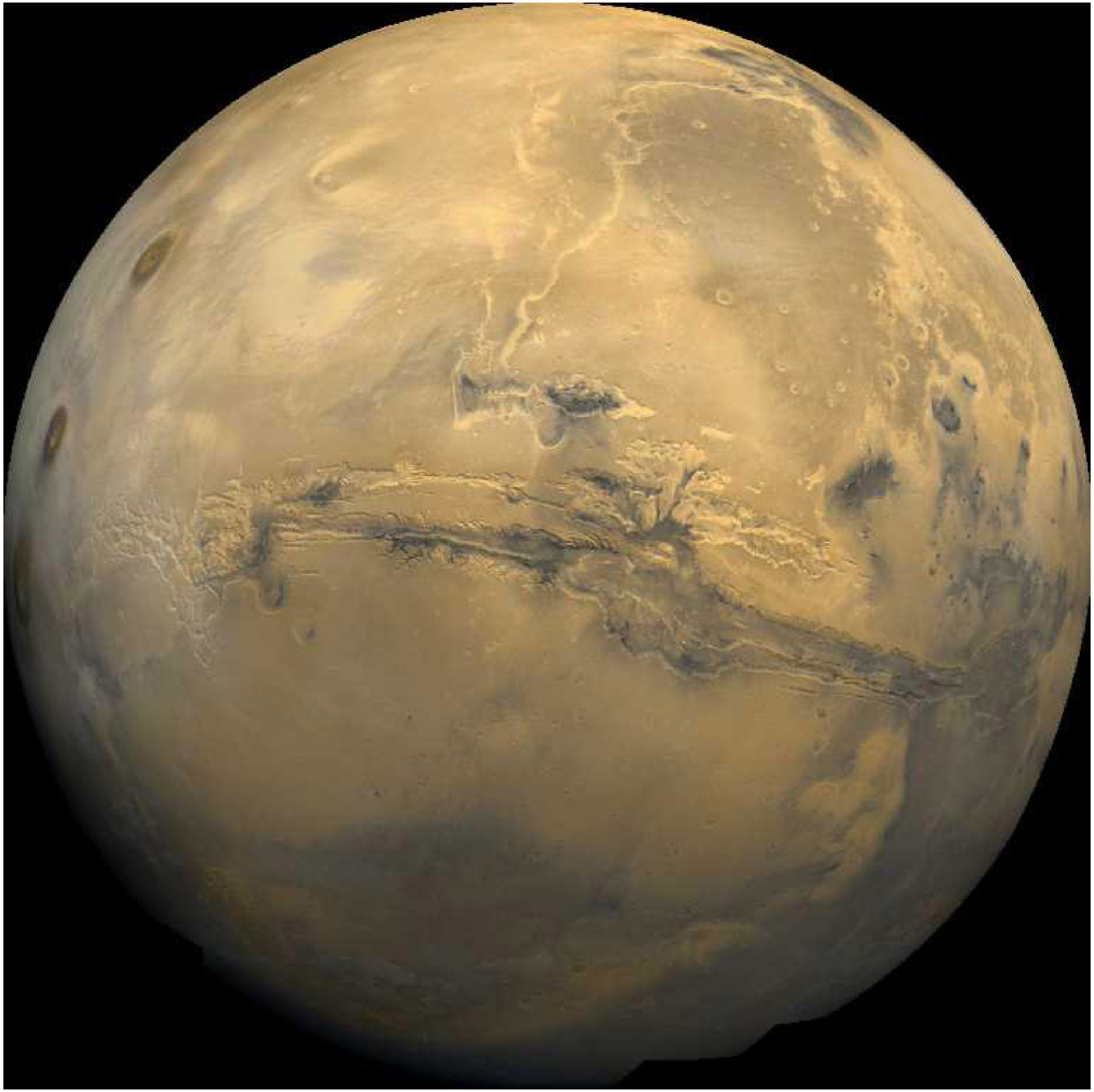
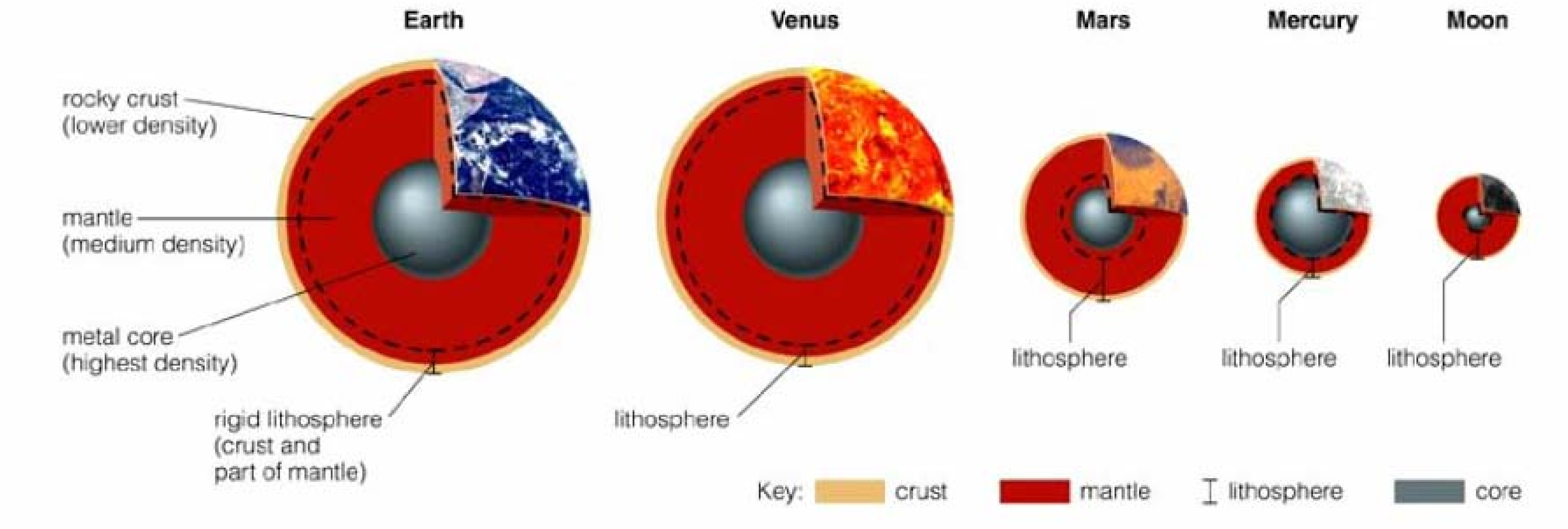
ASTRO710B – GEO710B: Mars – From interior to its moons



