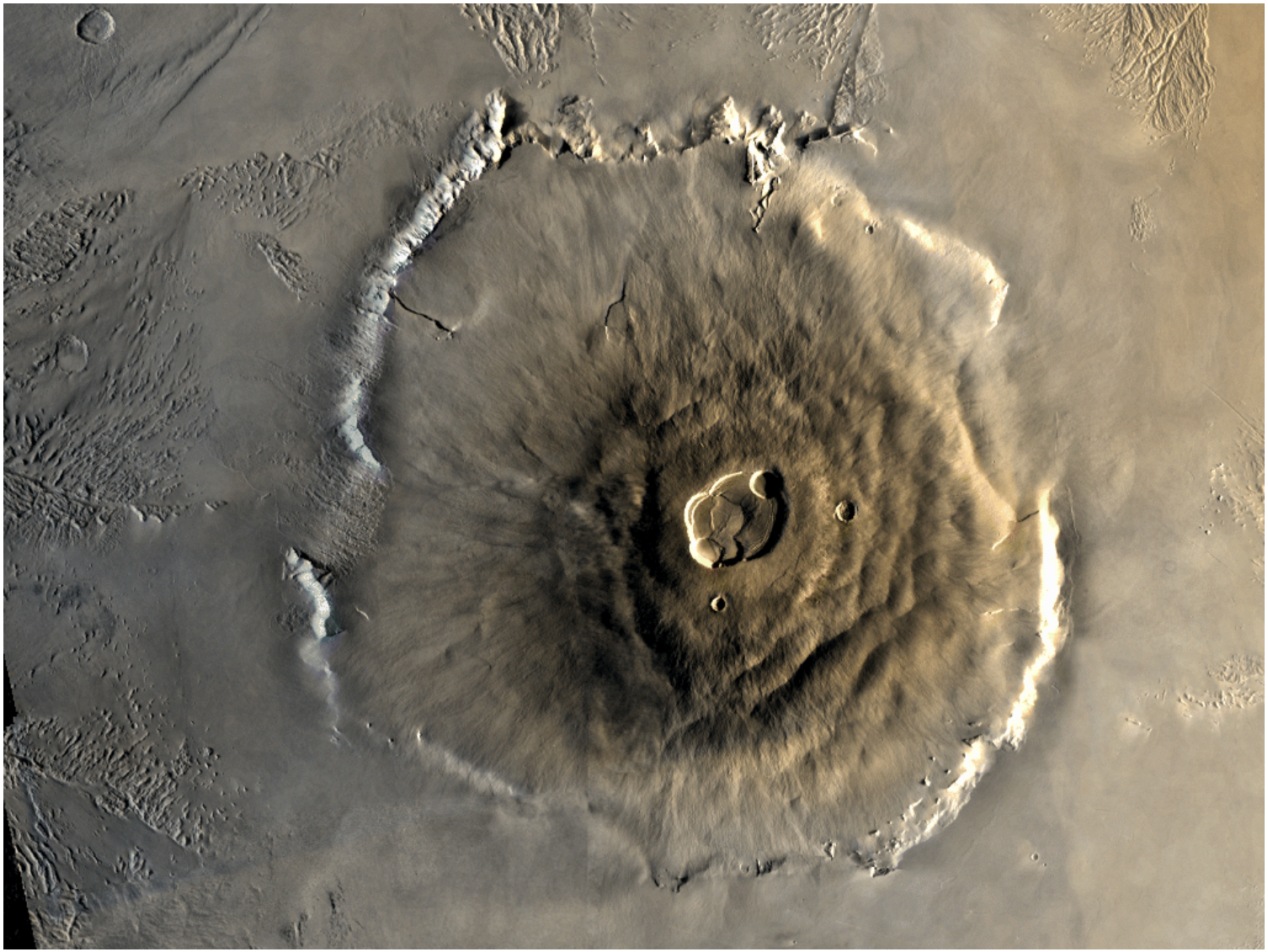
What deductions can we make about the Martian atmosphere from this image?

- Density?
- Cratering size distribution and erosion rates?

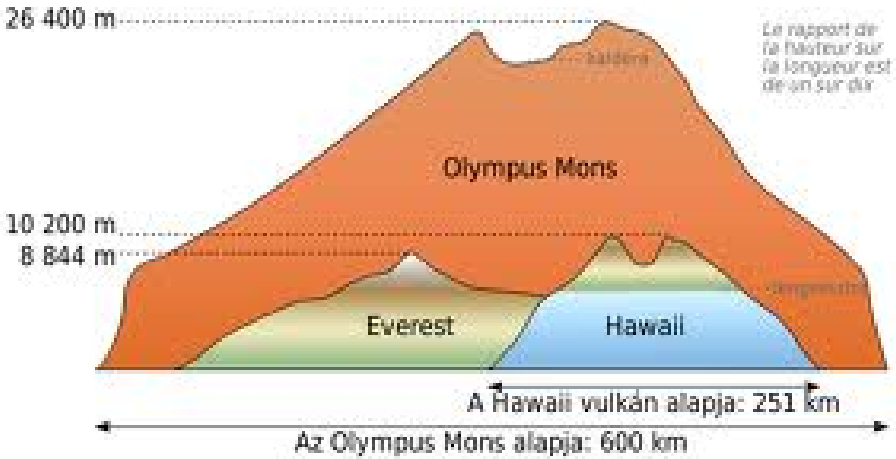
Vallis Marineris - NOT a river valley!!

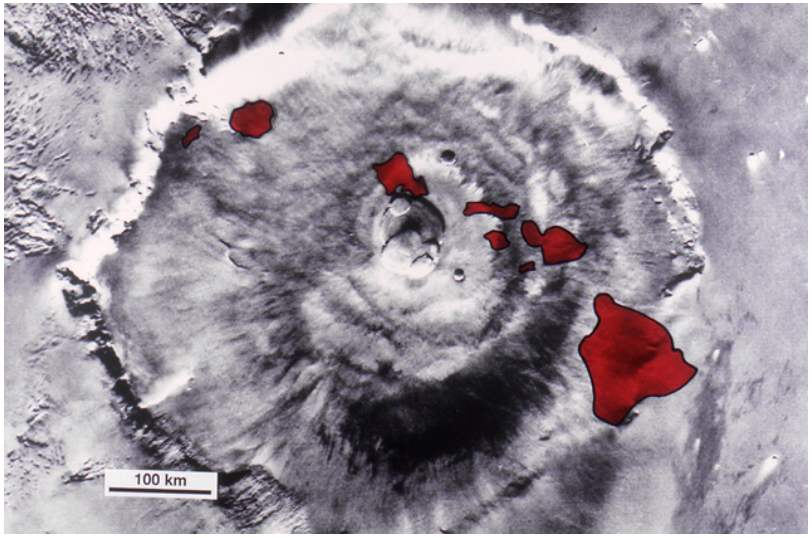


Olympus Mons (Nix Olympica)

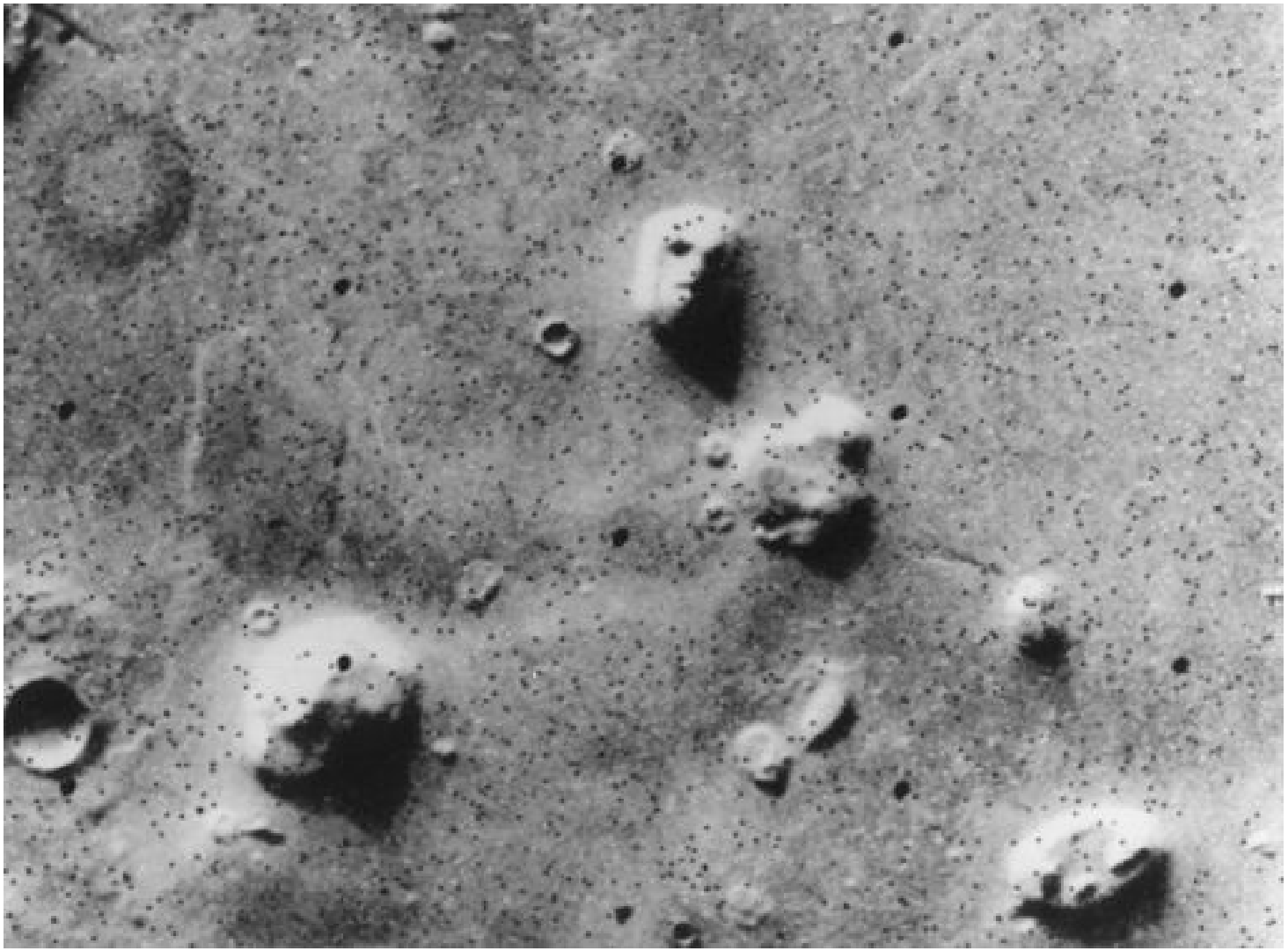


Az Olympus Mons, a Hawaii vulkán és a Mount Everest méretének összehasonlítása

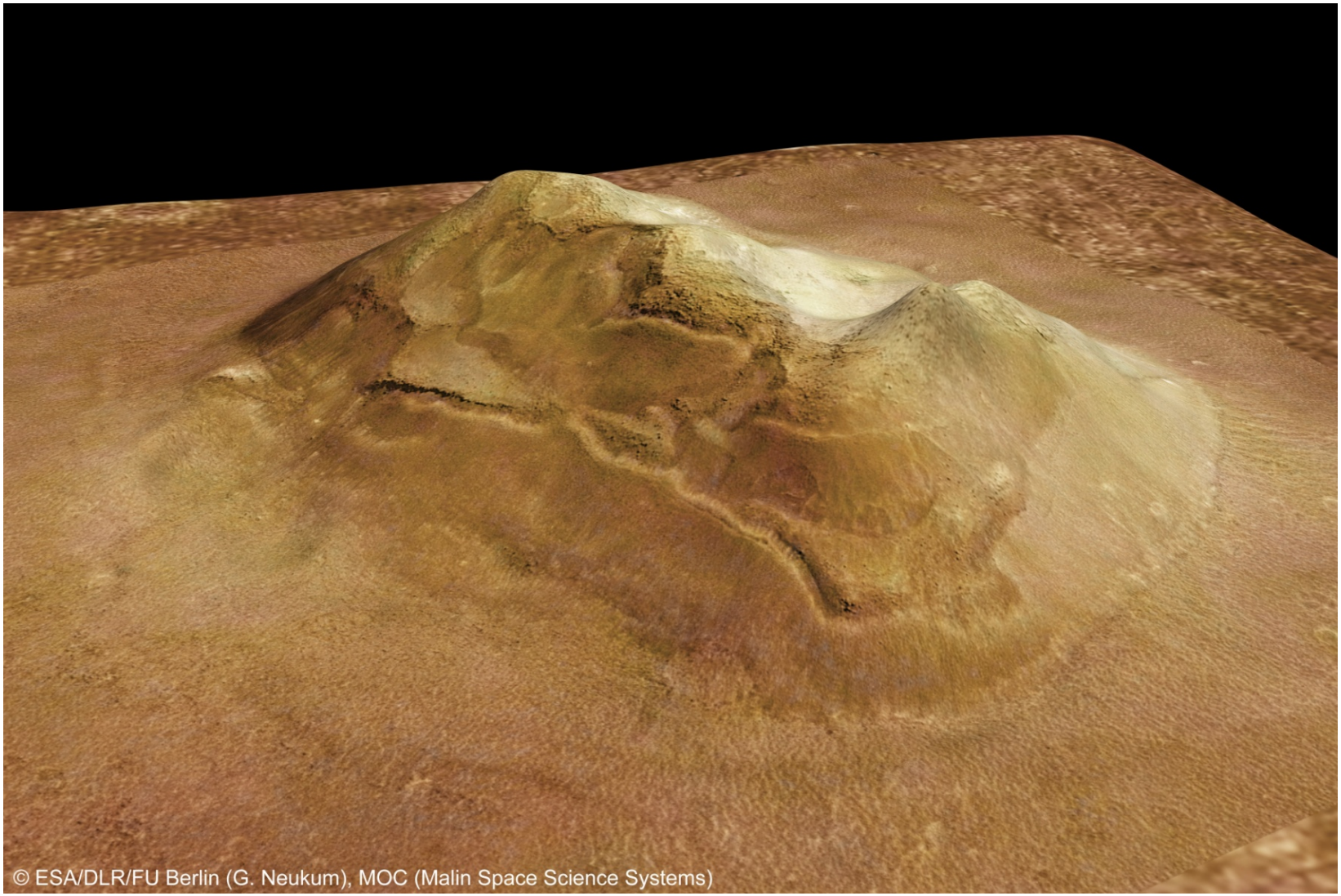


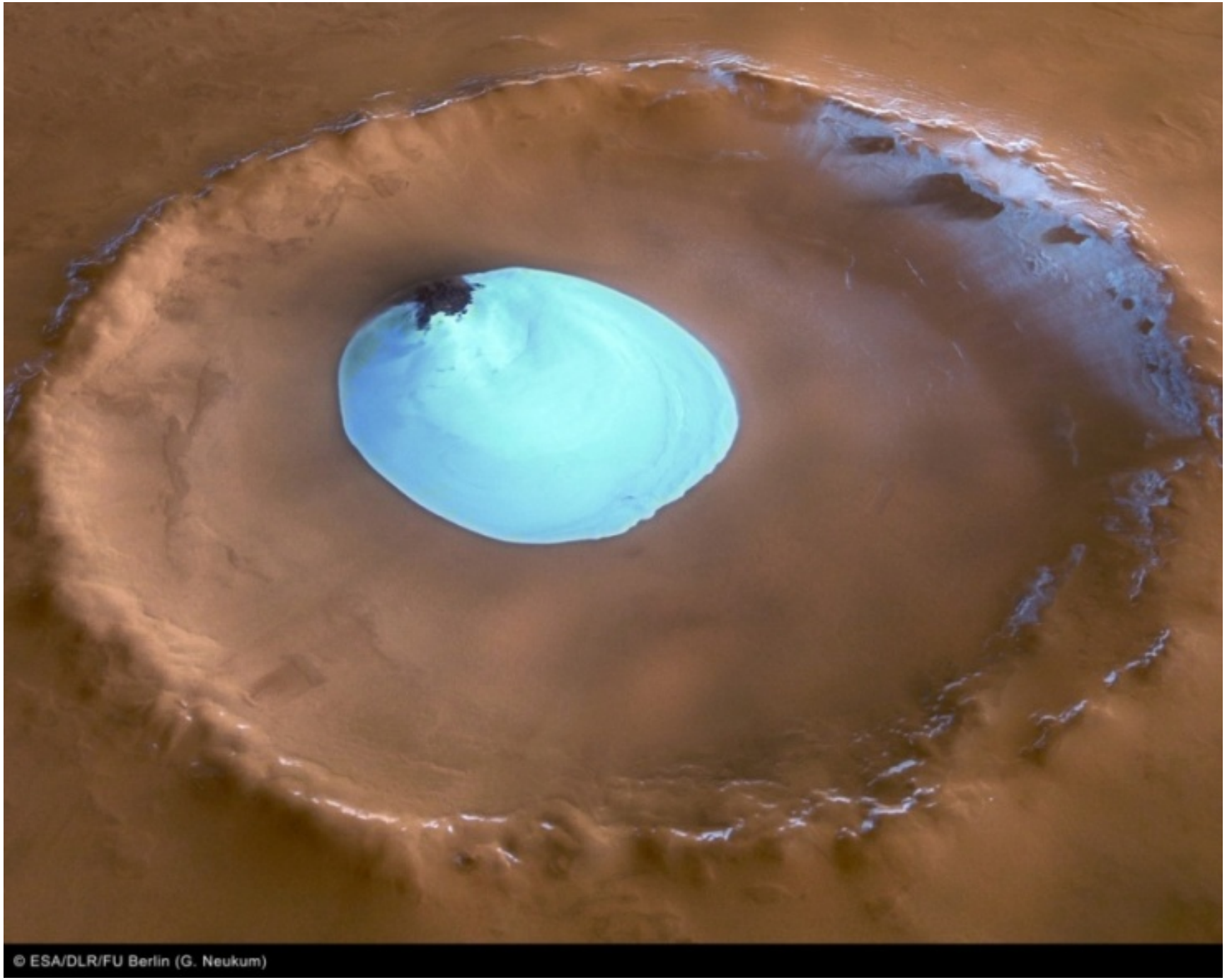


Cydonia – Viking Orbiter (1976) – a conspiracist's delight

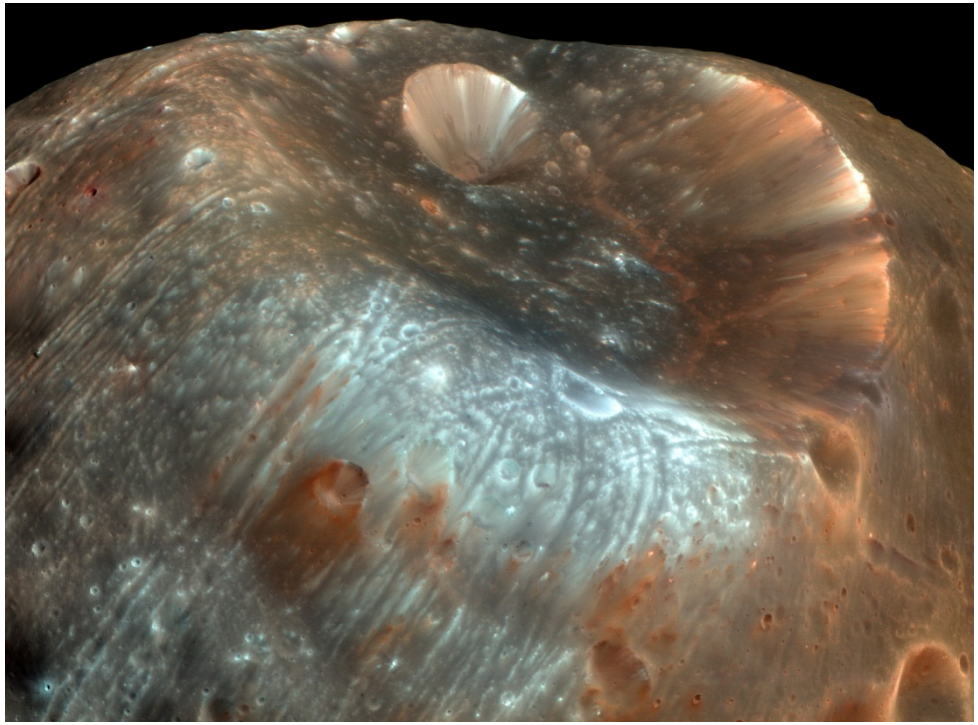


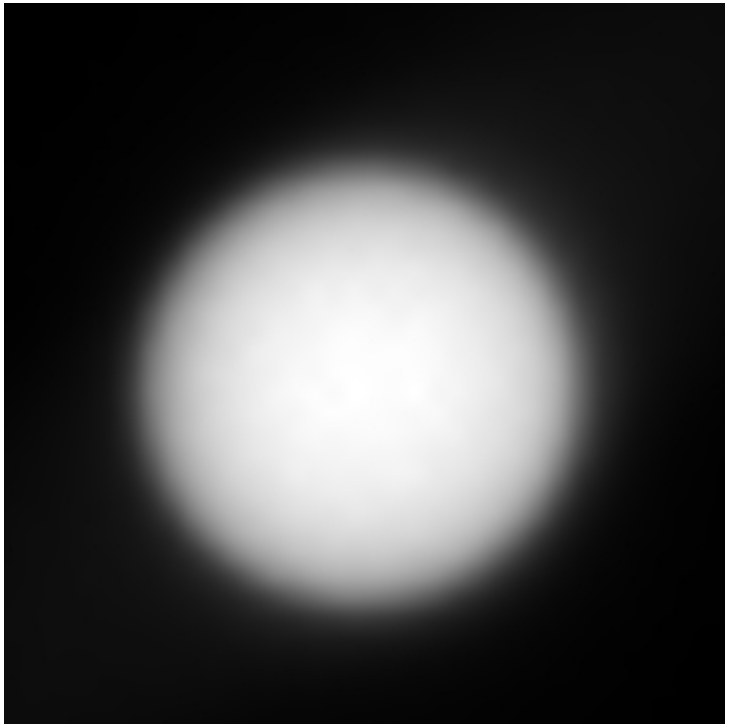
Mars Express

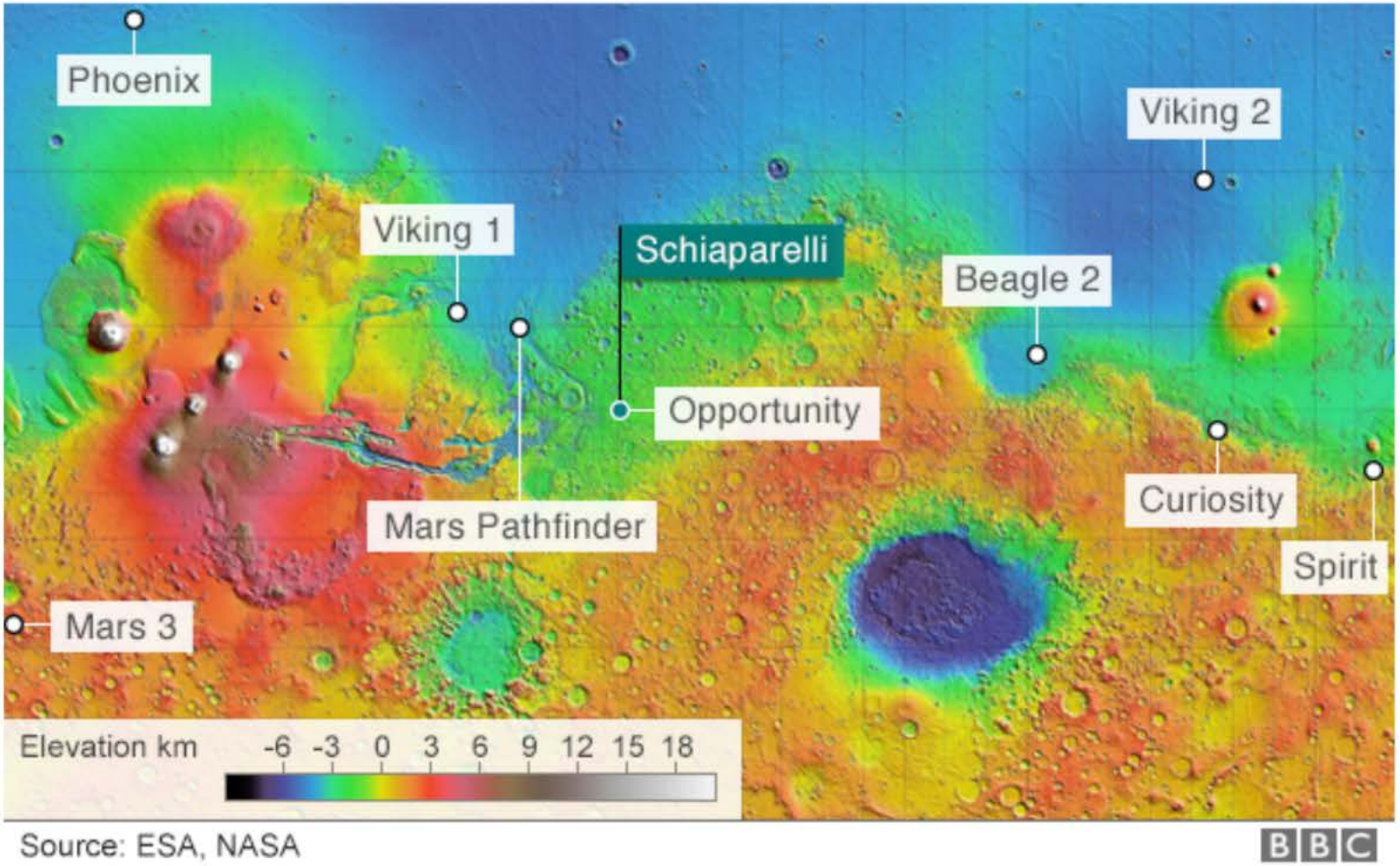



© ESA/DLR/FU Berlin (G. Neukum)

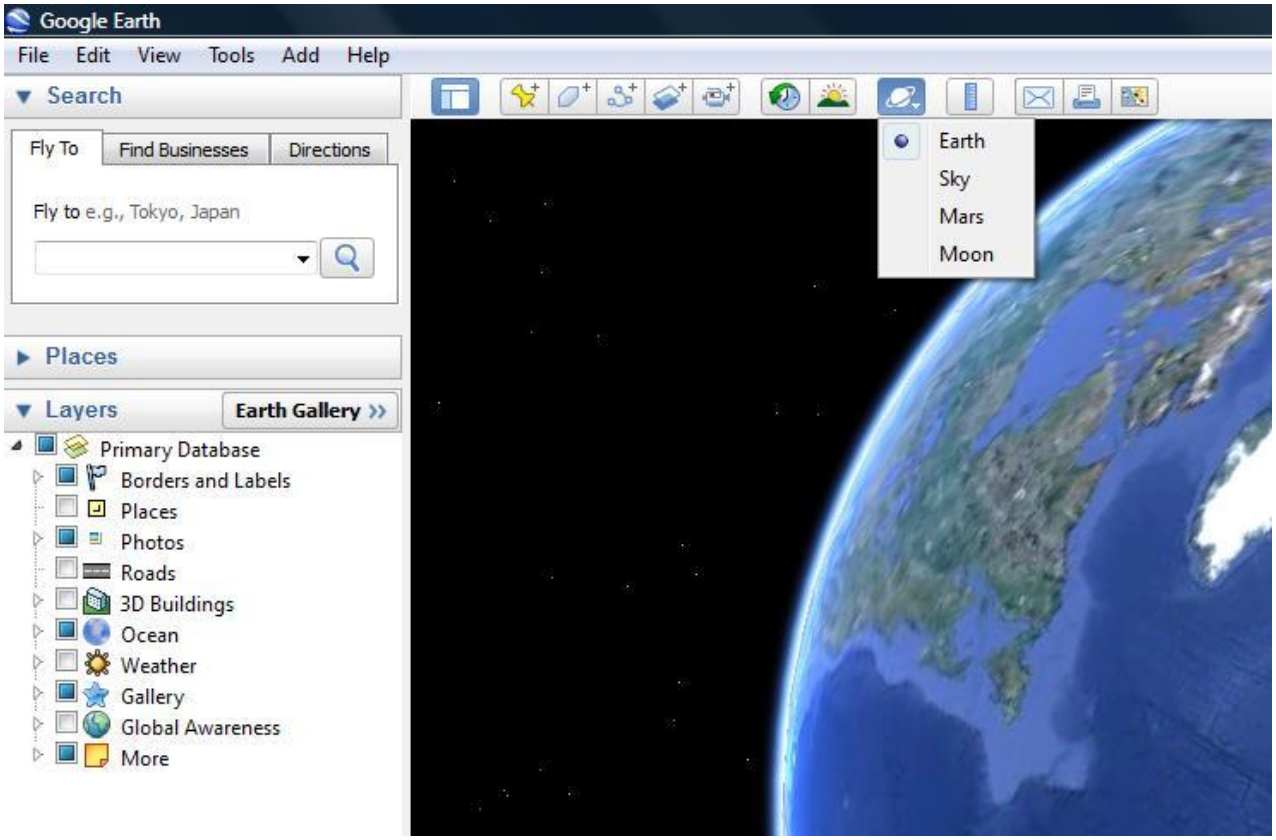
Mars Express and MER views of Phobos

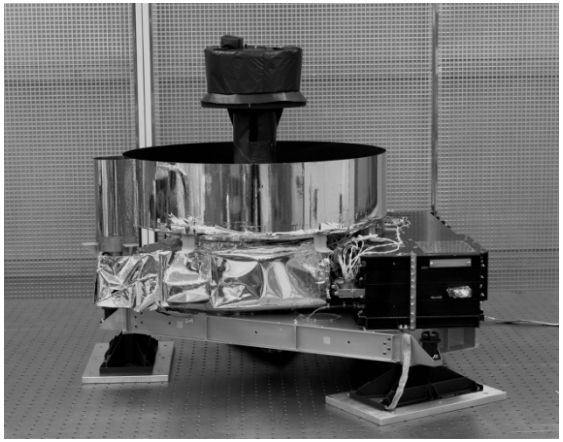





Phoenix
Viking 2
Viking 1
Schiaparelli
Beagle 2
Opportunity
Curiosity
Mars Pathfinder
Spirit
Mars 3
Elevation km
-6 -3 0 3 6 9 12 15 18
Source: ESA, NASA
BBC

Exploring Mars yourself!



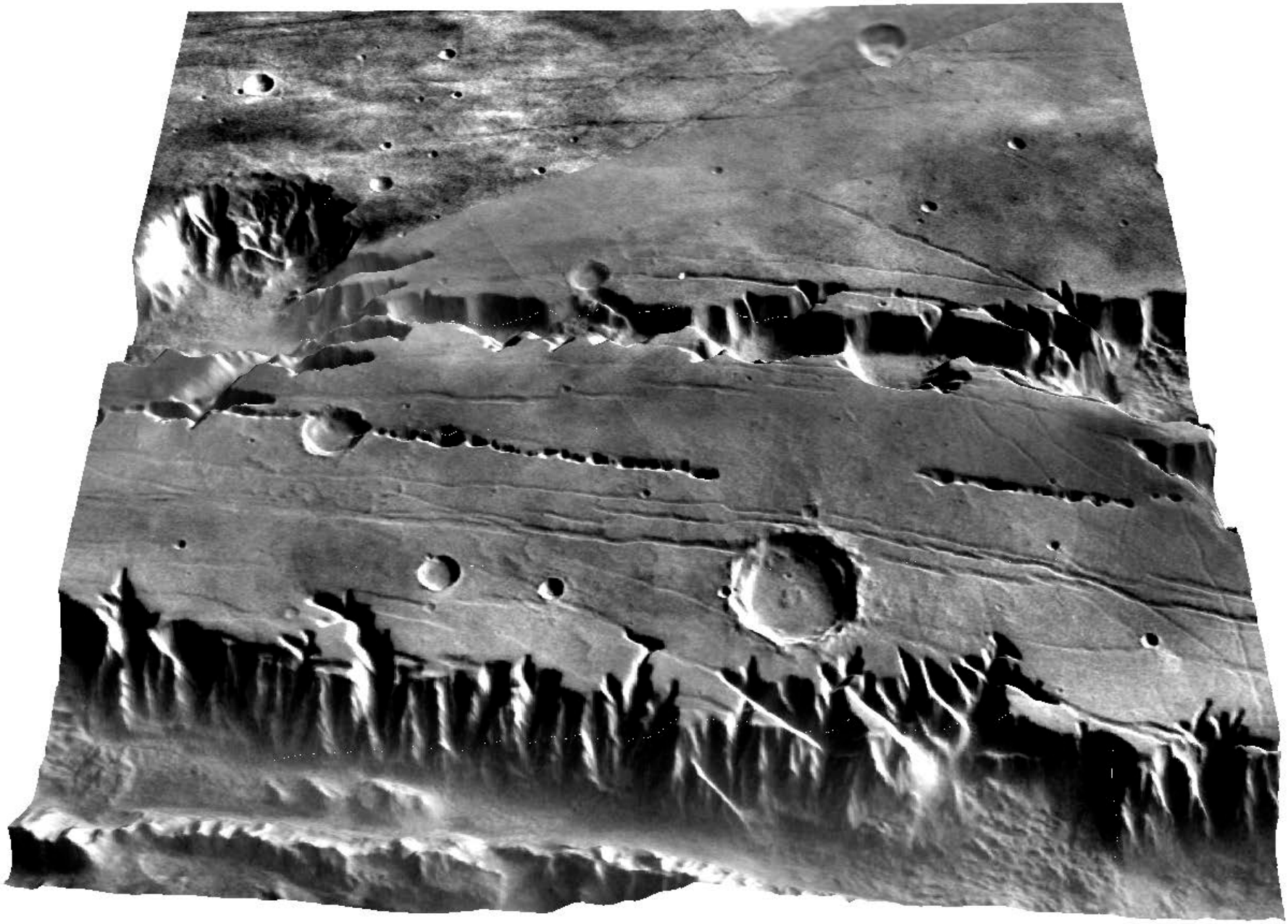


MOLA = Mars Orbiting Laser Altimeter
MGS = Mars Global Surveyor
DTM = Digital Terrain Model

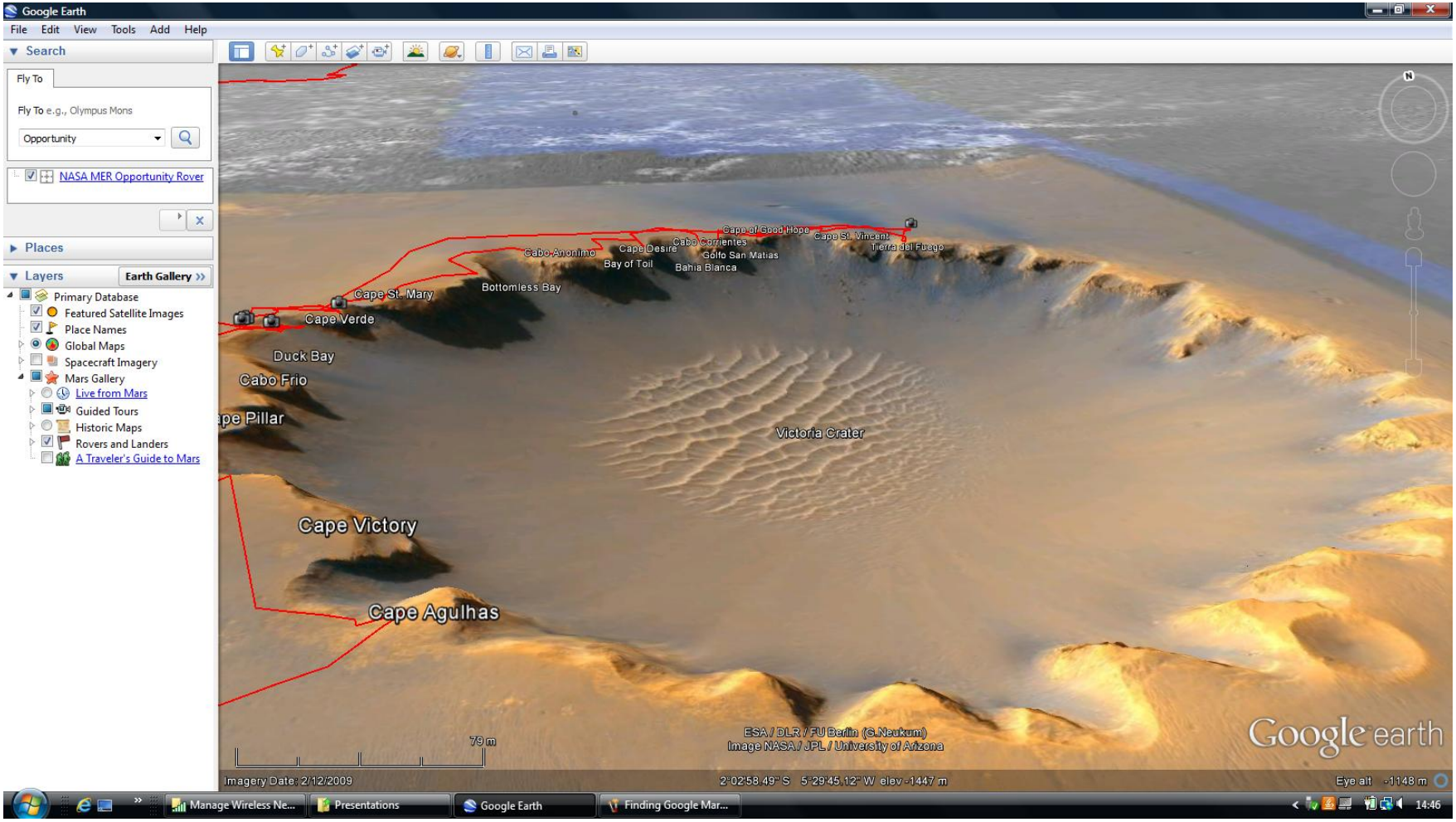
- MOLA – an MGS instrument was used to create a DTM for Mars

- MGS, Mars Express and other imagery draped onto the DTM

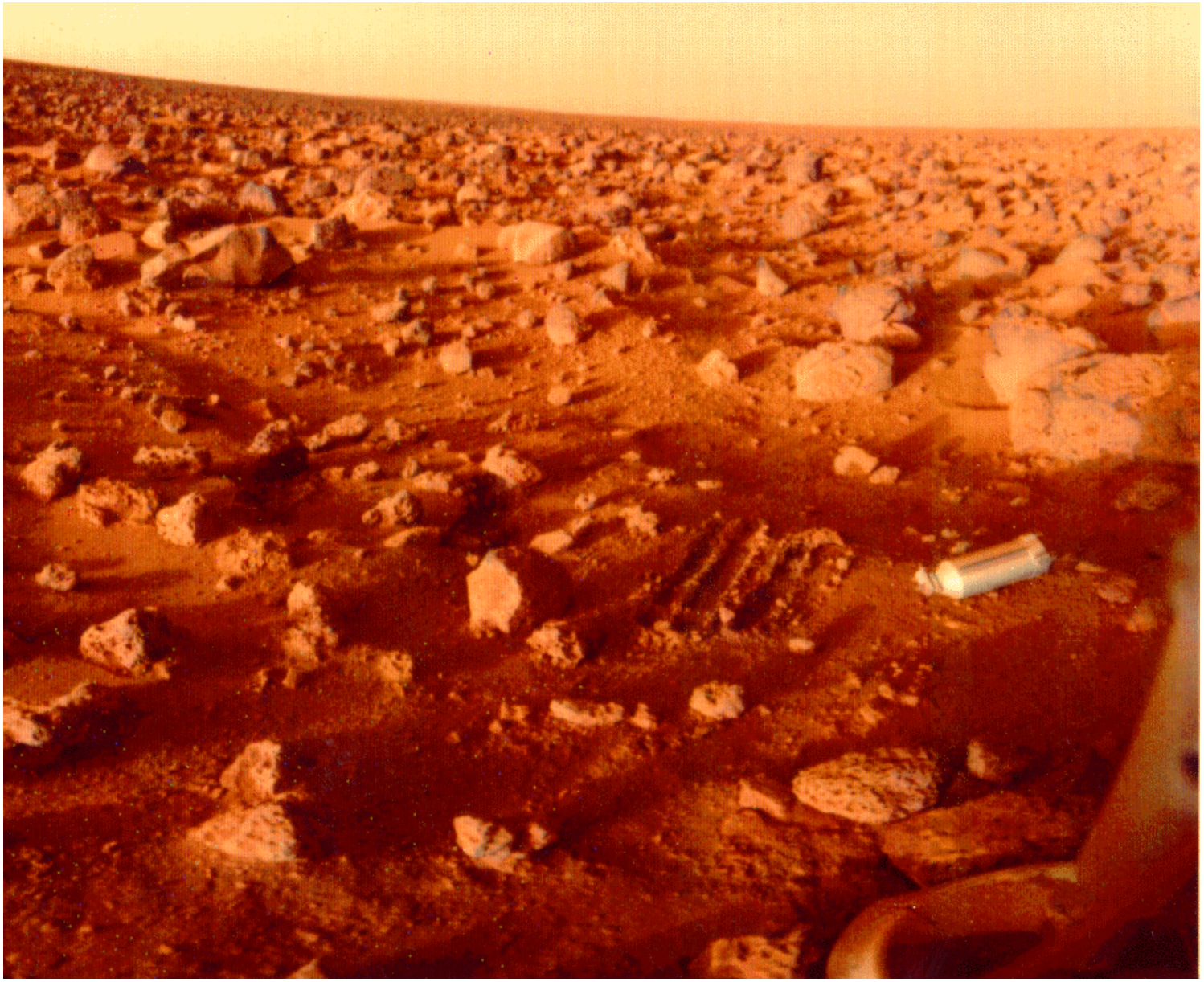
MTM -05/277 E: Tithonium Chasma (3 X Vertical Exaggeration)

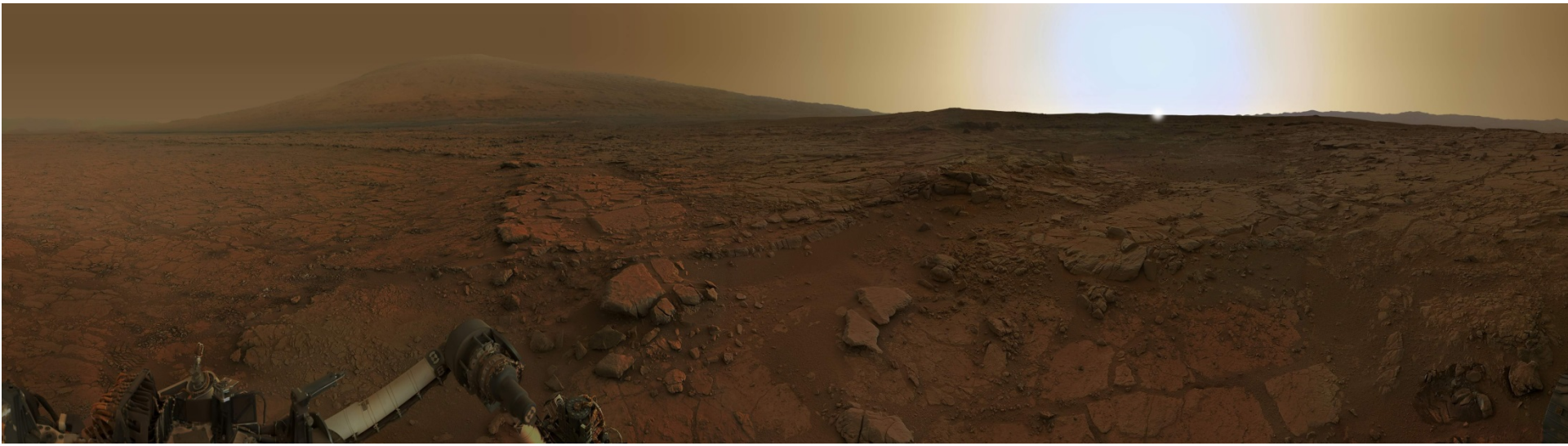


“Google Streetview” at MER sites!



1976 – Viking 2

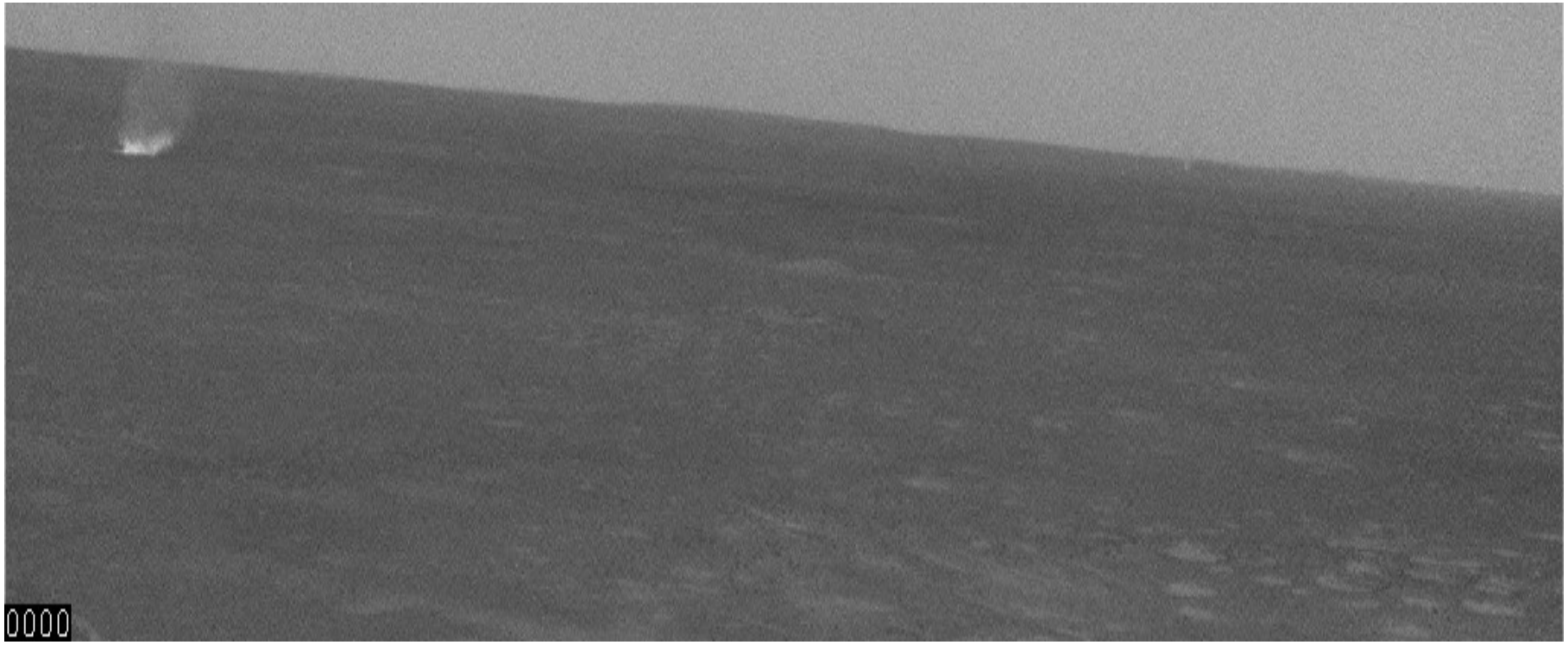




Today’s weather on Mars – courtesy of REMS on MSL (“Curiosity”)

http://marsweather.com/data

Dust devils (2009 – Gusev crater)



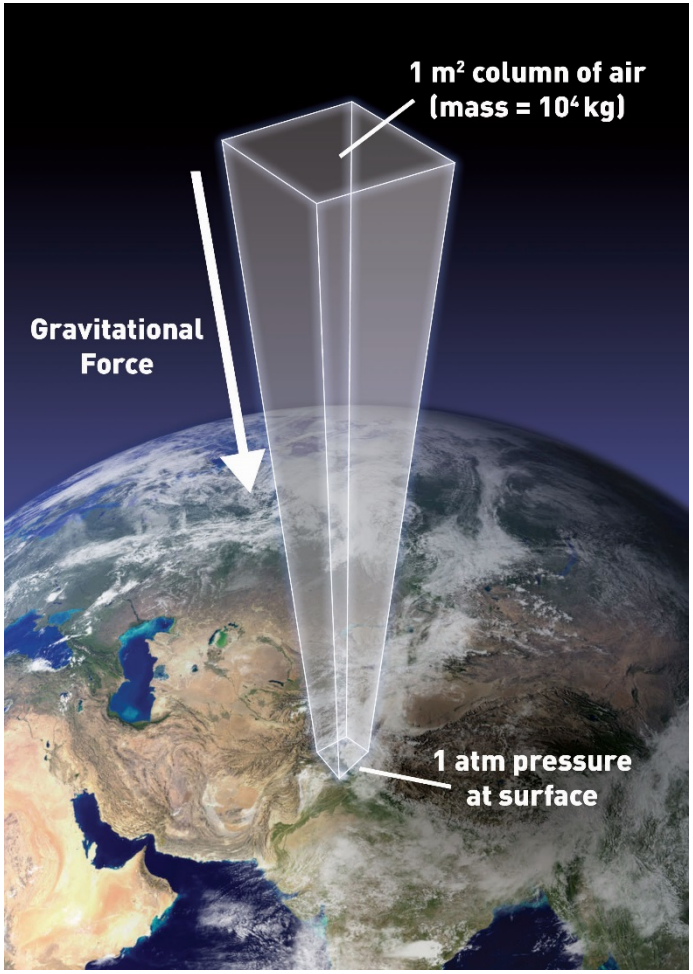

You are here

Atacama and Mars compared…….