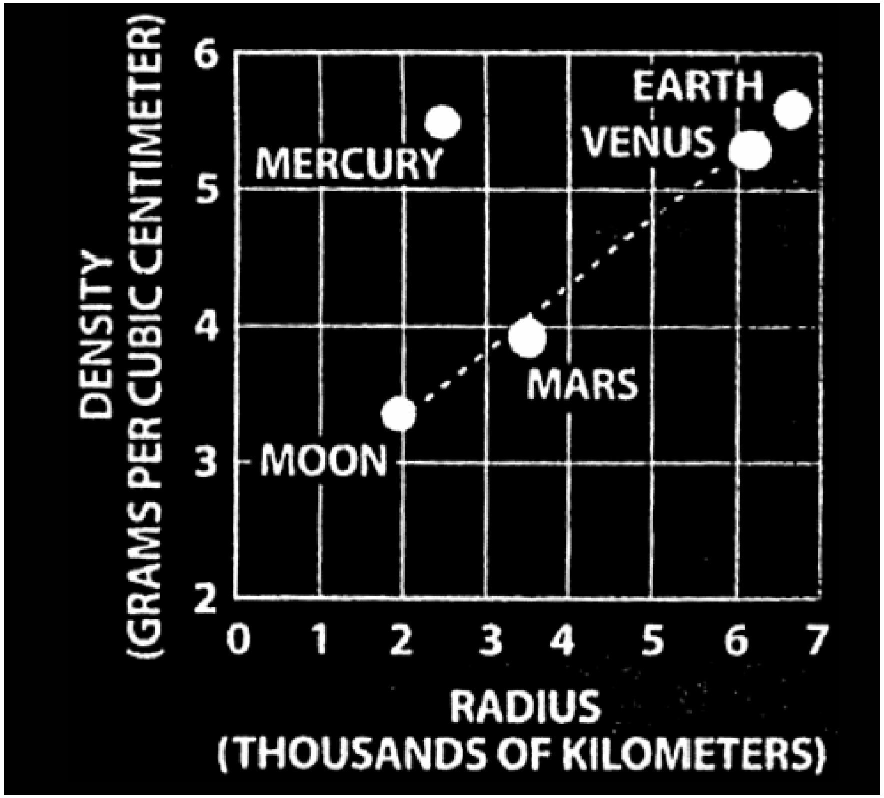
Physical properties of solid Mars (i)