- The origin of atmospheric pressure on Earth is due to the weight of atmosphere above us

- **Standard pressure at Earth's surface = 1013.25mb or 101325Pa**

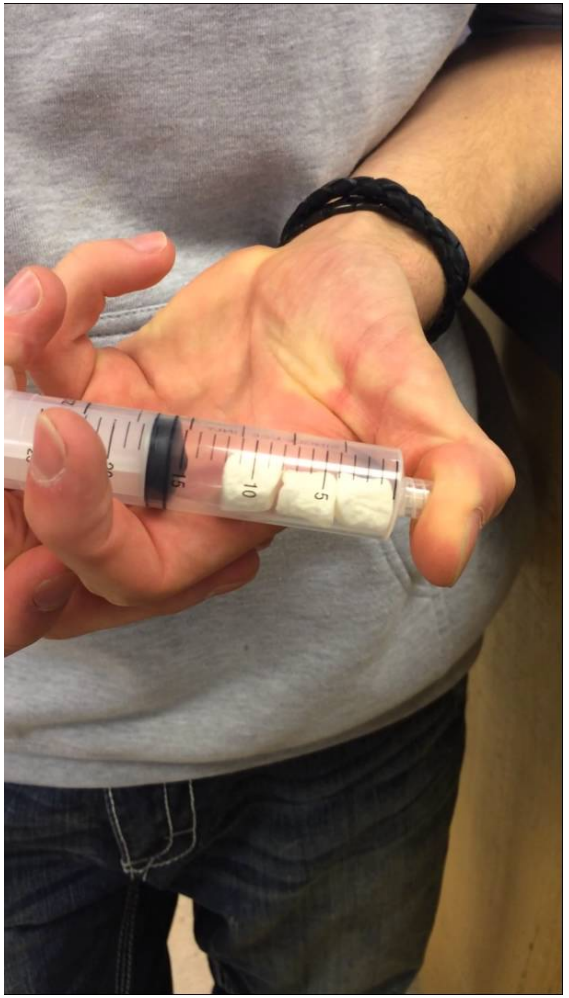
- **ATV and ISS internal pressurised volumes are maintained at these levels**



The consequences of reduced air pressure

- Insert the marshmallow into the syringe and then push the plunger in until it is nearly touching the marshmallow.

- Seal the syringe opening at the end with a finger. The sealed syringe is now a pressure chamber and in

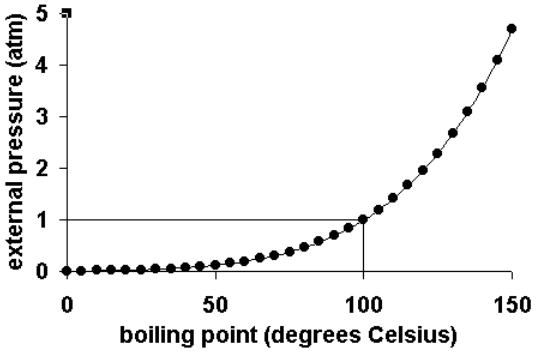


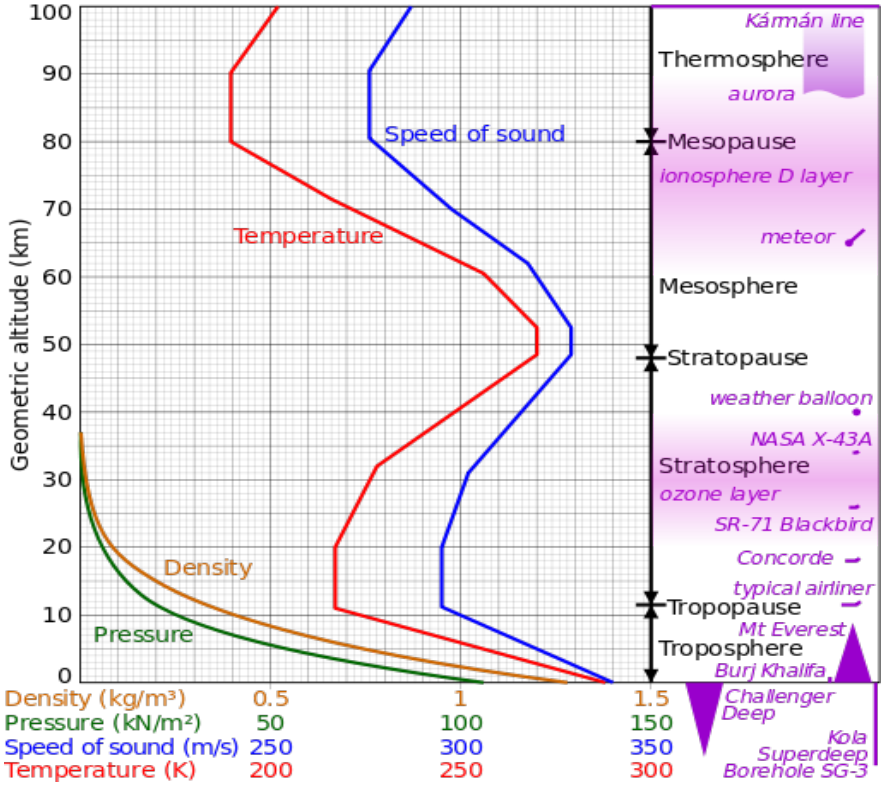
Pressure and the boiling point of water

- Students each have a syringe and a beaker of hot (not boiling) water - around 80C is sufficient.
- The syringe tip is dipped into the hot water.
- By pulling the plunger out, a small amount of water is extracted into the syringe (around 1-2ml)
- Remove the syringe from the water and, keeping the syringe nozzle down, seal the end of the syringe with a finger.

The aeromedical definition of space

- At altitude of 8850m, water boils at 70 C
- Higher still, it boils at lower temperatures due to further reduction in pressure



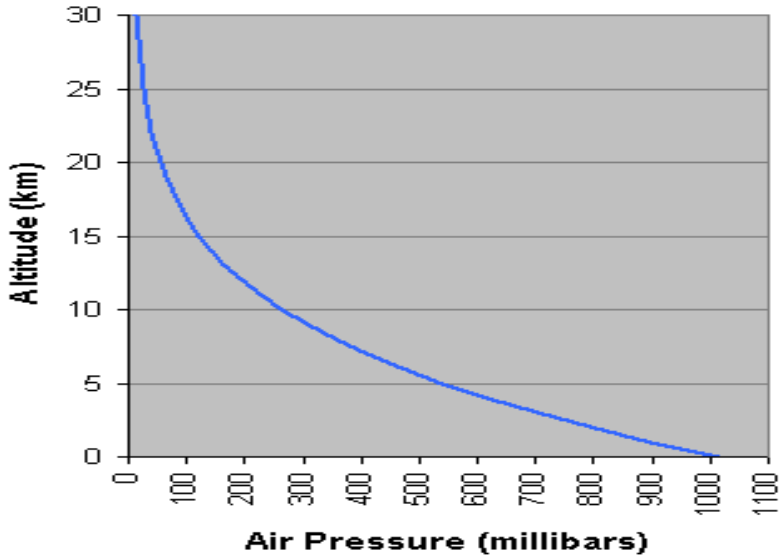


- 20 km above the Earth, air pressure is 6.3kPa
- At this pressure, water boils at 37 C
- **“Armstrong Line” – pressure suit needed for survival**

Just as with capacitors and radioactive decay, we get an EXPONENTIAL drop of pressure as altitude increases

$P = P_0 e^{-(mgh/kt)}$

$P = P_0 e^{-(Mgh/RT)}$



- For Mars, use mean value of m for a 99% N2 atmosphere
- For Earth, use 79% N2, 21% O2 to calculate m
- Use local values of g (Mars = 38% Earth gravity field strength at surface)

Proof? Same principle as for capacitors and radioactive decay

- Consider box, width A, height dx, Vol dv=Adx
- Increase in pressure dP is weight/area = Nmg/A
- So rate of pressure change with height = dP/dx = Nmg/Adx = Nmg/dV
- Since PV=NkT, PdV= NkT
- So rearrange with expression for dV in terms of P and substitute into dP/dx equation
- When integrating remember that P<P at surface so we can reverse order with a minus sign

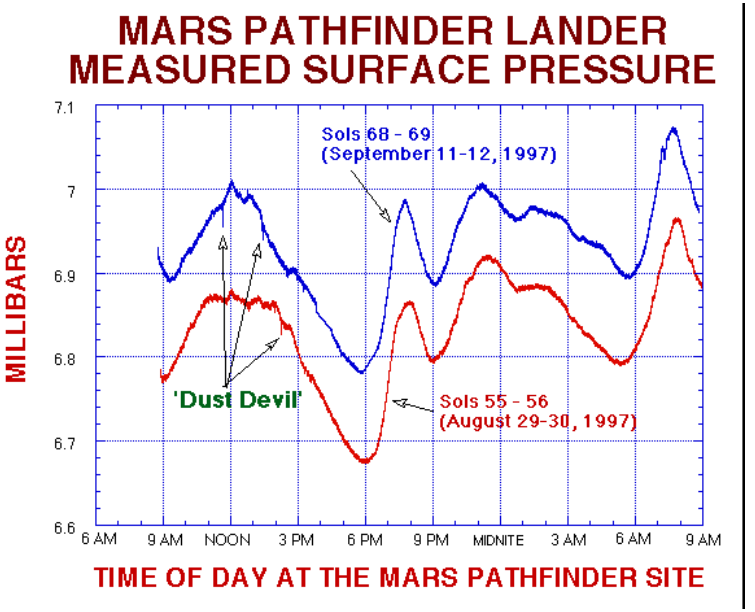
P, V, T and Ideal gas behaviour (pV=NkT, pV = nRT)

What is the physical cause of the expansion of the marshmallows?

- From the measurements you made, could you QUANTIFY the pressure in the syringe after it's pulled out?

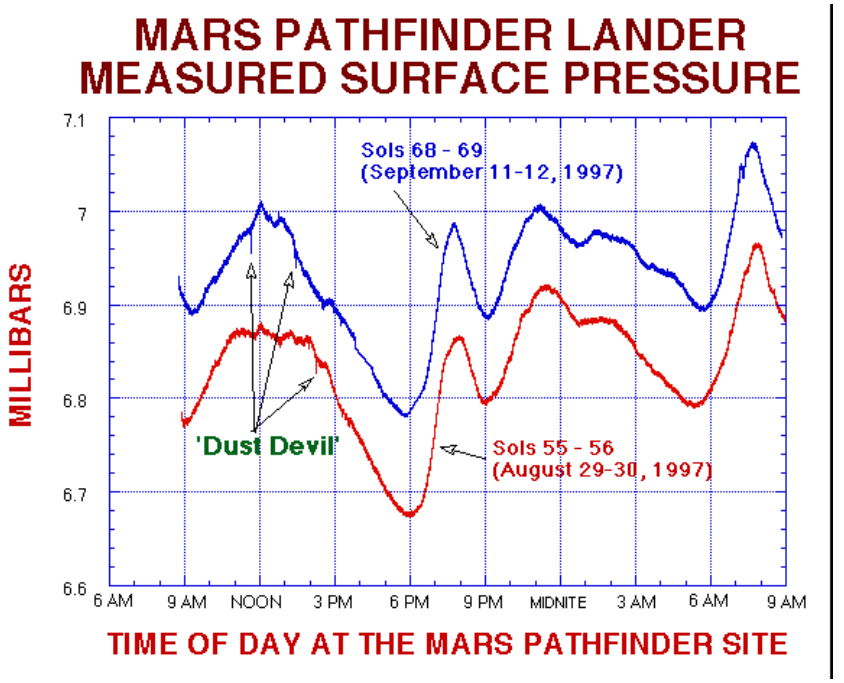
- What do we mean by an ideal gas, anyway?

- Simulating Earth vs Mars, Earth vs Venus??

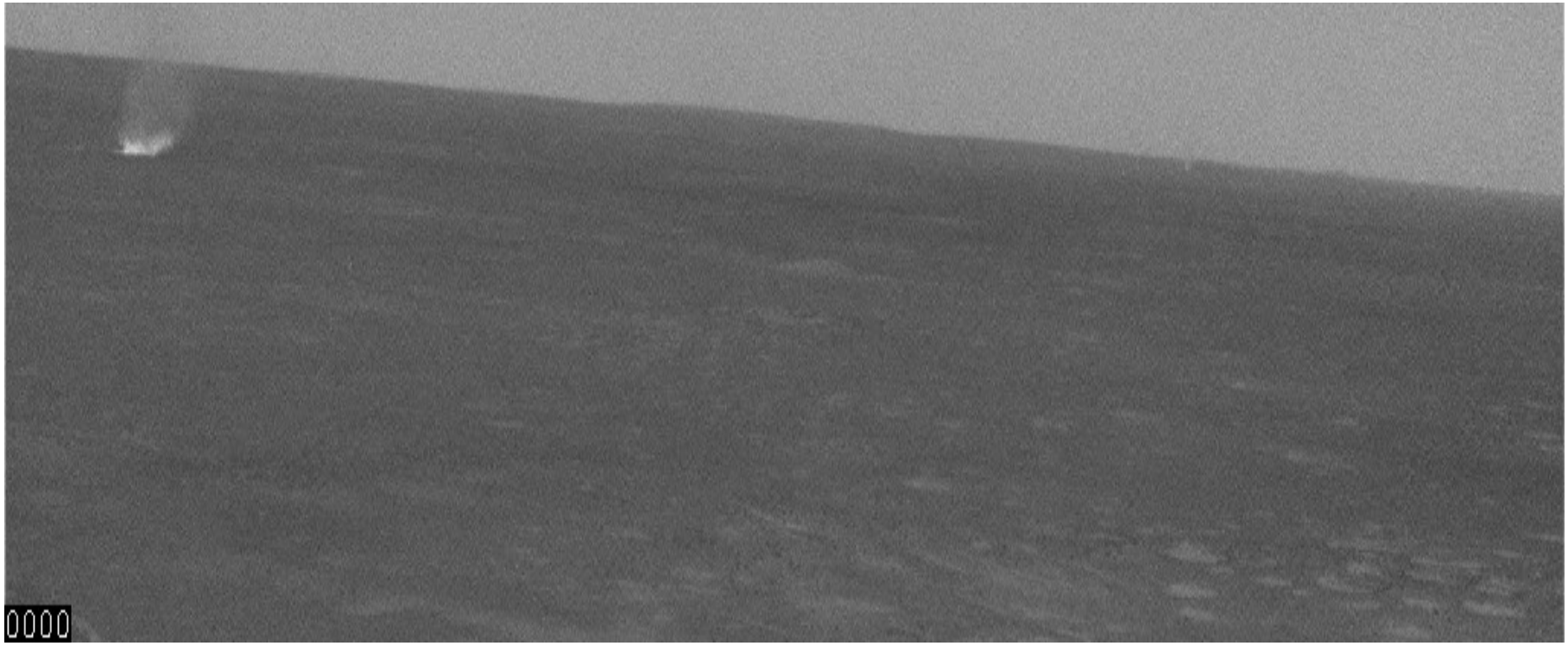


Surface pressure on Mars comparable to those found at 30-35km altitude above Earth – considerable variation during Martian year

- Greater orbital eccentricity than Earth
- Southern winter coincident with Martian aphelion



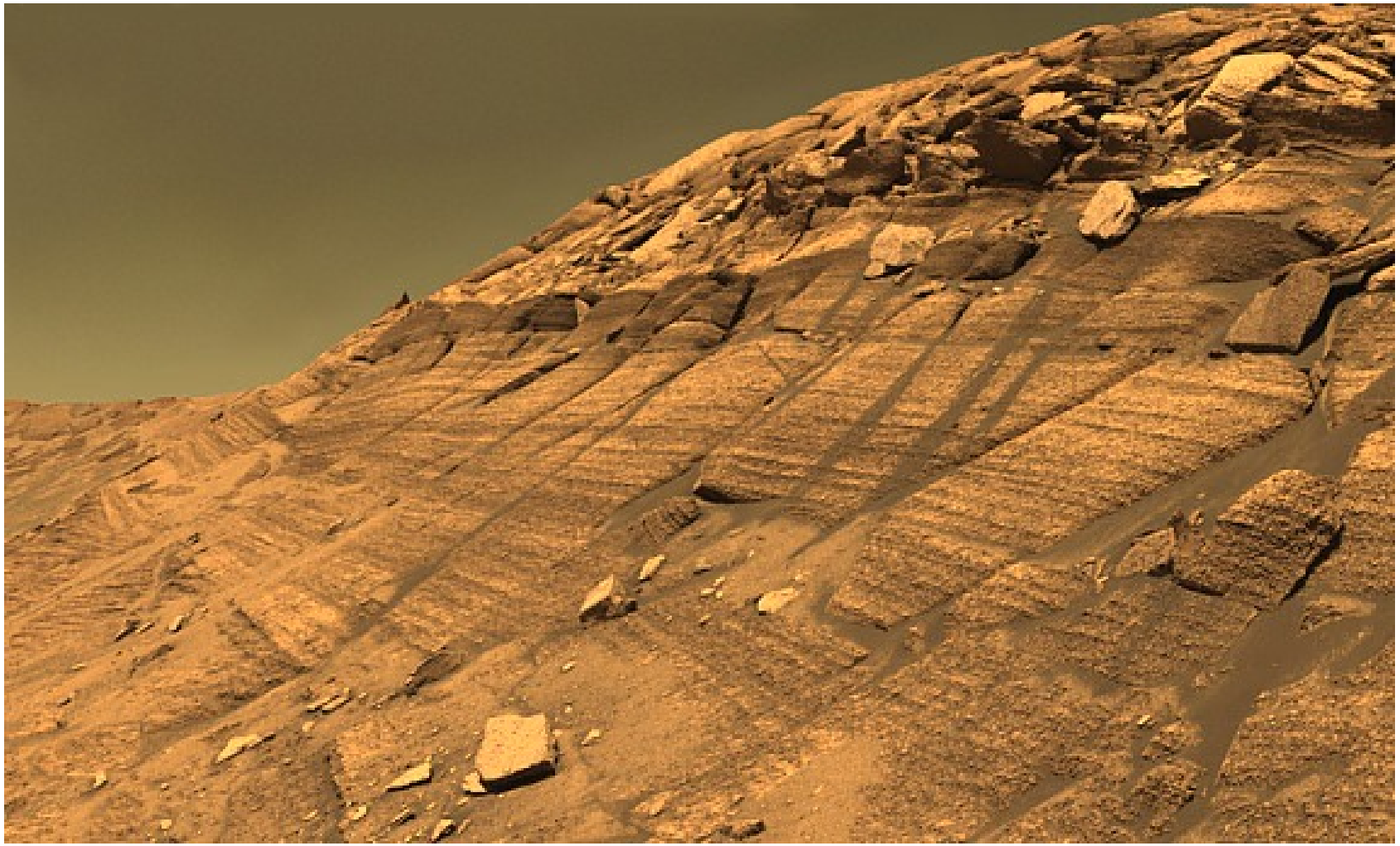
Real dust devils, Hollywood and The Martian



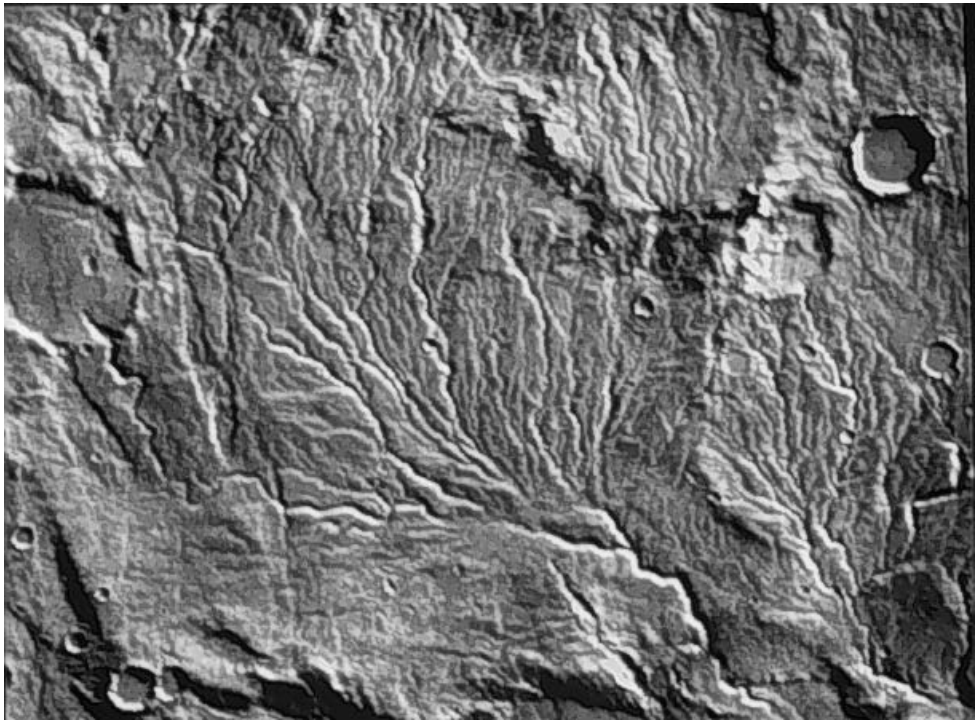
EMU, Orlan, Apollo EVAs and the challenges of Mars

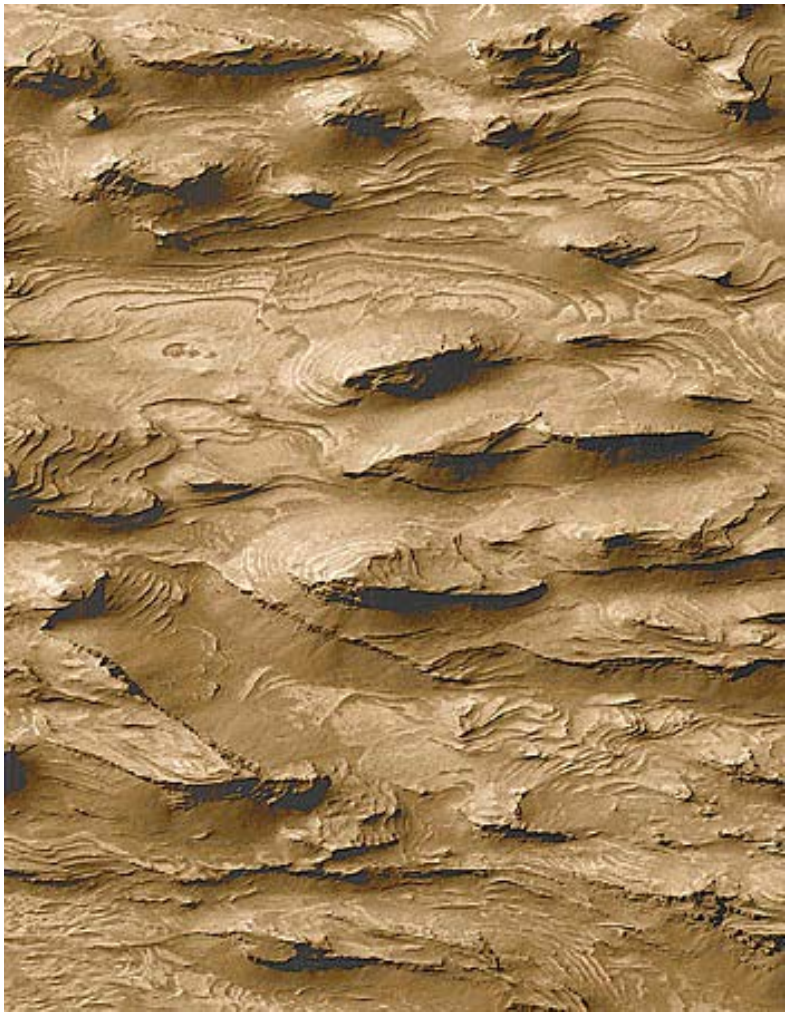
- Higher gravity (more than twice) than Moon
- Dust, dust, dust!

Evidence of water (MER)

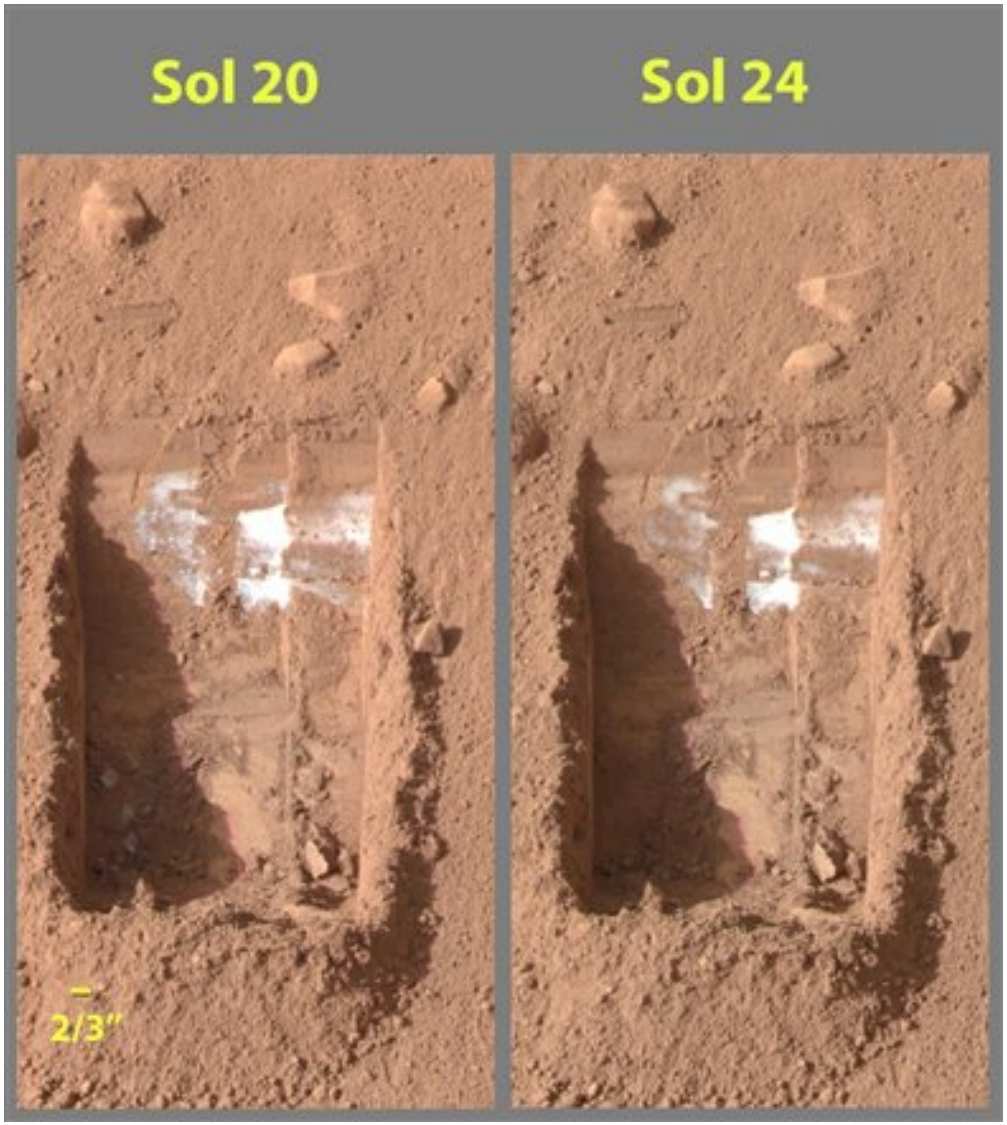


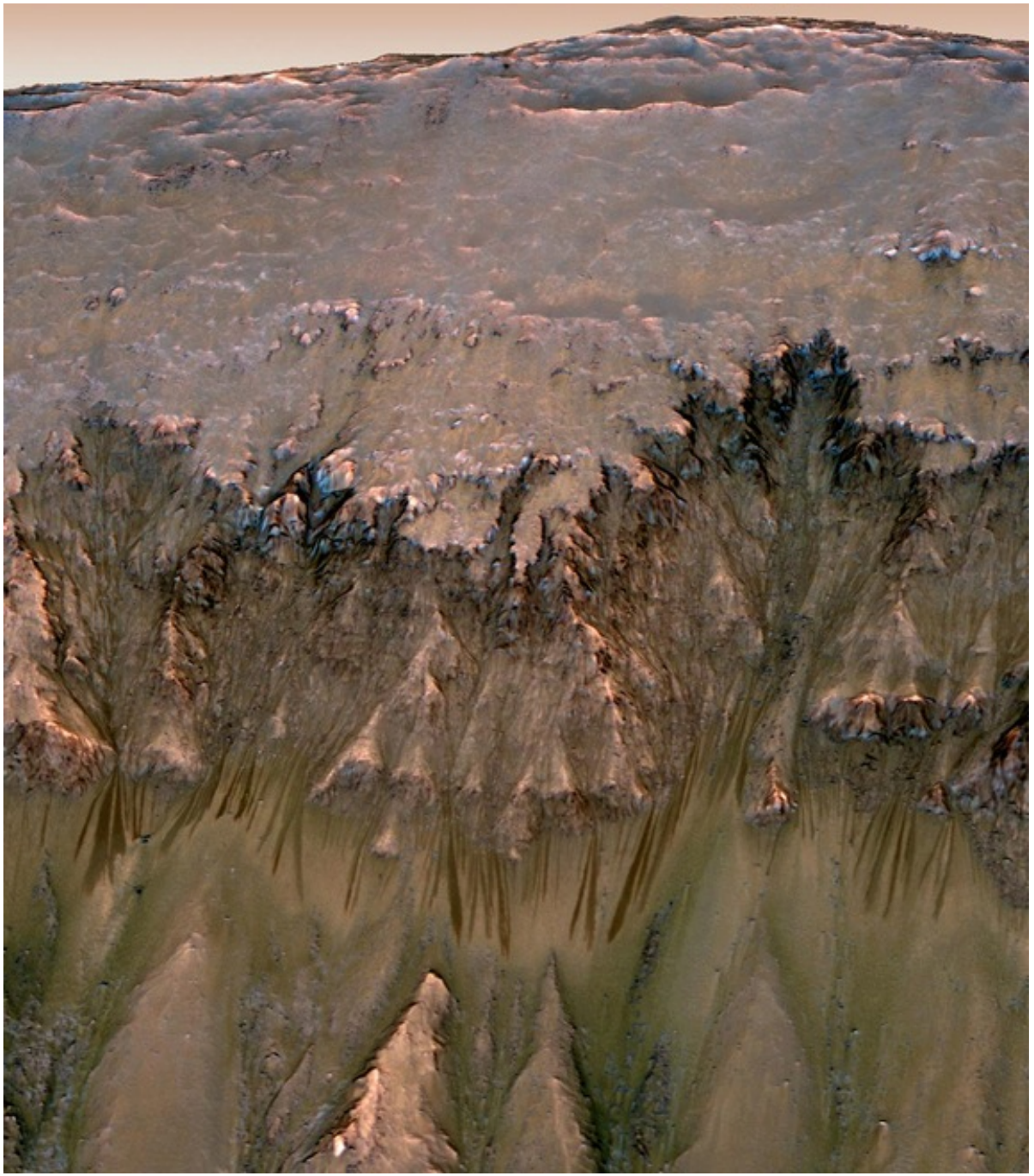
Viking, Mars Express (small and large scale)



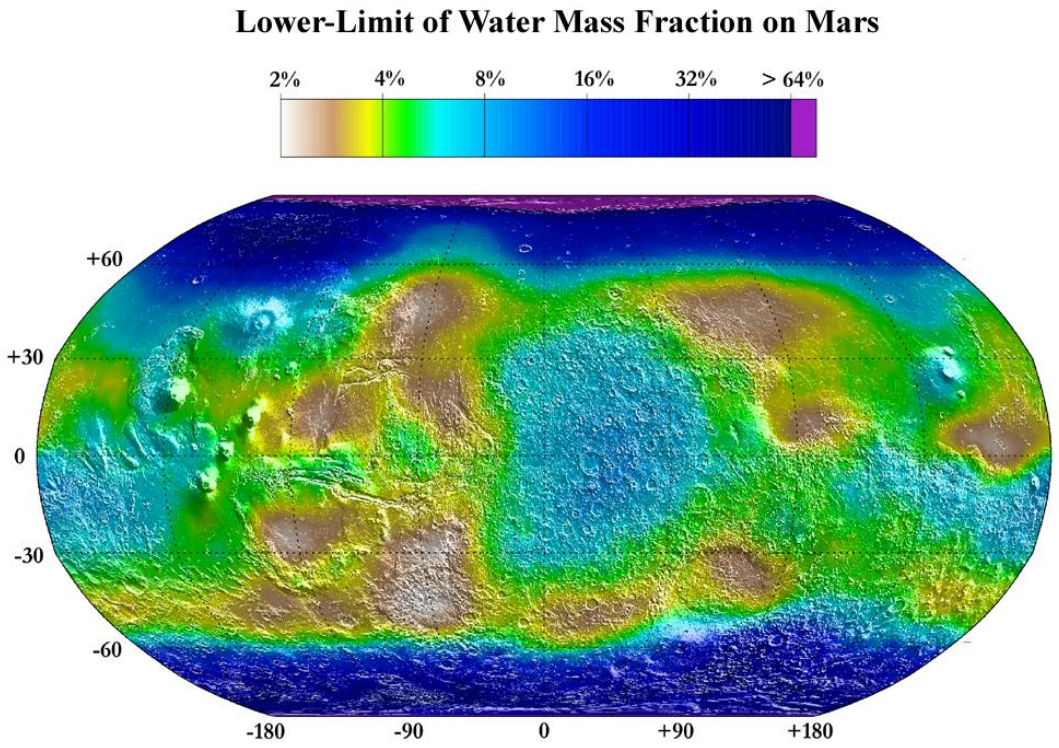


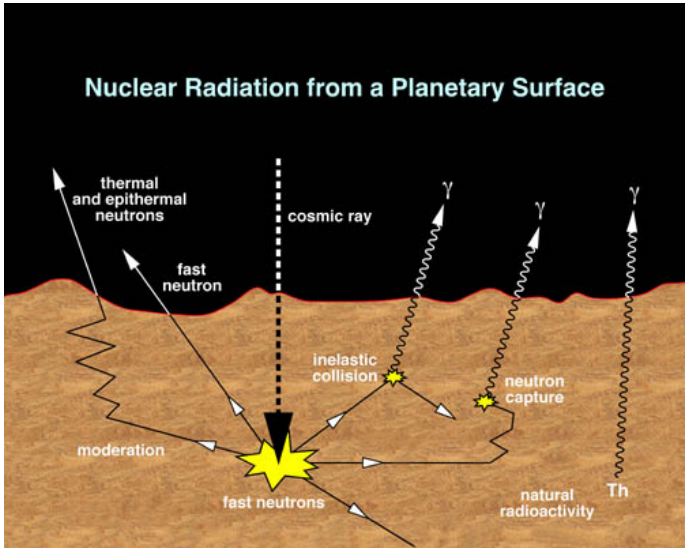
Phoenix – Martian polar regions



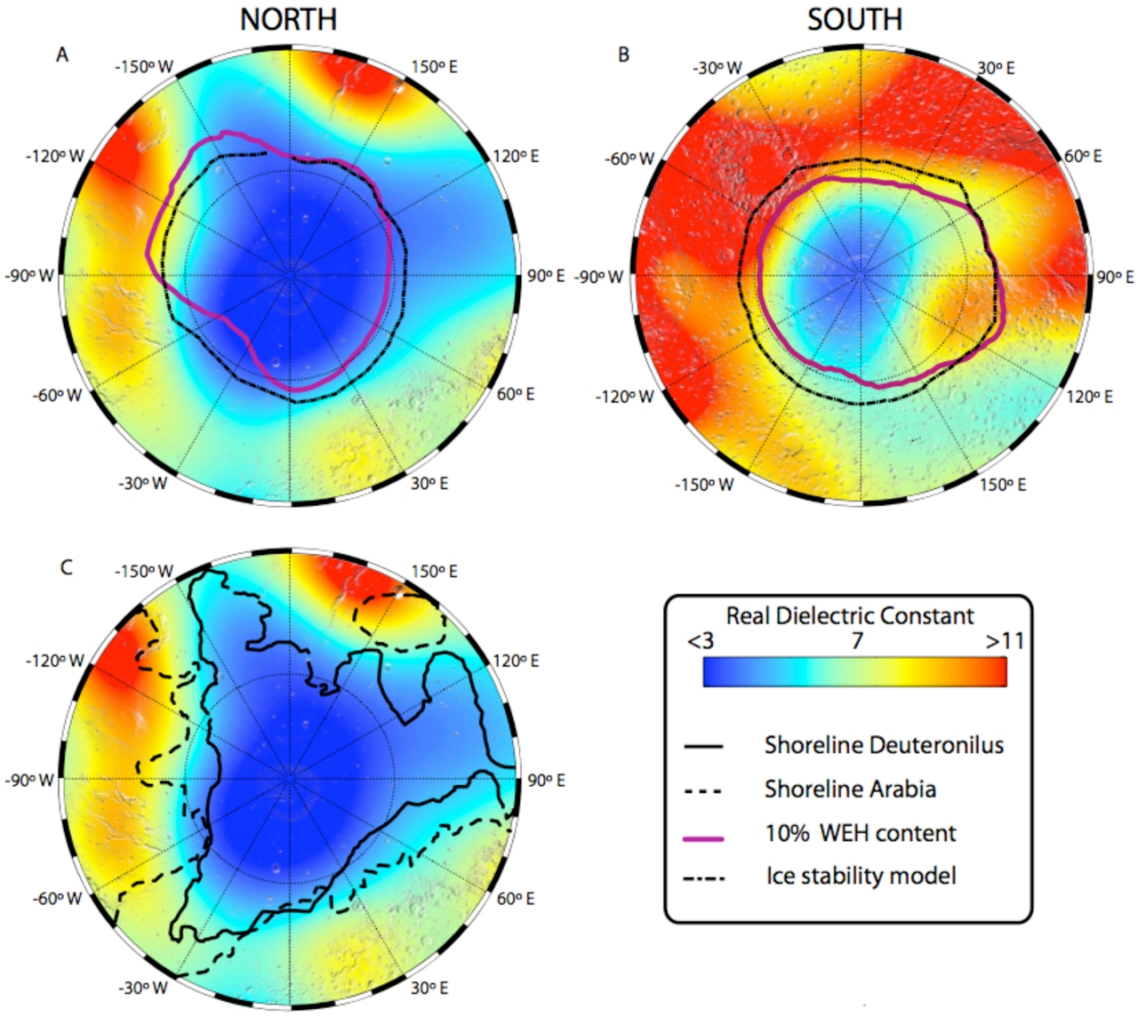


Mars Odyssey derived data from neutron and gamma ray spectrometry



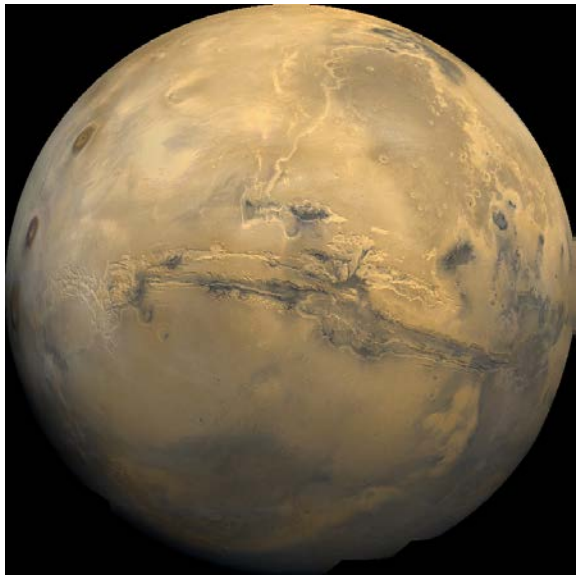


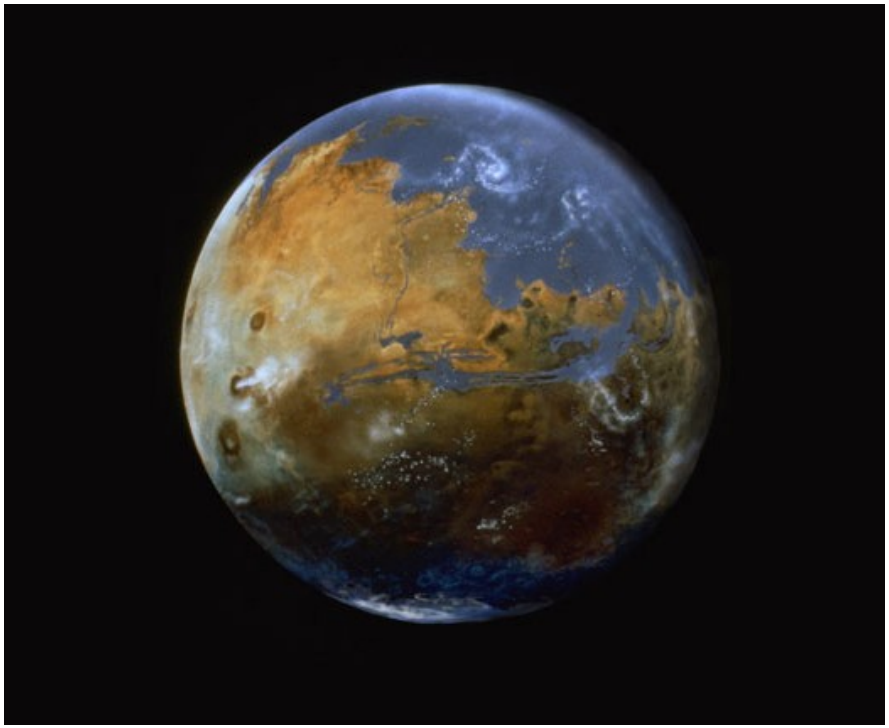
MARSIS data, Mars Express



- 60-80m depth penetration
- Low-density sediments mixed with ice would correlate with low observed dielectric constants in Northern Hemisphere beyond the polar latitudes

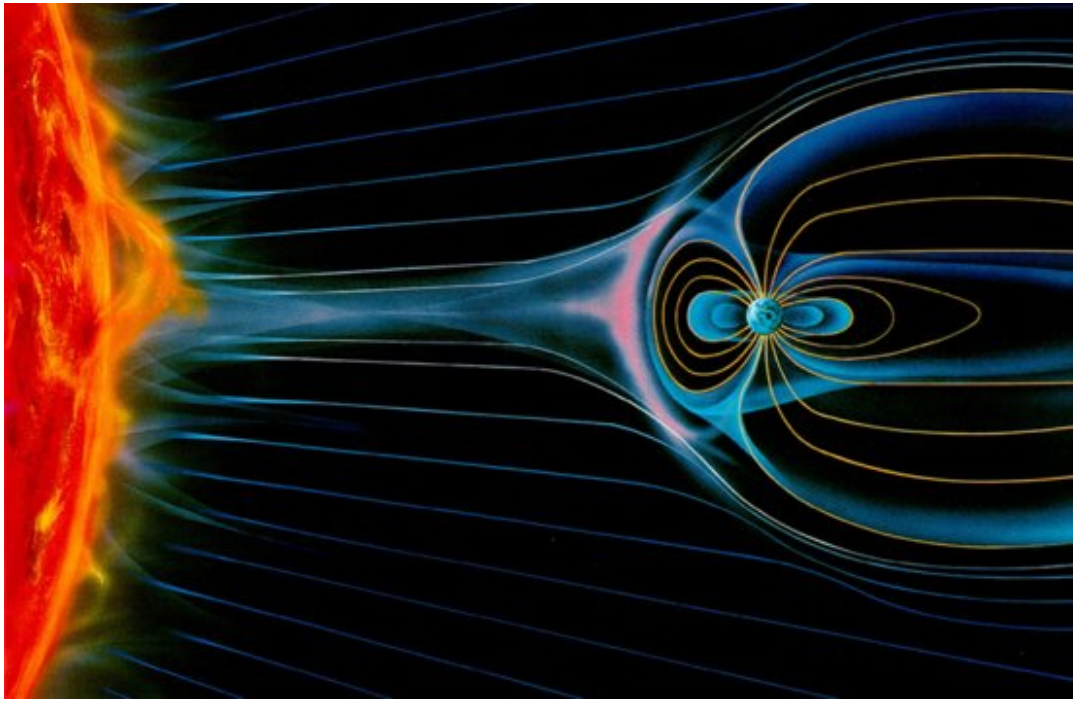
Mars now, and 3.8Billion years ago





Electric motors and solar weather

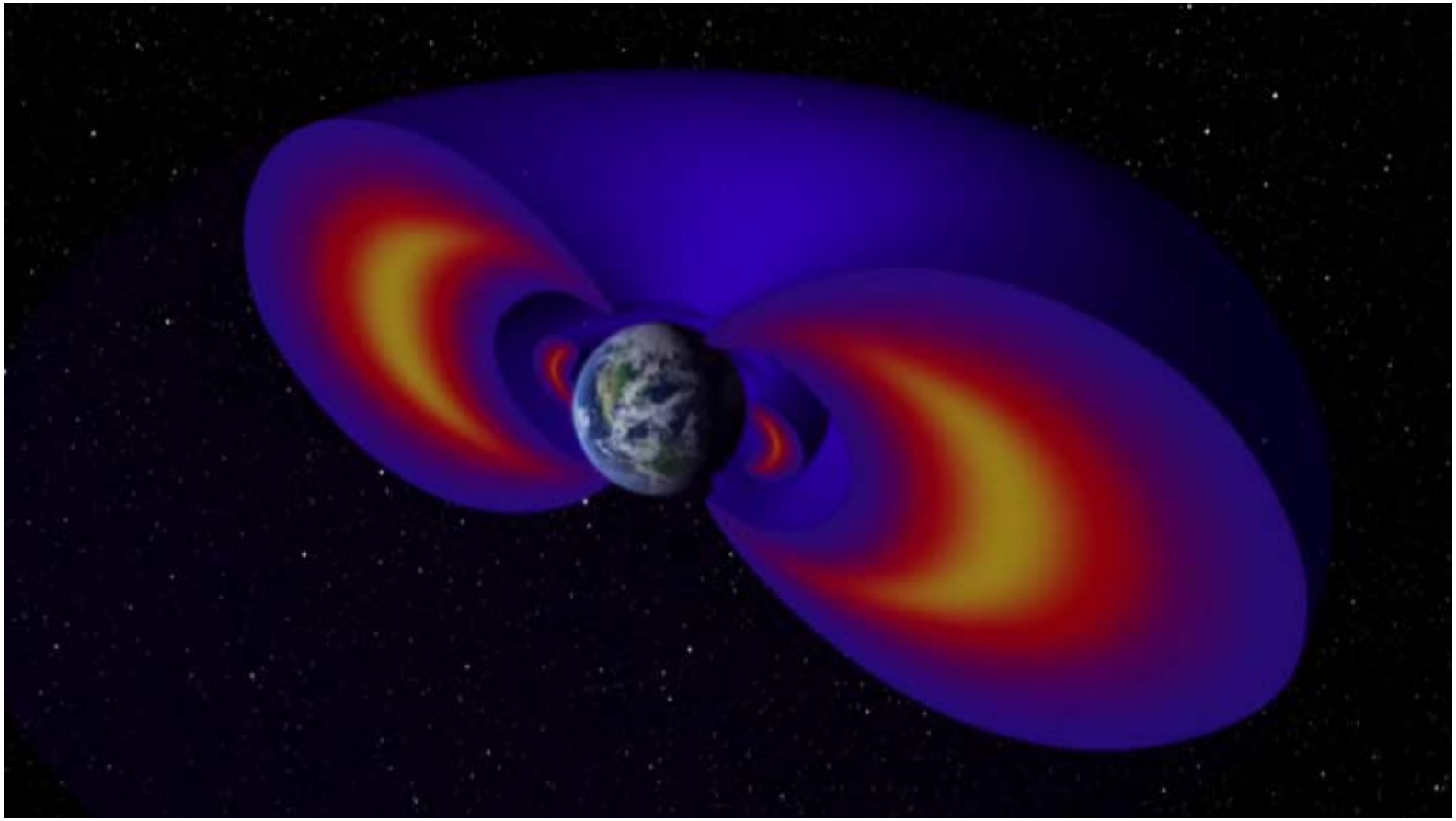
- Lorentz force – for a charged particle moving in a magnetic field, $F = q(v \times B)$



The solar wind (a stream of high-energy protons and electrons) is a flow of trillions of individual electric currents, all susceptible to deflection by magnetic fields

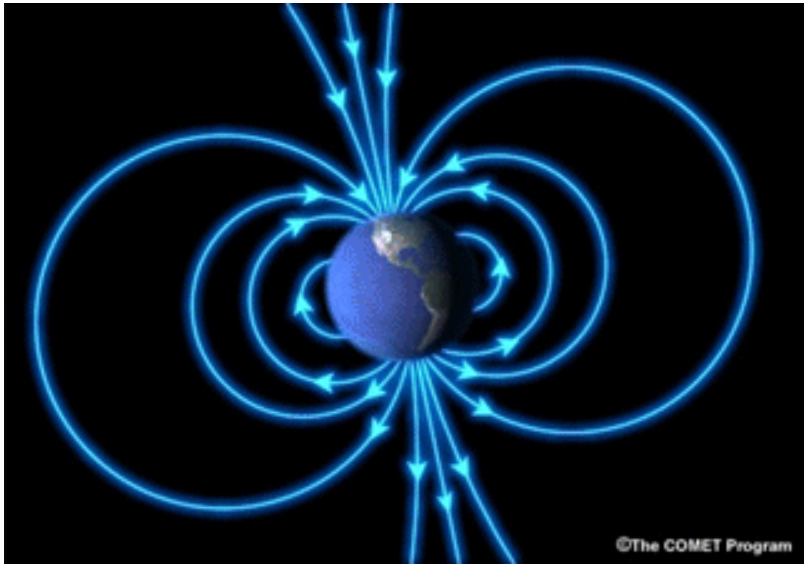
Earth's magnetic field protects us from our atmosphere being stripped away

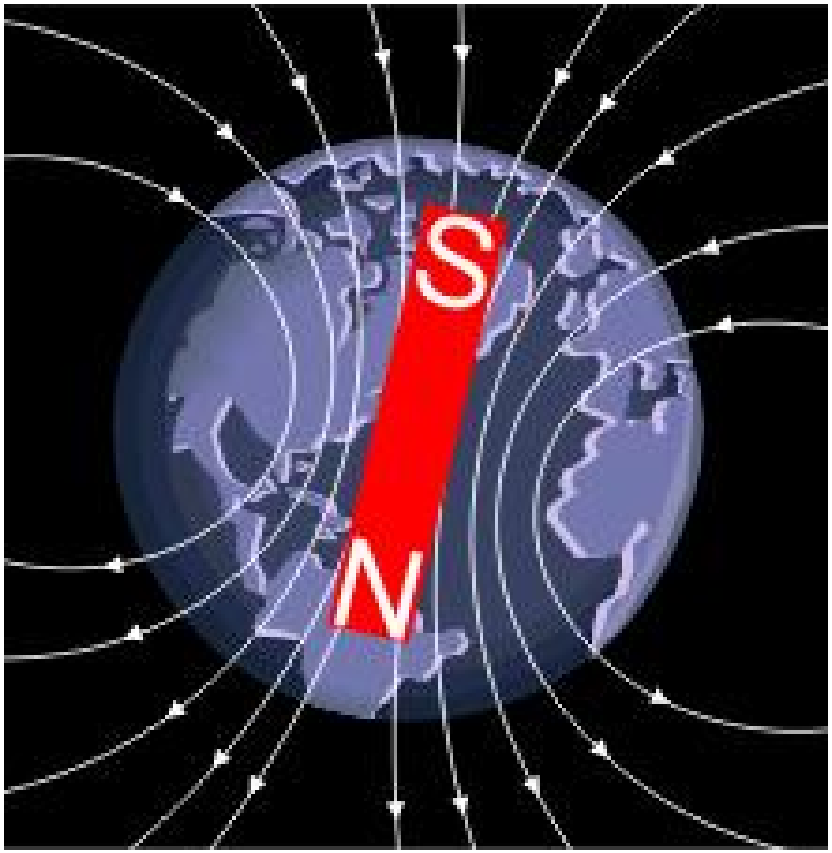
The Van Allen radiation belts



Highly energetic charged particles are trapped in the belts, oscillating back and forth as they spiral along field lines

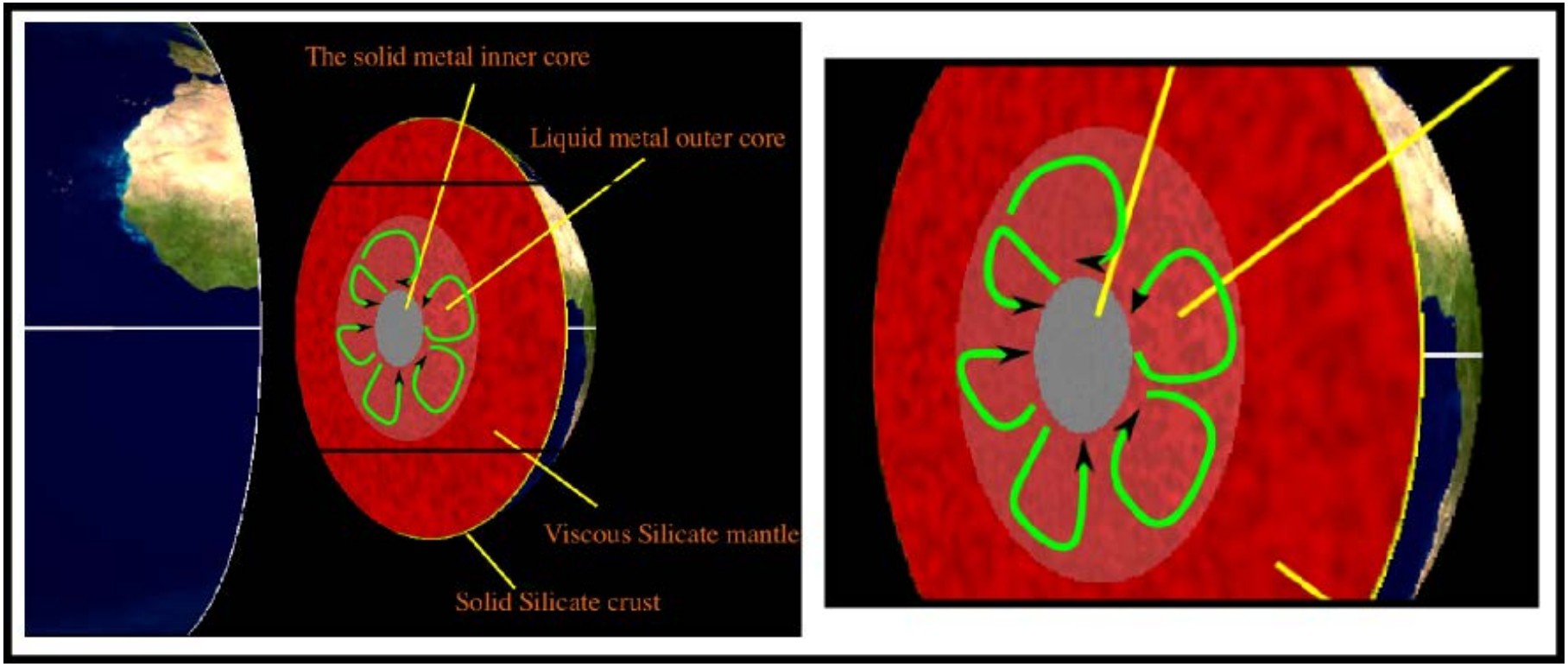
Could there be a giant iron bar magnet inside the Earth? NO!!



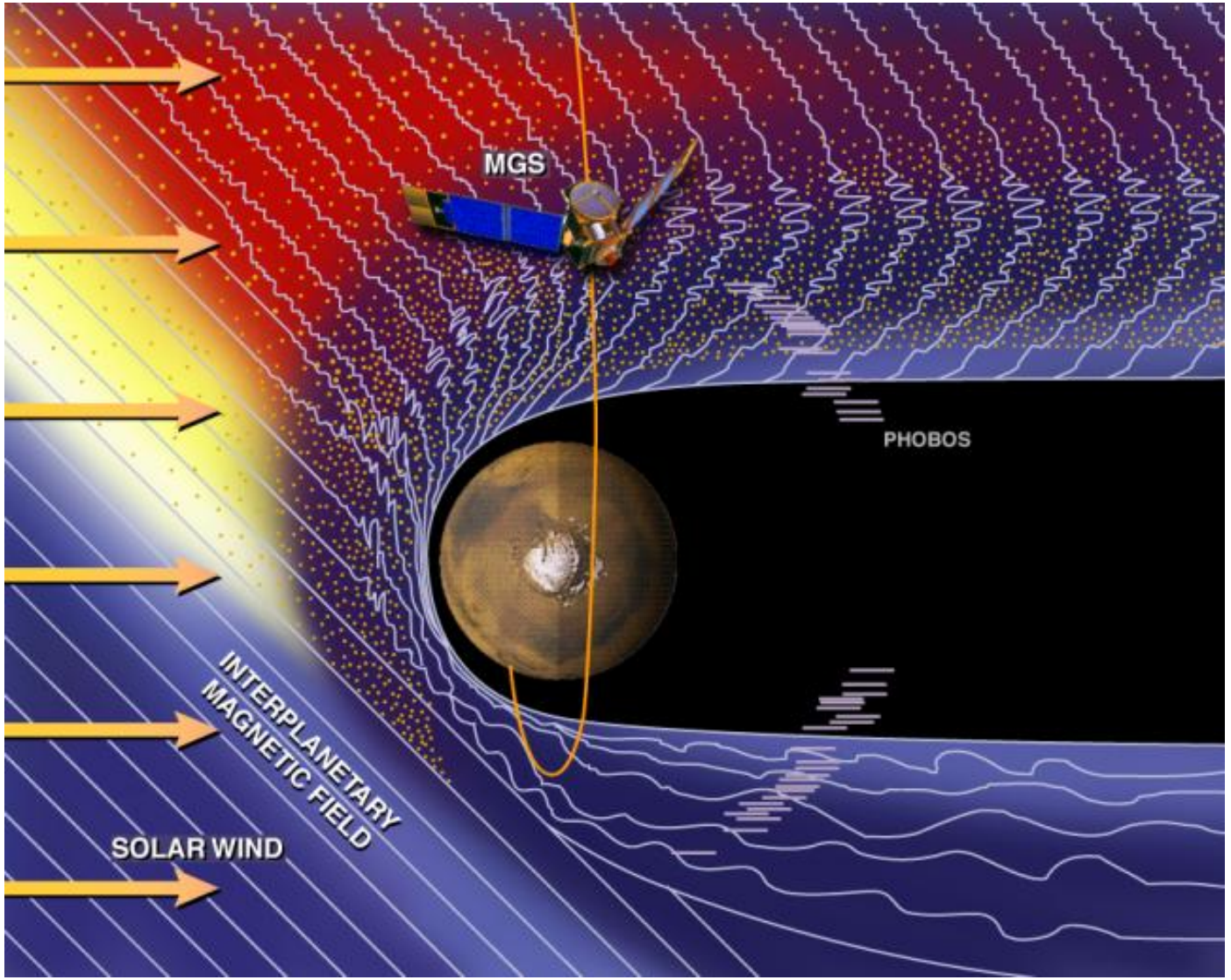


Curie temp for Fe is around 1000K

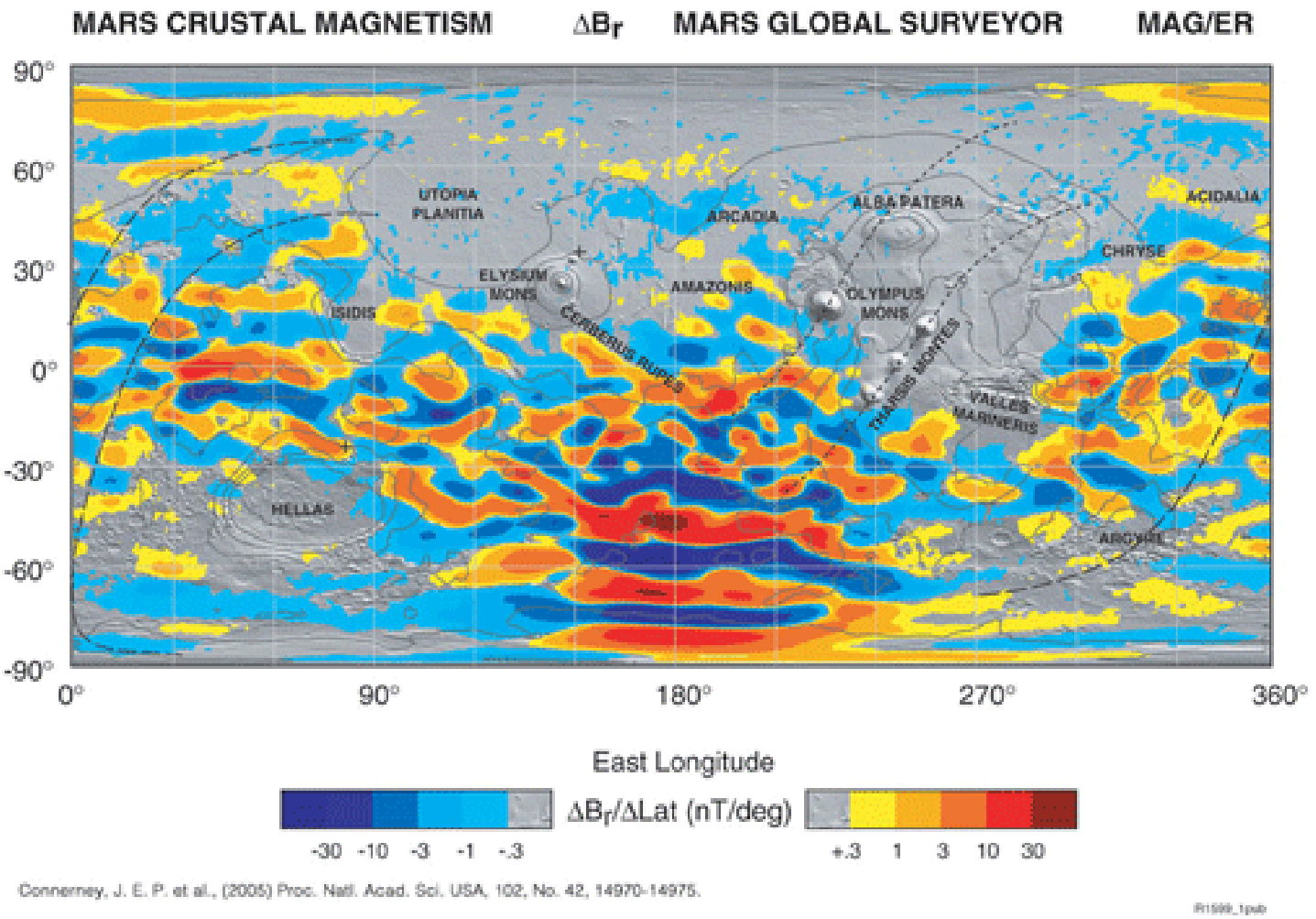
Planetary geomagnetic dynamo – needs convective liquid core



Mars – no global magnetic field

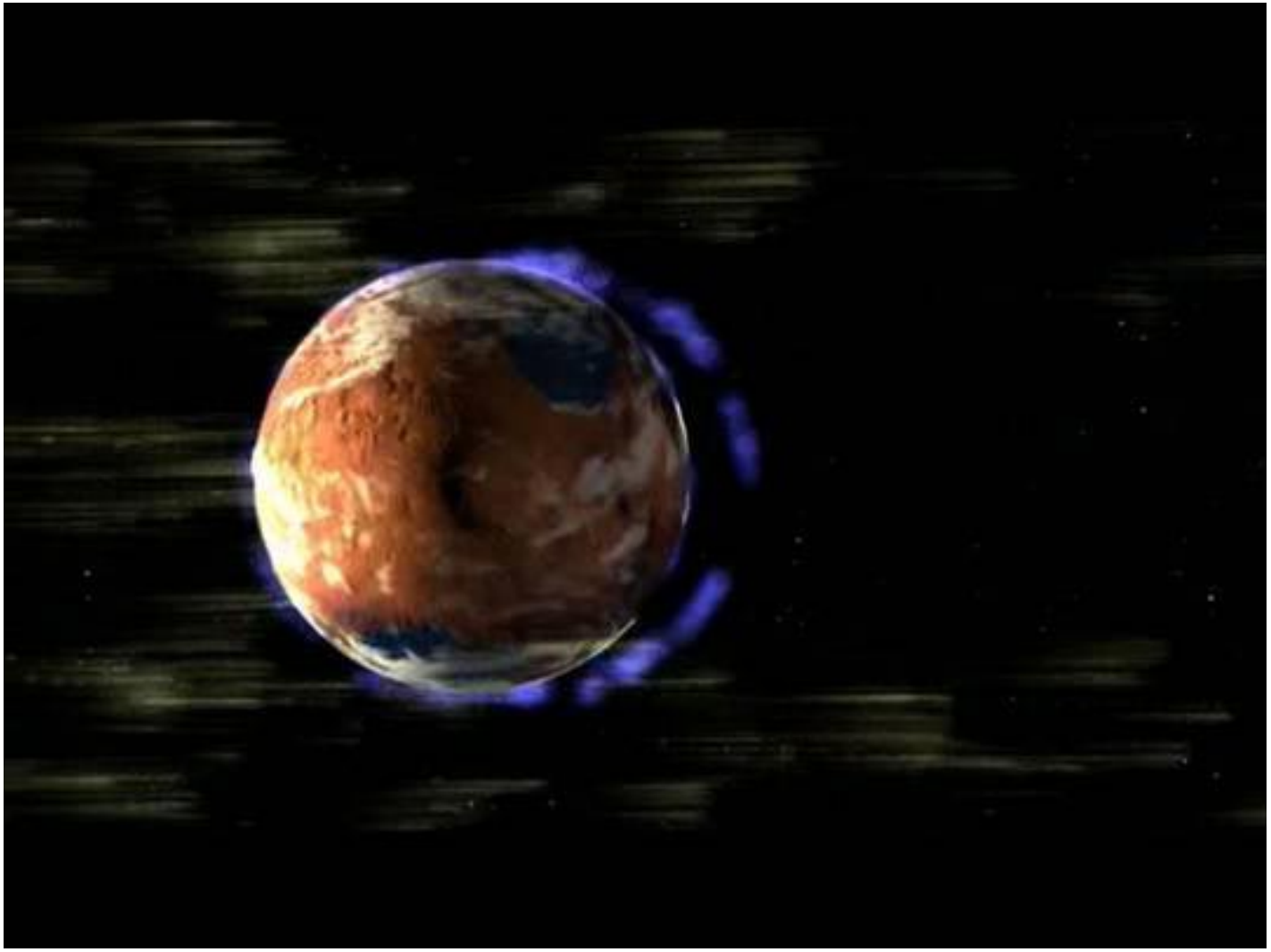


Martian fossil field.....approximate Earth B value at surface = 0.0005T



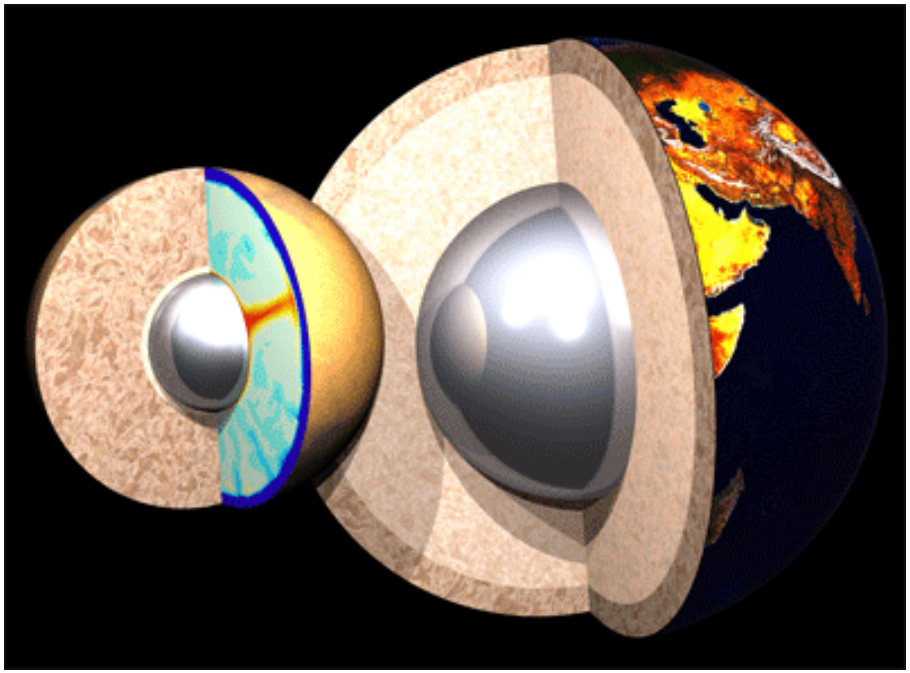
Connerney, J. E. P. et al., (2005) Proc. Natl. Acad. Sci. USA, 102, No. 42, 14970-14975.

Mars has faint global aurorae

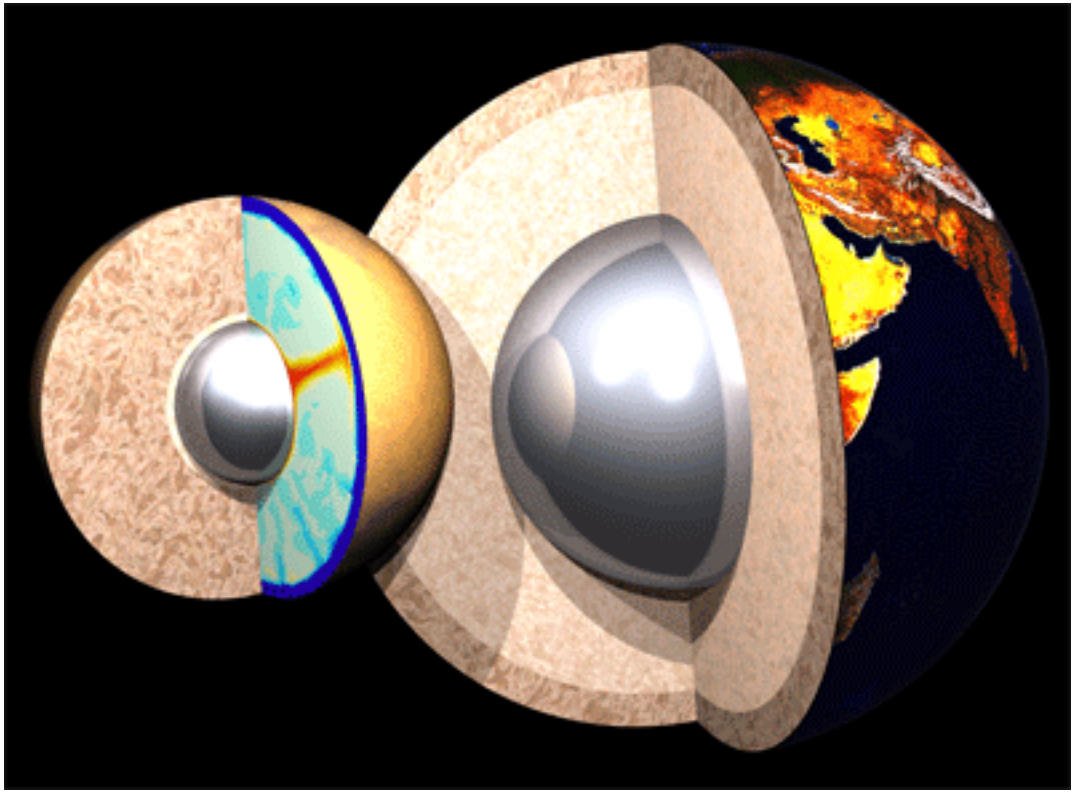


Putting the whole Martian story together.....

- Why did Mars lose its “internal dynamo” generating its magnetic field so quickly compared to Earth?
- How does the existence of Vallis Marineris, the giant volcanoes and lack of plate tectonics back up this scenario?
- Could this happen to Earth?

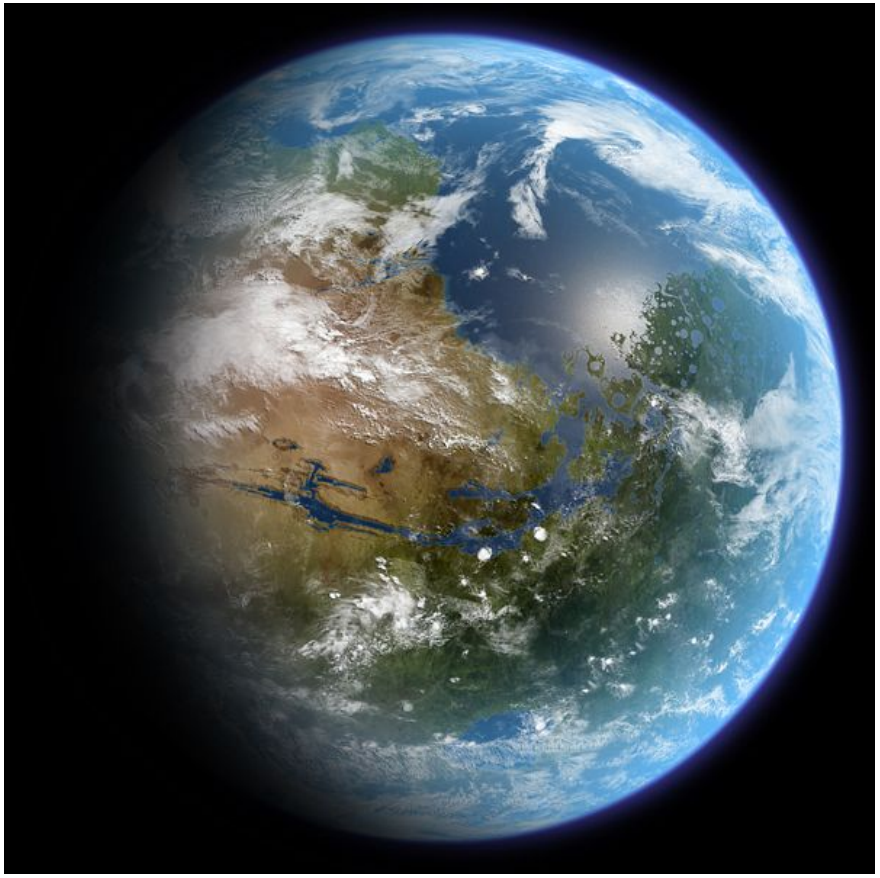


Mars' core cools faster than Earth's



- Dynamo mechanism fails (goodbye magnetic field)
- Mantle motion insufficient to dive full place tectonics (hence giant volcanoes)
- Surface area/volume ratios also come into effect
- Earth had initially higher internal temps after formation due to gravitational self-accretion potential energy infall

The past.....and perhaps the future

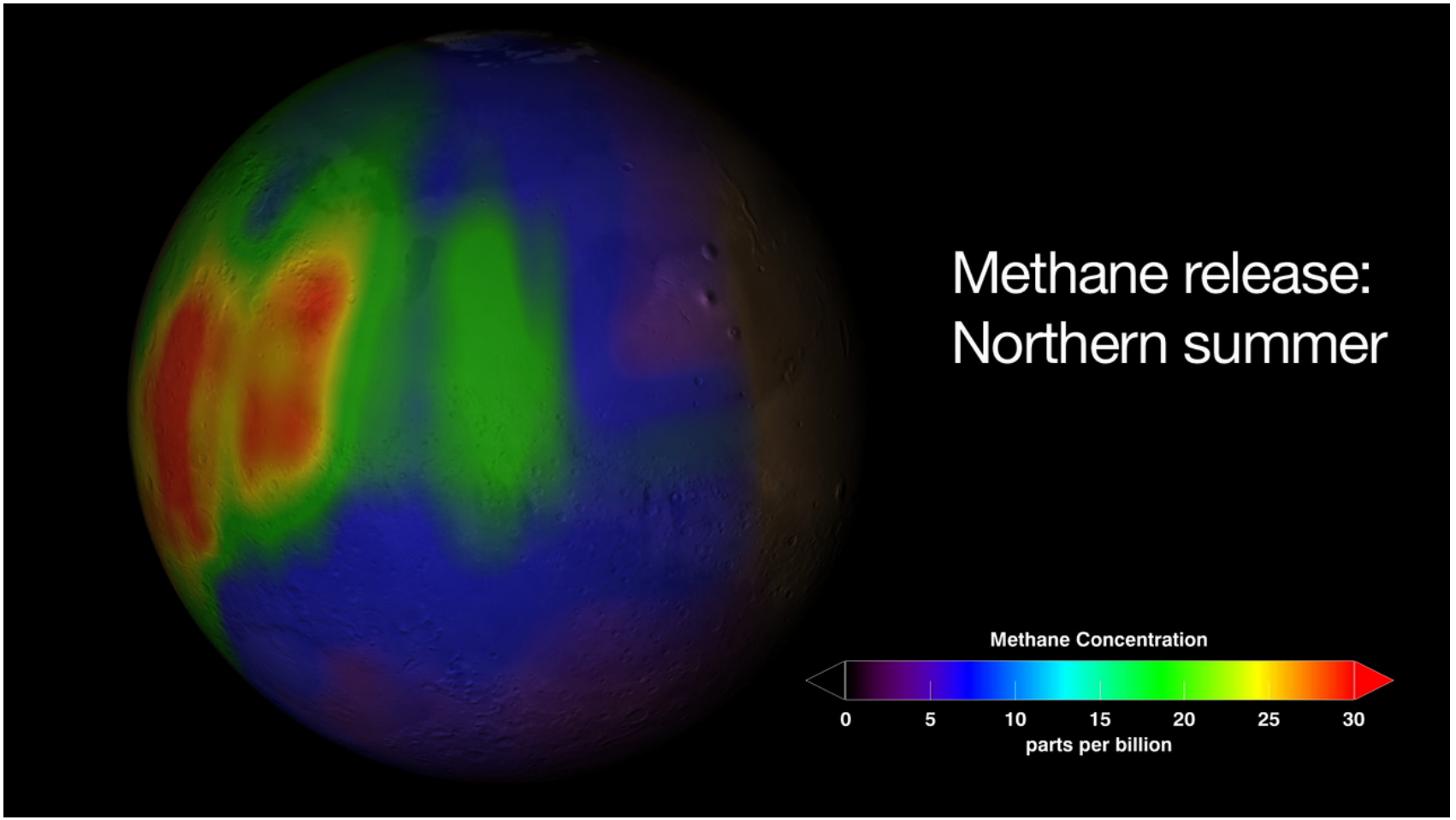


Does “Bigfoot” live on Mars??!

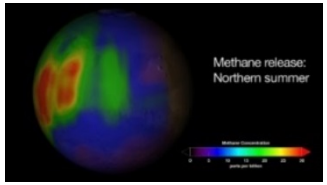
1967 - California

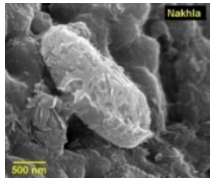
MER “Spirit” 2007 – Gusev Crater

Mars Express – methane discovery....so what?

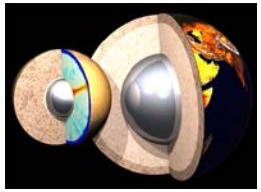


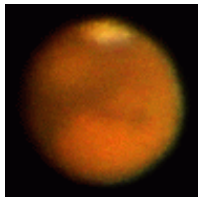
Using space contexts to teach the curriculum – examples using the planet Mars

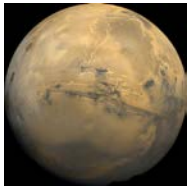


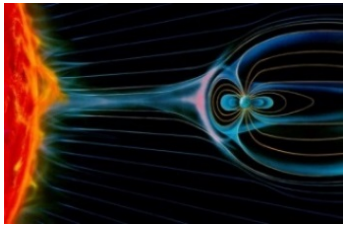


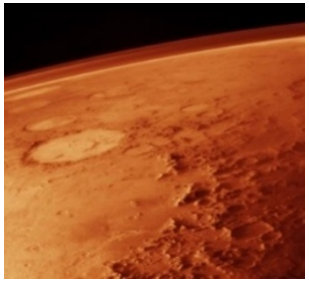
- Newton's Laws and Rocketry
- Gravitational field theory
- Atmospheric physics and ideal/non-ideal gases ($pV=NkT$, $P = P_0e^{-(mgh/kt)}$)
- EM fields and radiation
- Interaction of charged particles with magnetic fields
- Radioactive decay and cosmic rays
- Origins of magnetic fields

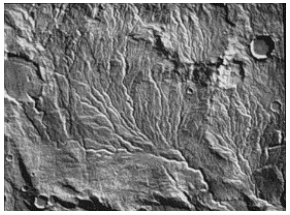


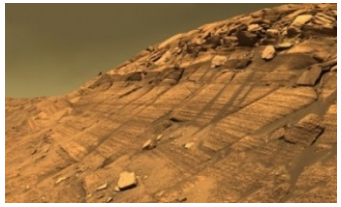


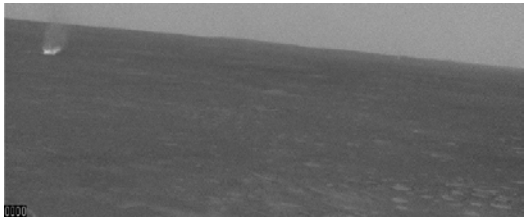


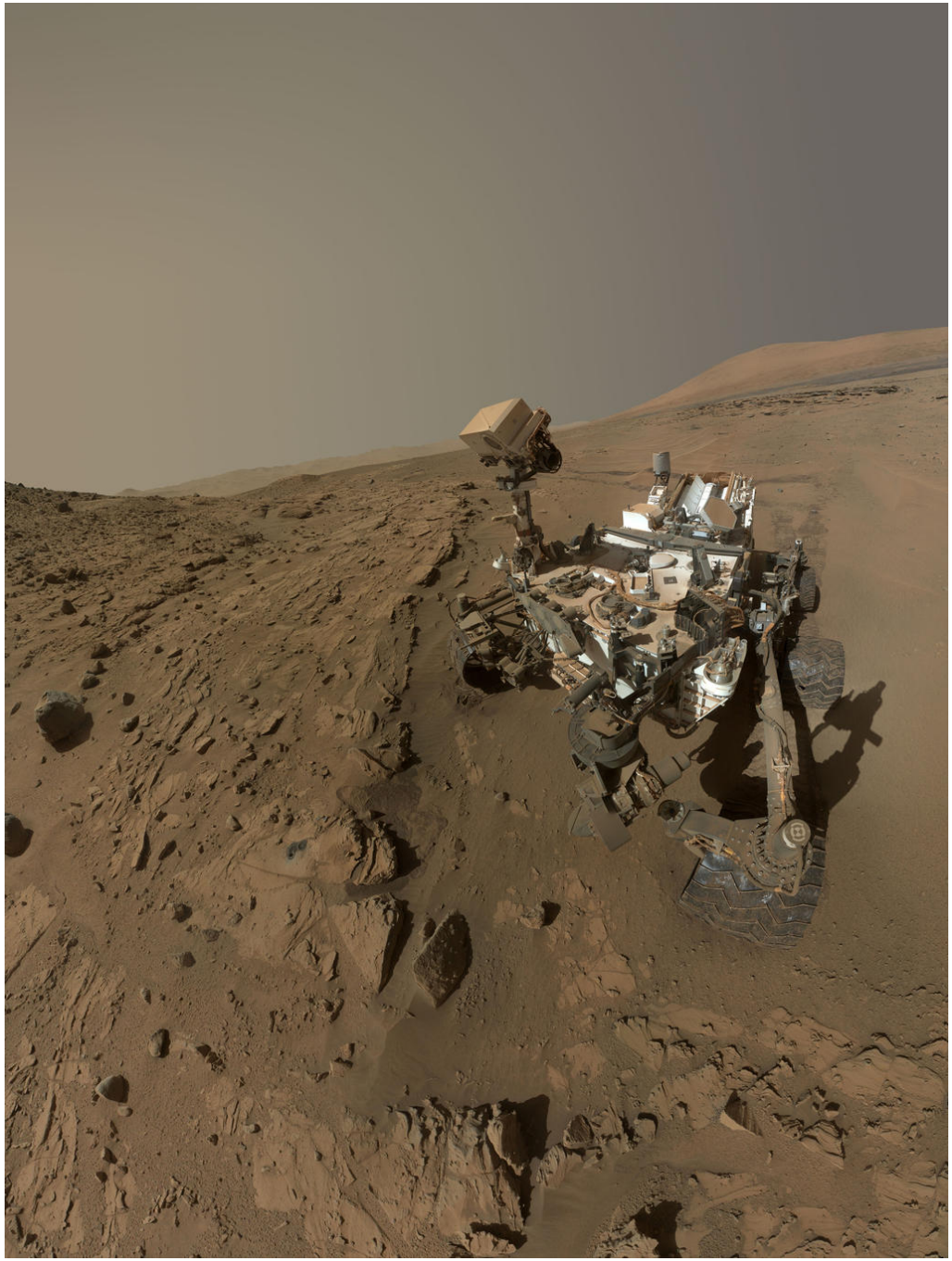












MSL (Curiosity”) in Gale Crater, 2016

An Update from Mars

Professor John Bridges
Space Research Centre
Dept. of Physics & Astronomy

UNIVERSITY OF LEICESTER

40 years ago – Viking 1,2 Landers & Orbiters

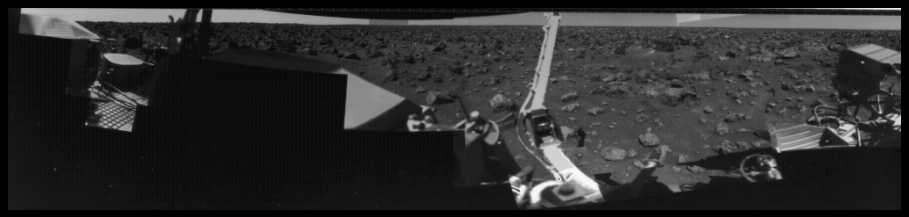
Before Viking we didn't know …

- ***Accurate atmospheric composition***
- ***Martian meteorites***
- ***Landing sites***
- ***Sedimentary rocks or basalts?***
- ***Differentiated igneous crust?***
- ***Has there ever been life?***

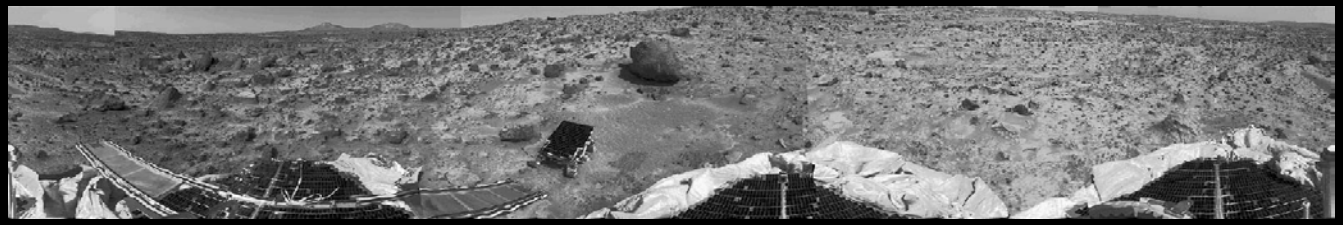
Viking Mosaic 1982
8-300m/pixel

40 years ago – Viking 1,2 Landers & Orbiters

1976, Viking 1 Chryse Planitia

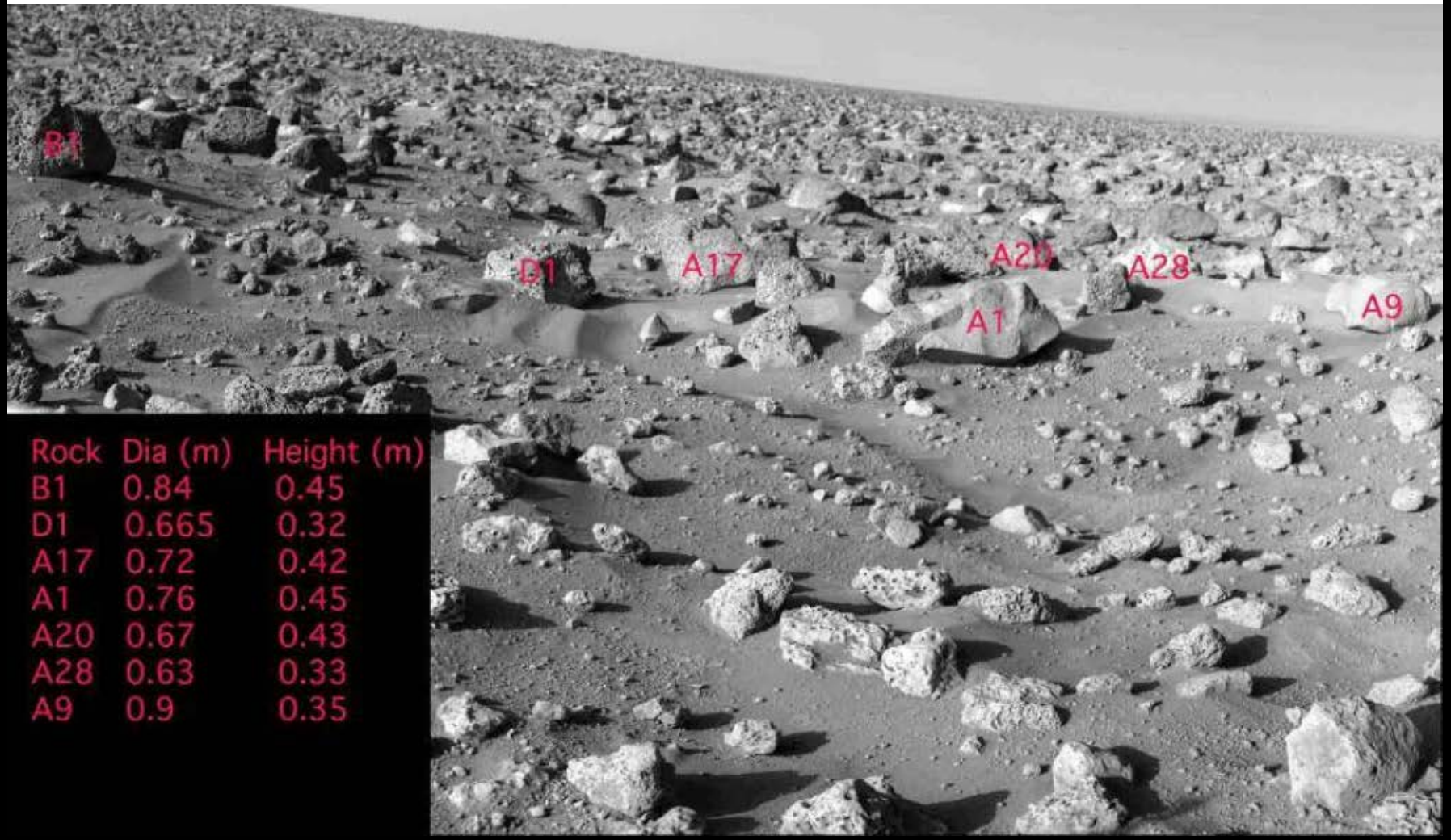


1976, Viking 2 Utopia Planitia



1997, Pathfinder Ares Vallis (Chryse)

Viking 2 Landing Site - basalts?

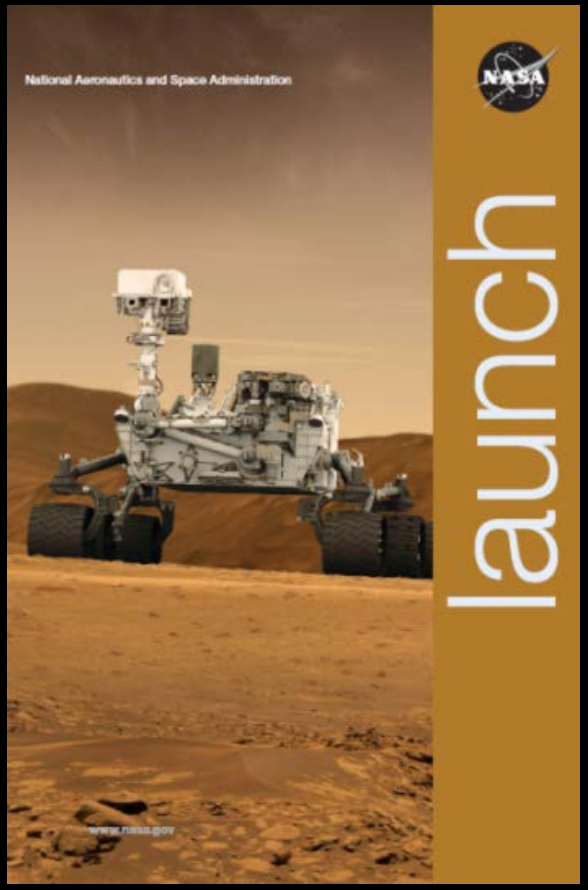


Rock	Dia (m)	Height (m)
B1	0.84	0.45
D1	0.665	0.32
A17	0.72	0.42
A1	0.76	0.45
A20	0.67	0.43
A28	0.63	0.33
A9	0.9	0.35

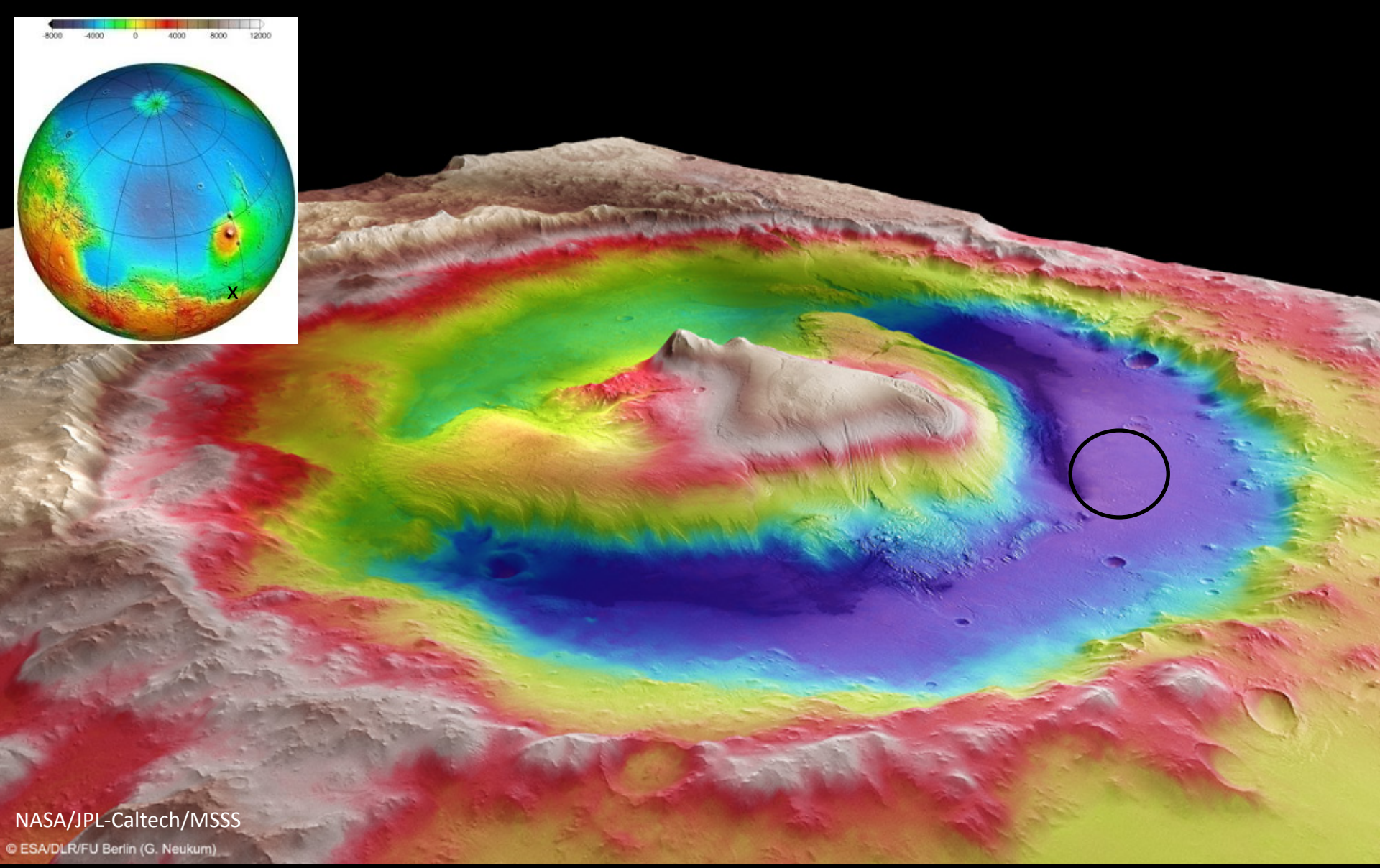
Viking Orbiter images of fluvial channels

Hints of a warmer, wetter past…

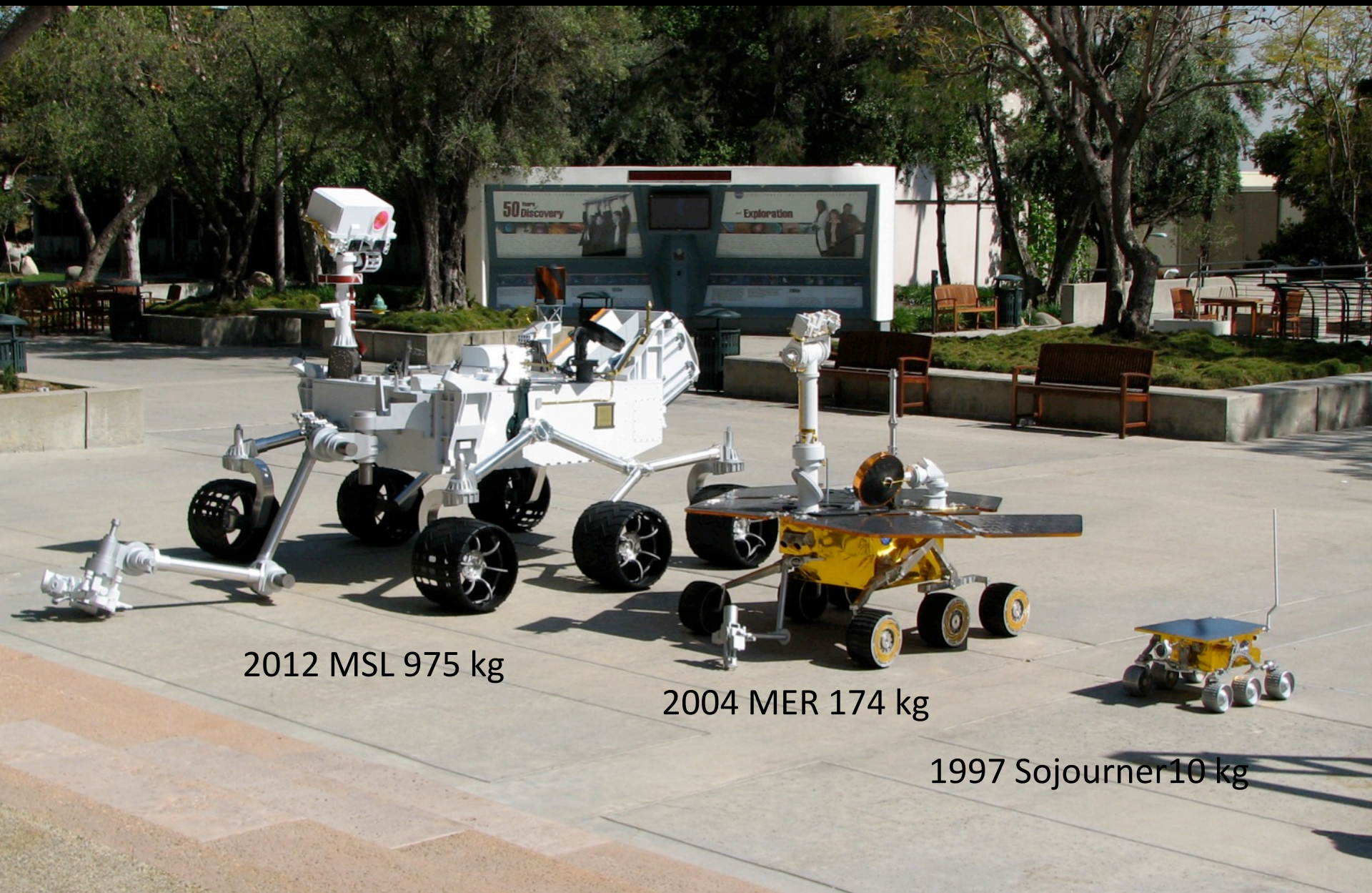
2011 Mars Science Laboratory Launch…

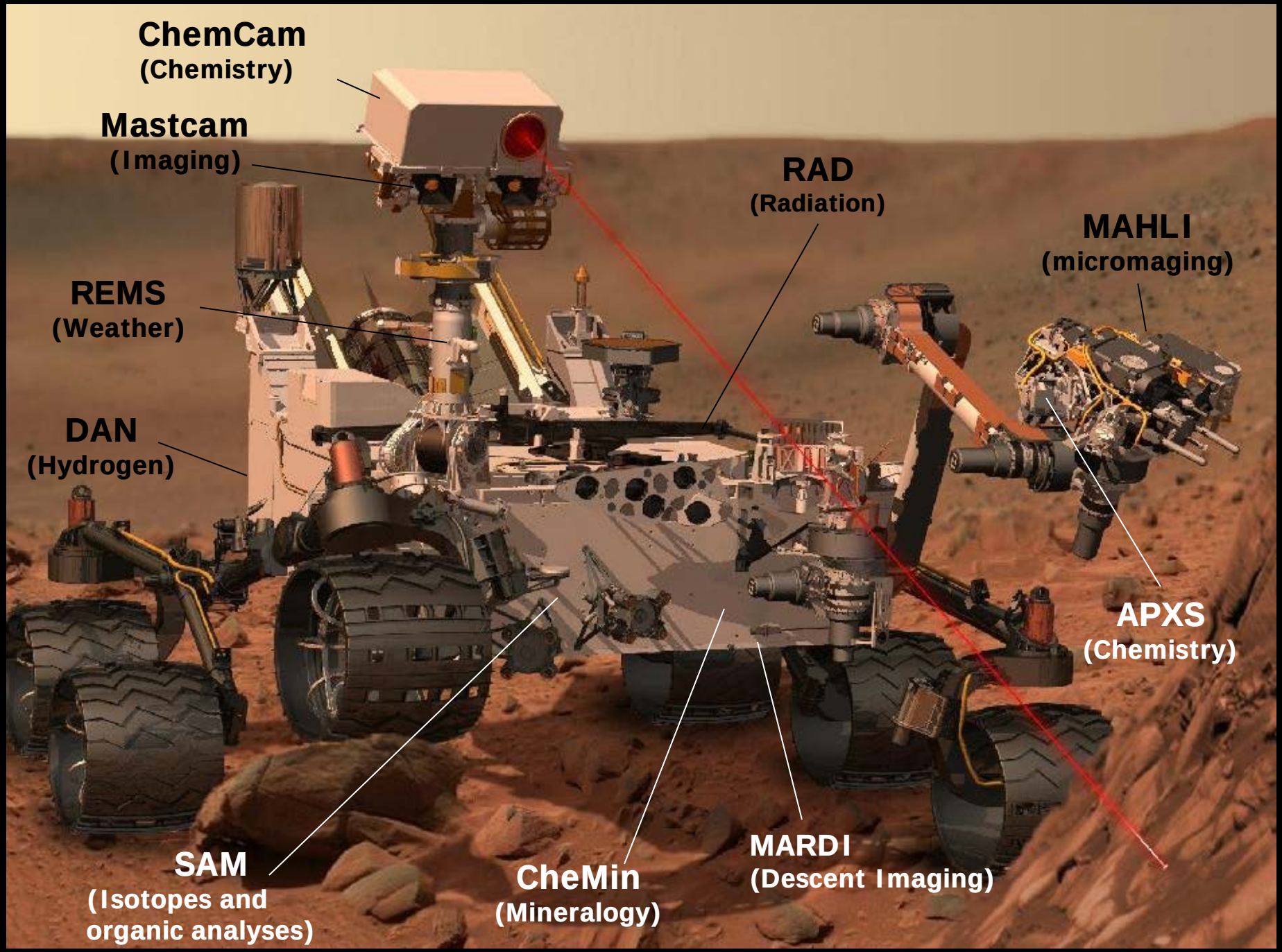


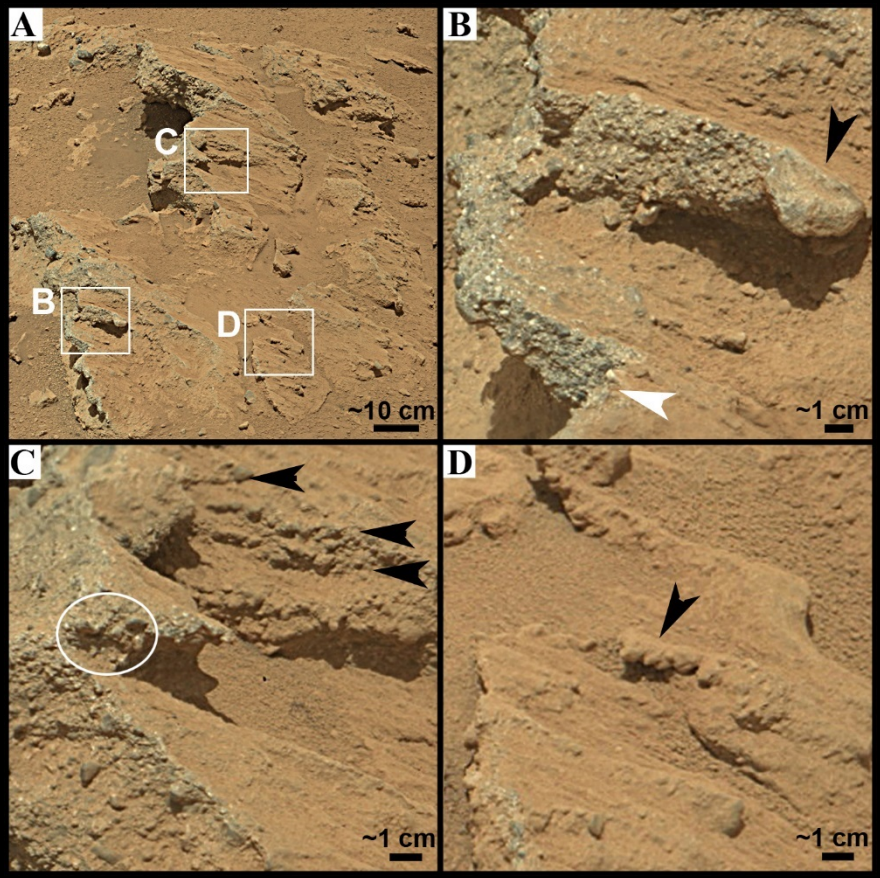
Launch on Atlas V 541, Nov. 2011
Cape Canaveral


-8000
-4000
0
4000
8000
12000
X
NASA/JPL-Caltech/MSSS
© ESA/DLR/FU Berlin (G. Neukum)

Three Rover Generations




ChemCam
(Chemistry)
Mastcam
(Imaging)
RAD
(Radiation)
MAHLI
(micromaging)
REMS
(Weather)
DAN
(Hydrogen)
APXS
(Chemistry)
SAM
(Isotopes and
organic analyses)
CheMin
(Mineralogy)
MARDI
(Descent Imaging)



Hottah Facies v.
Atacama conglomerate – river pebble beds

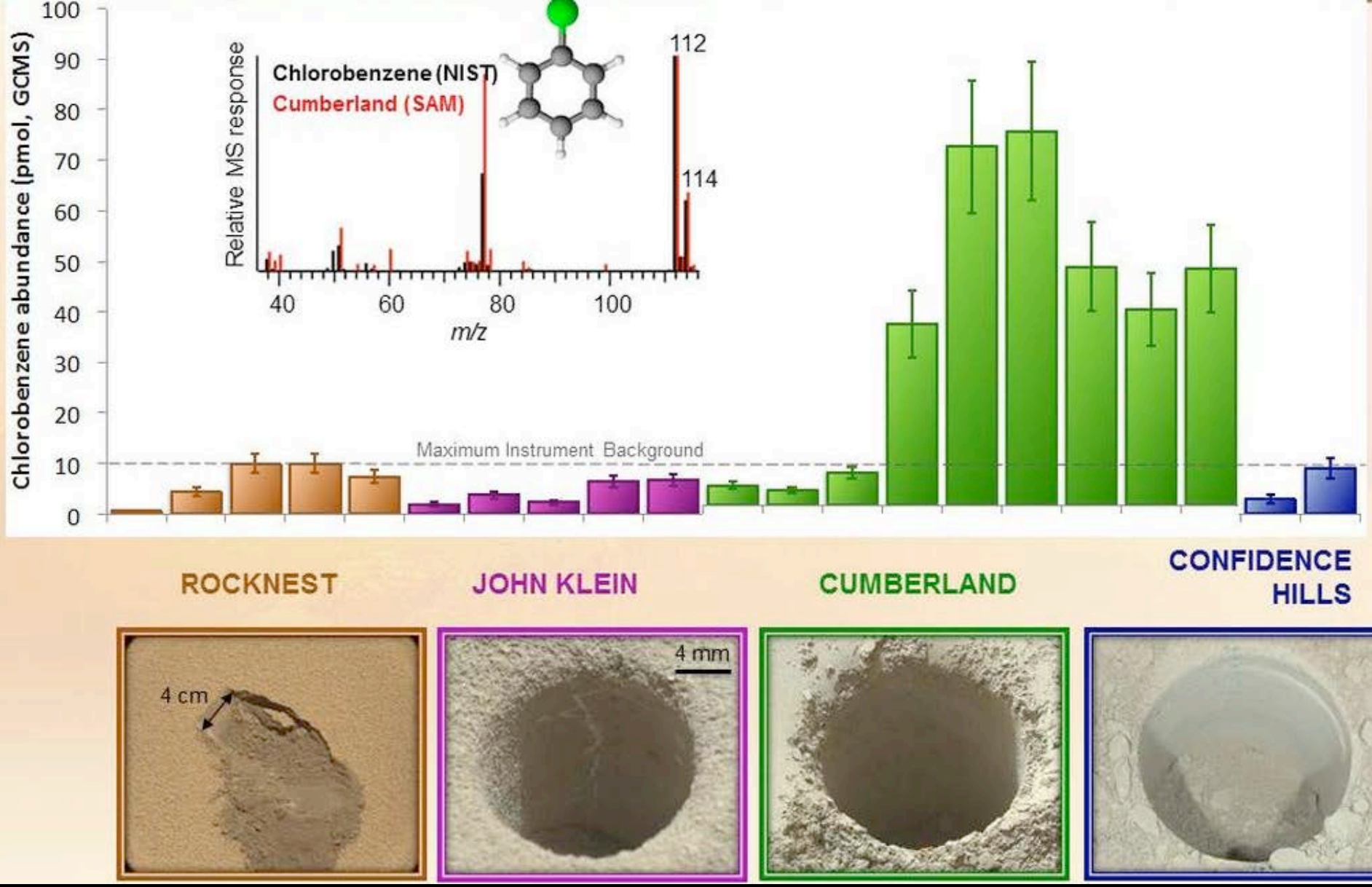
NASA/JPL-Caltech/LANL/CNES/IRAP/LPGNantes/CNRS/IAS/MSSS

Large feldspar-rich crystals in an igneous clast: feldspar-rich ancient continental crust

CURIOSITY

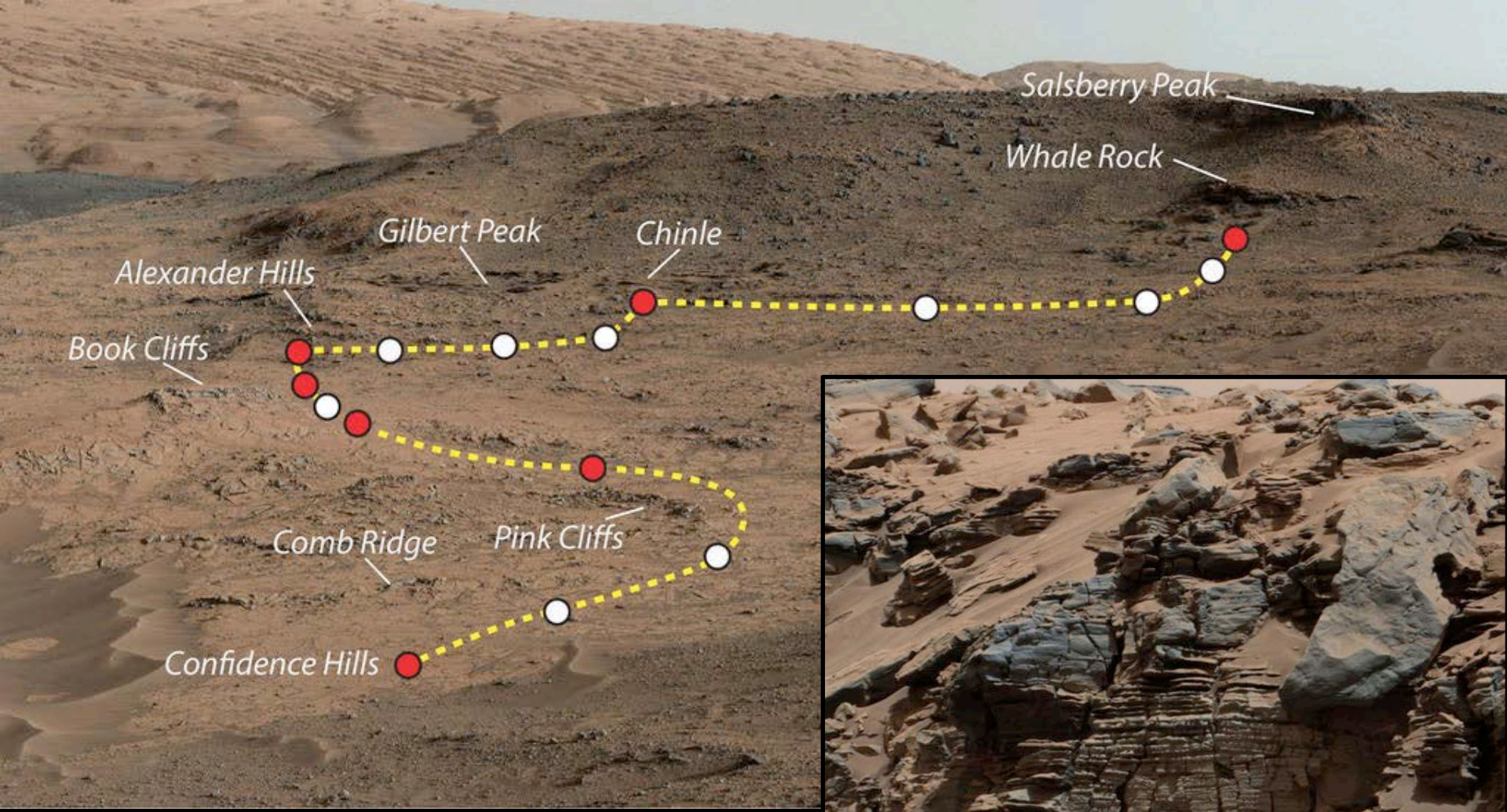
NASA/JPL-Caltech/D. Bouic

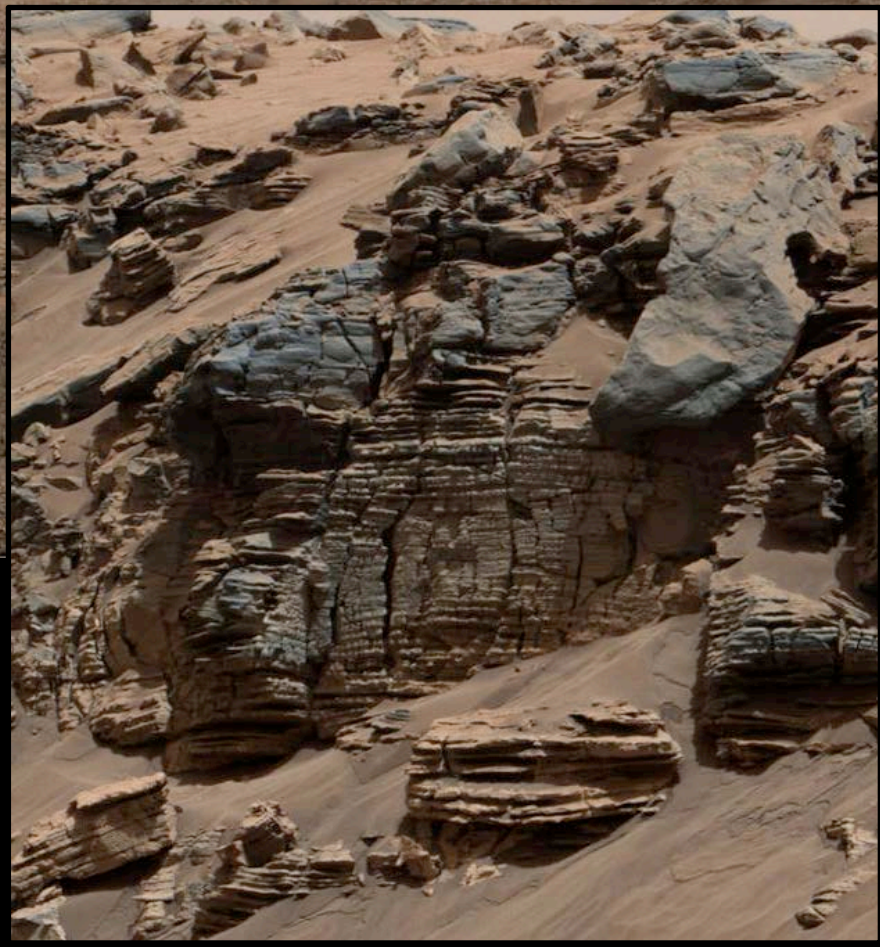
Curiosity at Work: Arm deployed at John Klein – drilling

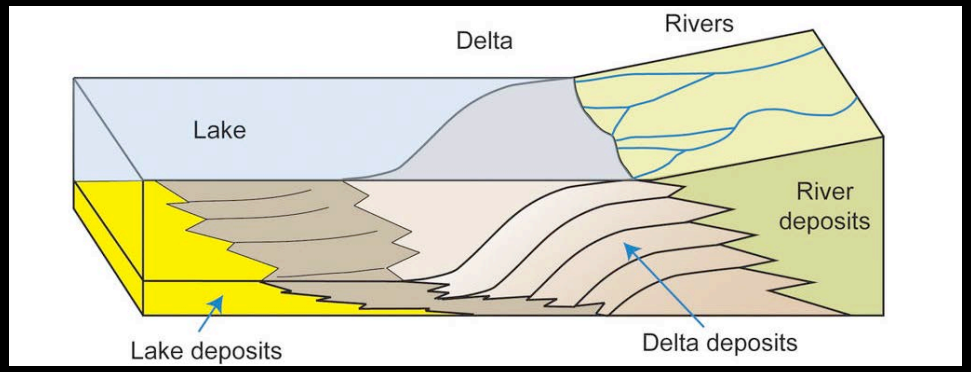


Benzene organics were detected in the Cumberland drilled sample

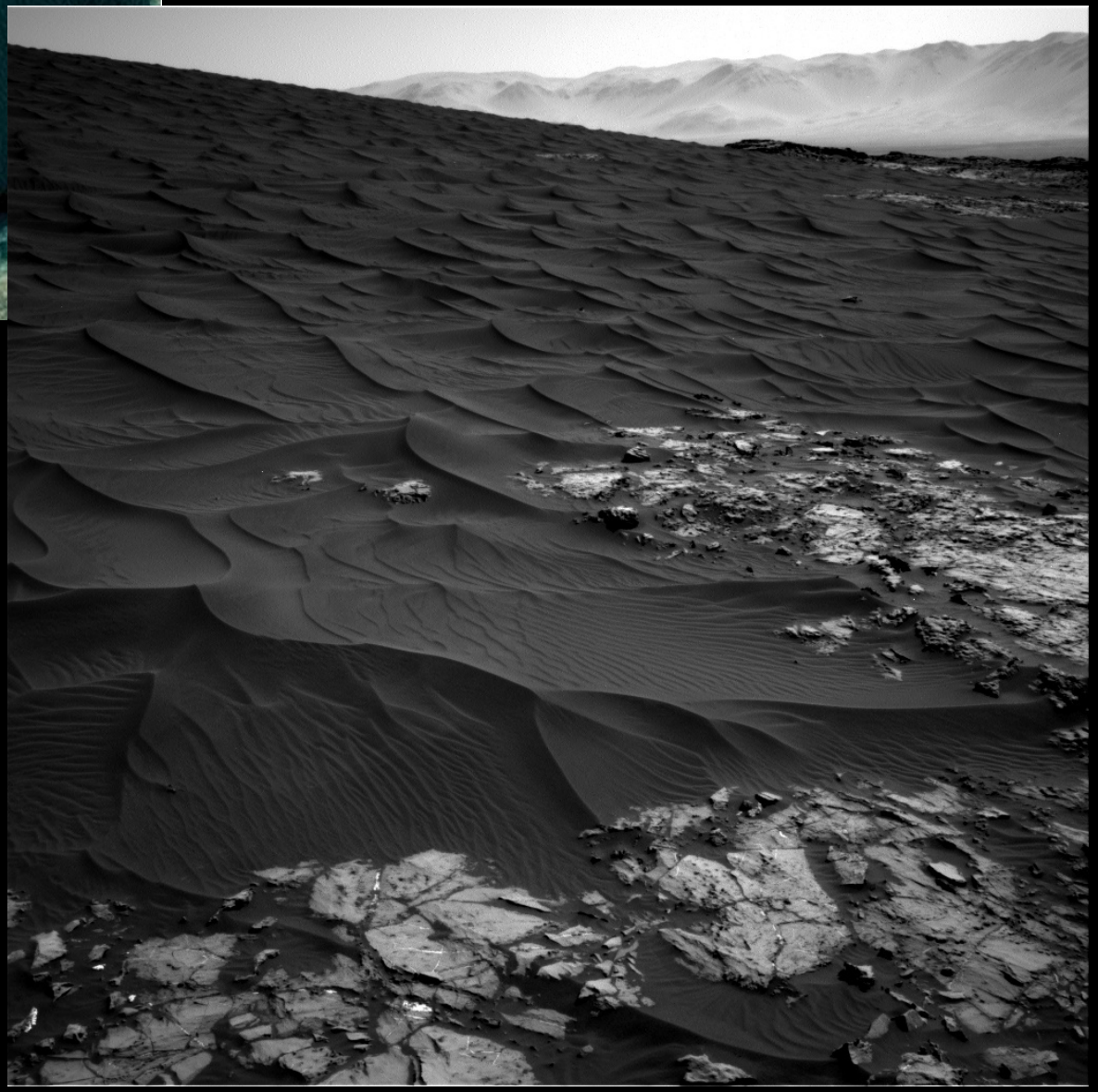
CURIOSITY

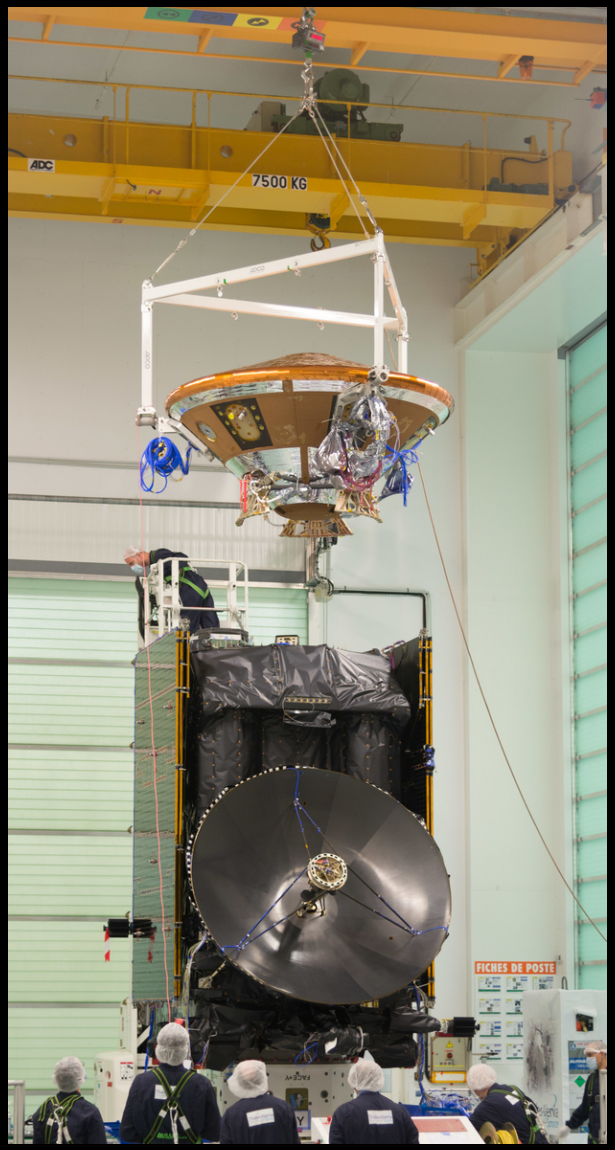

Salsberry Peak
Whale Rock
Gilbert Peak
Chinle
Alexander Hills
Book Cliffs
Comb Ridge
Pink Cliffs
Confidence Hills




Delta
Rivers
Lake
River deposits
Lake deposits
Delta deposits

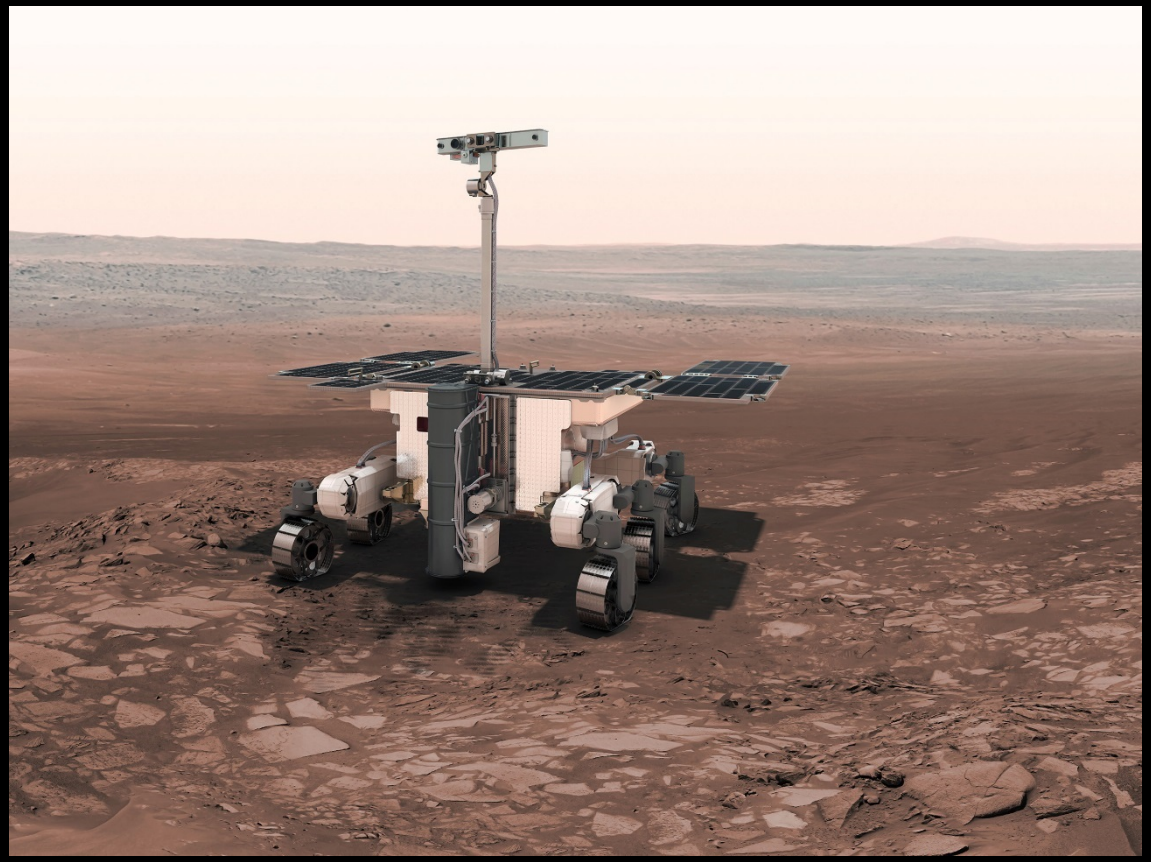
Bagnold Dunes
Sol 1248





ExoMars 2016

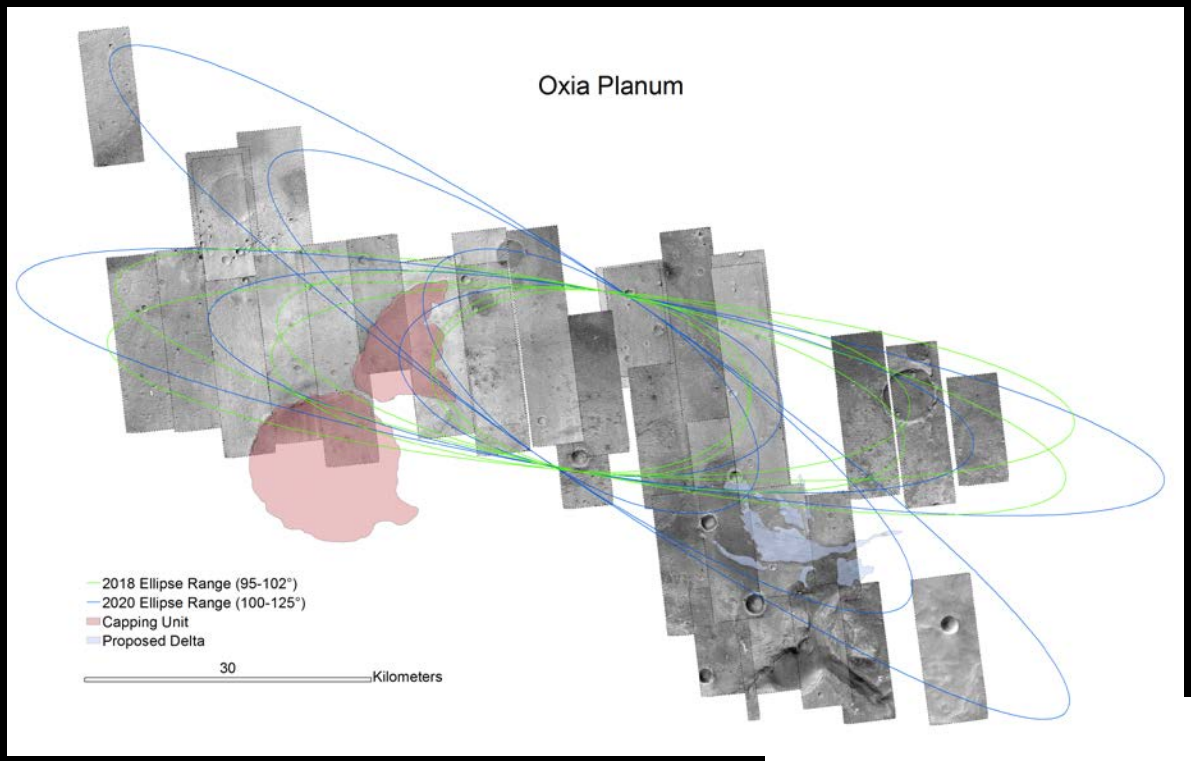
- Trace Gas Orbiter and Stereo Camera
- Entry Descent Module



ExoMars launch 2020

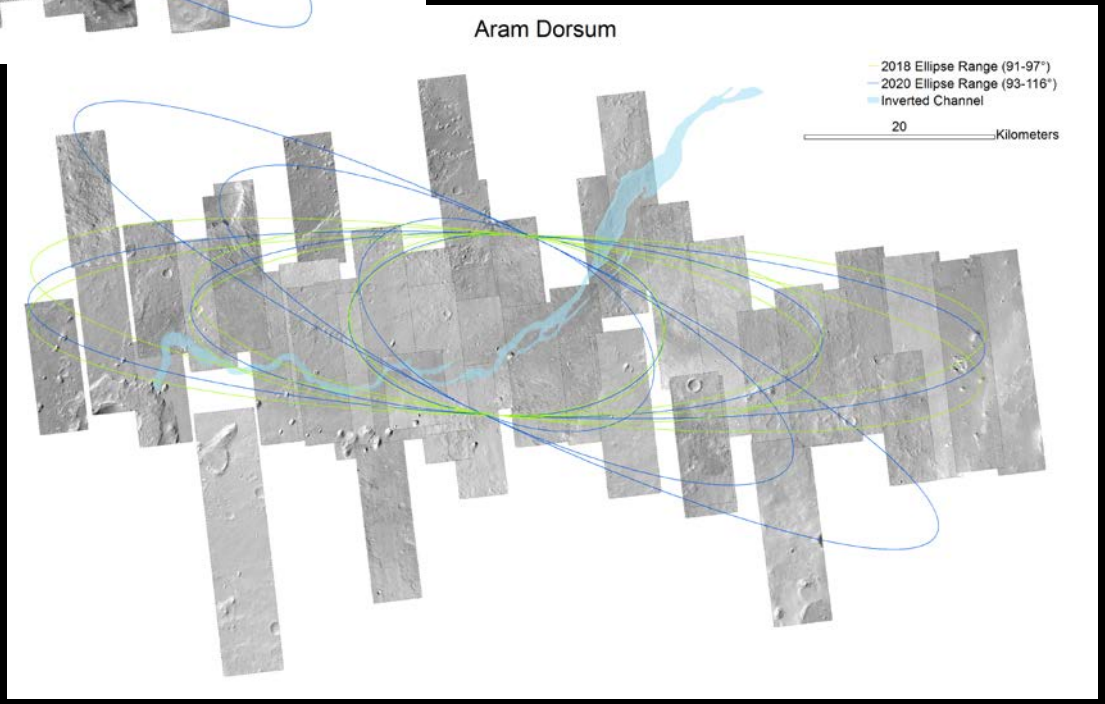
- Two metre drill
- Solar powered
- Mass spectrometer

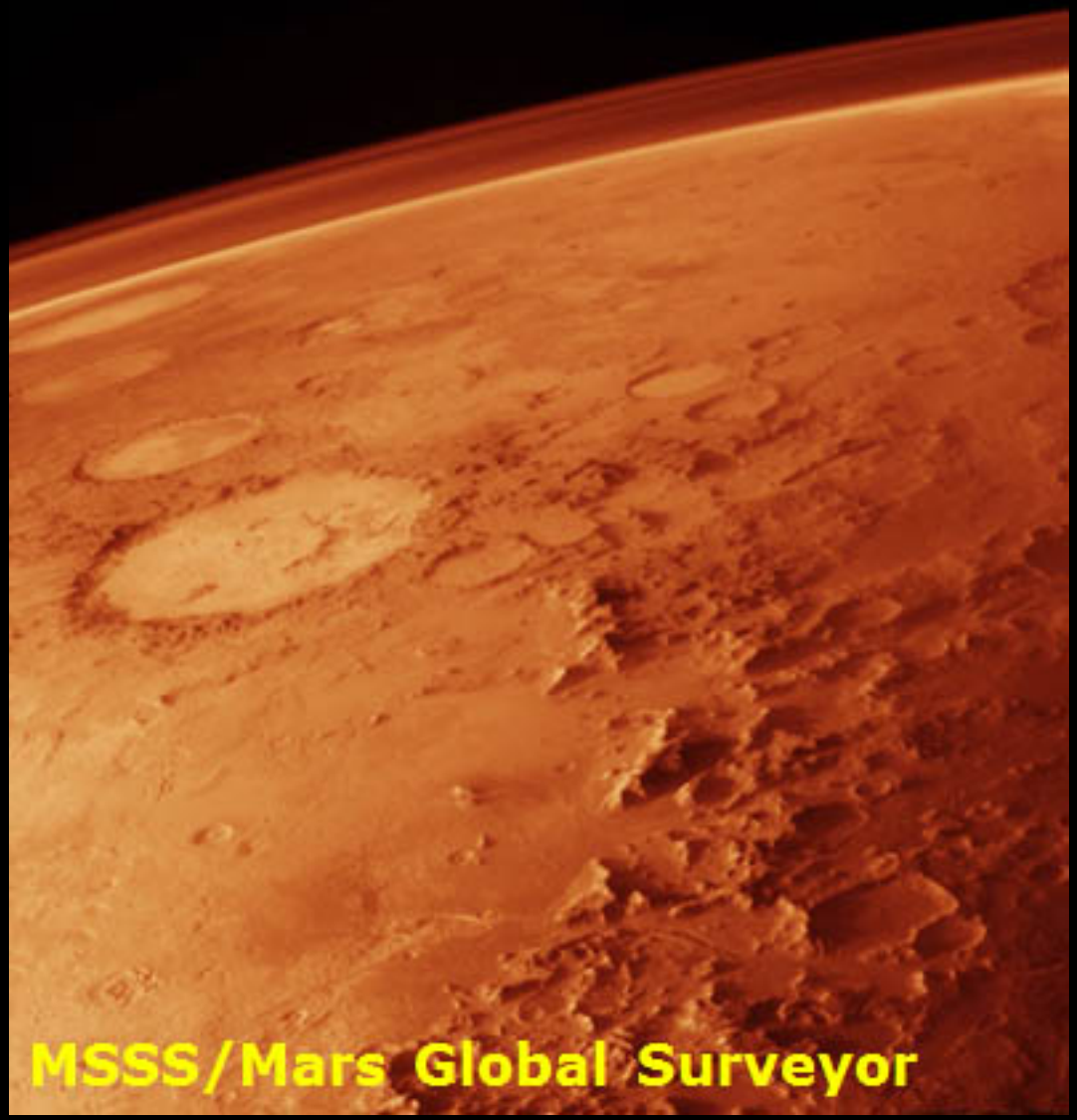
designed to search for signs of past life



HiRISE images of ExoMars landing sites

Henson et al. 2016



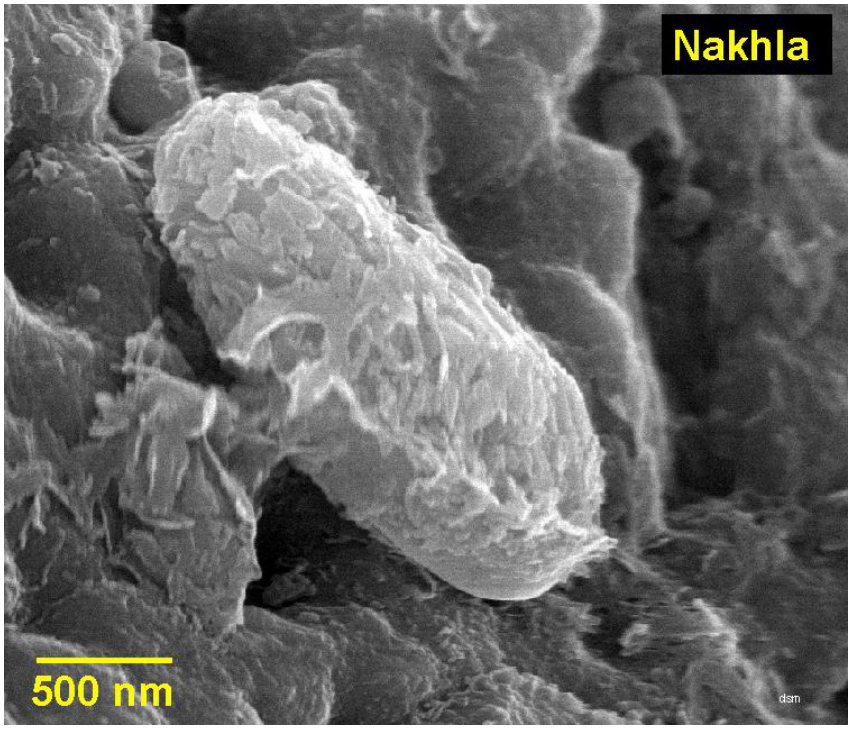


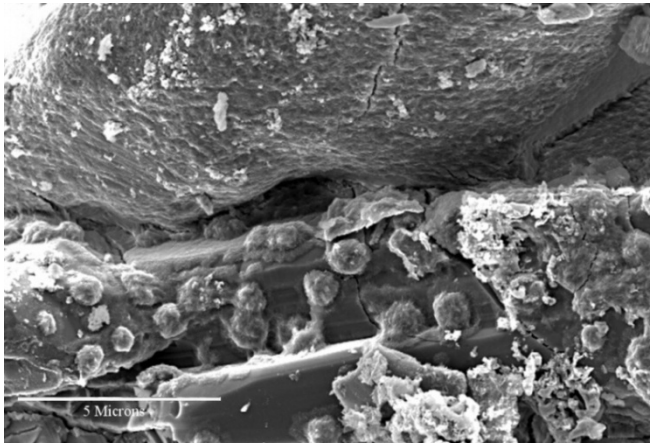
Our View of Mars has Changed

- Differentiated crust – not just basalts
- Mars is a world of ancient deltas, rivers, rainfall
  - Was there great chemical weathering associated with clay in Mt Sharp?
- Mars was habitable then great atmospheric loss

Future Missions: Mars2020 (sample caching), ExoMars 2020

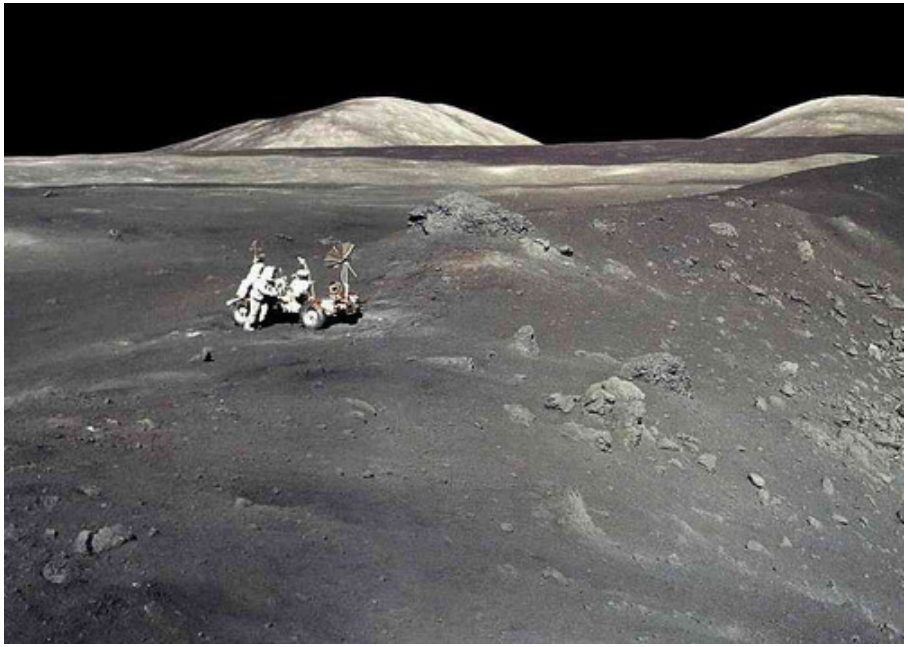
Mars.....on Earth!



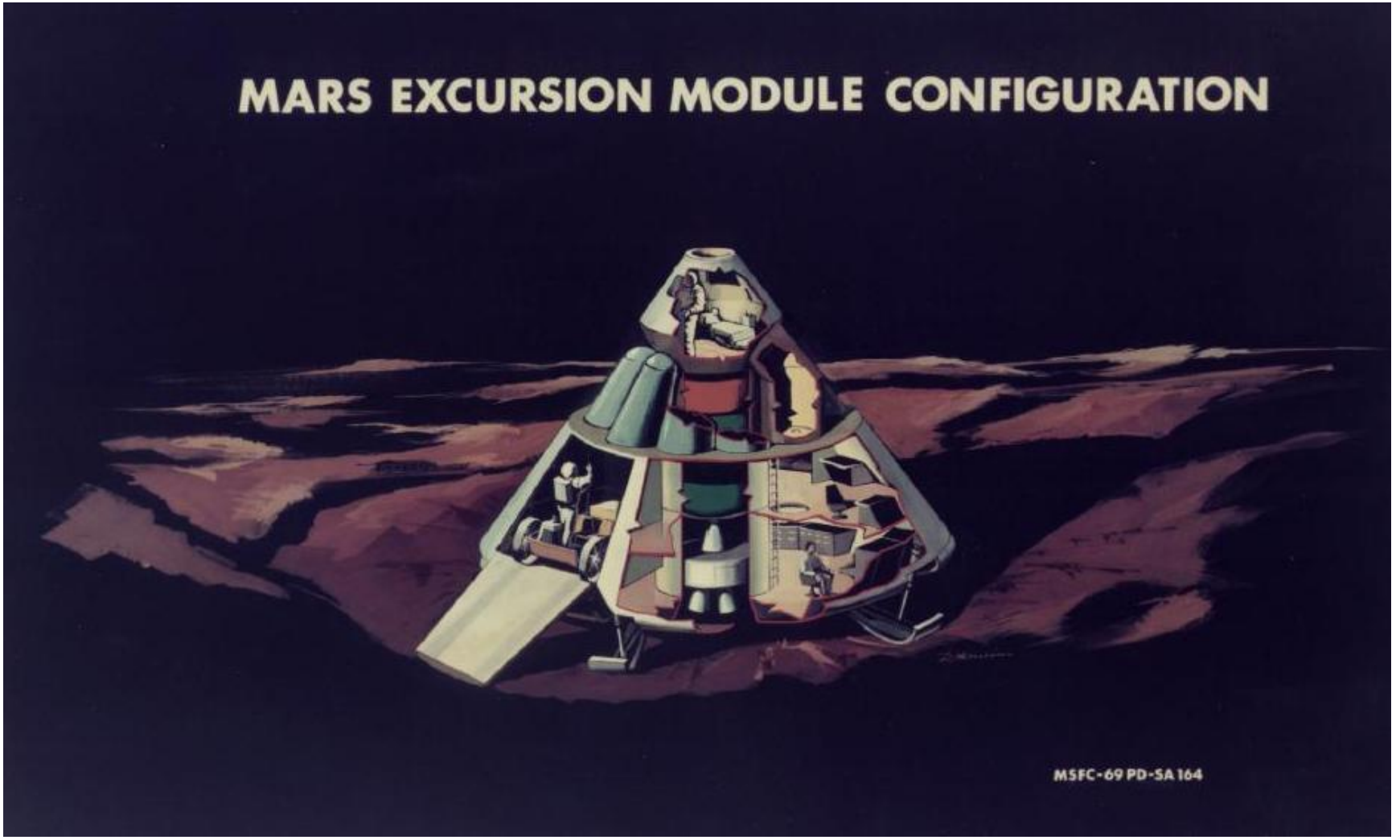


- Nearly 100 meteorites confirmed as Martian in origin
- The story of Nakhla – how do we know?

So why send humans at all?

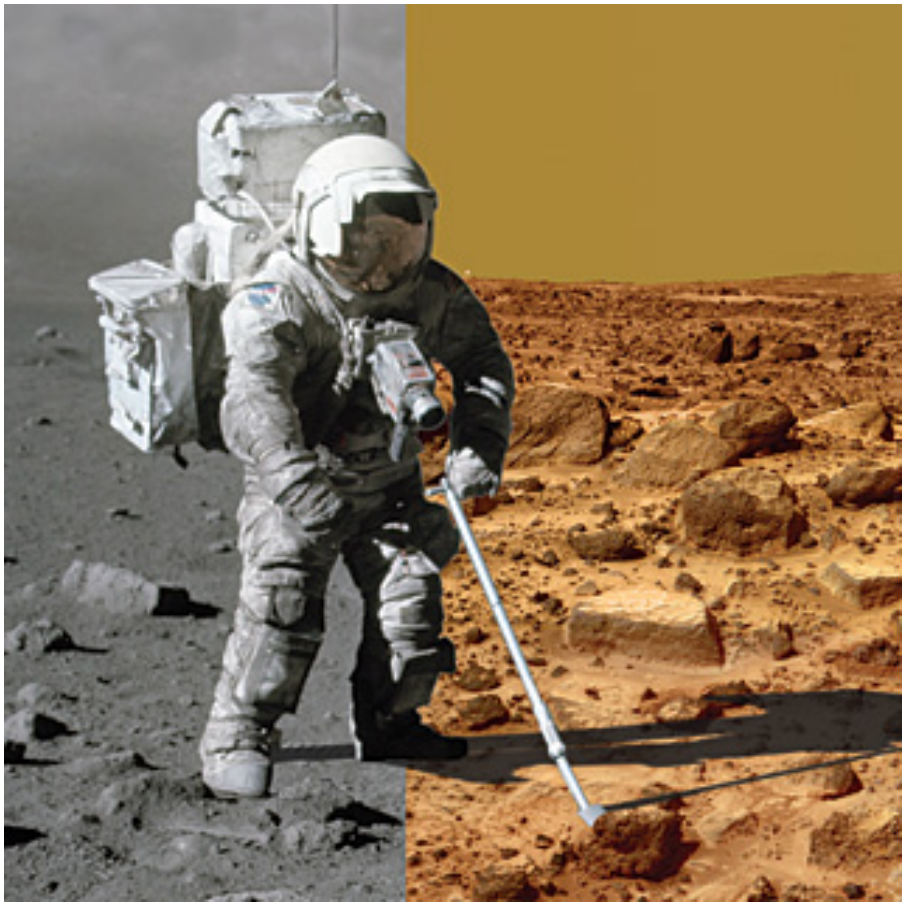


MARS EXCURSION MODULE CONFIGURATION



MSFC-69 PD-SA 164

When will this become reality?



1972- Dr Harrison Schmitt

2030 -??