Mars, like the other rocky planets, is likely differentiated into silicates & metals.

It has a single global crust (no plates) & a thick mantle, perhaps with hot plumes. A large metallic core made of Fe with a light element (S likely) has likely cooled based on the absence of a large magnetic field.

Physical properties of solid Mars (ii)



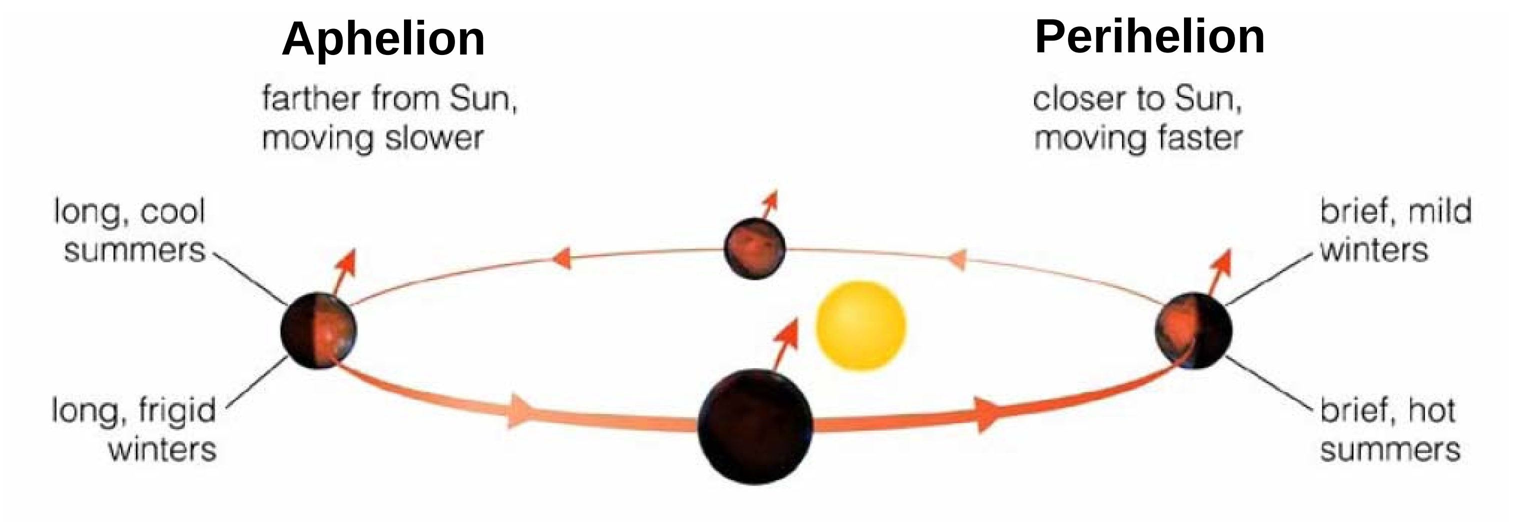
	Value	Comments
Radius	3,397 km	0.53 R_{Earth}
Mass	6.42×10^{23} kg	~11% M_{Earth}
Density	3.93 g/cm^3	< ρ_{Earth} ~ 5.5 g/cm^3
Gravity	3.71 m/s^2	0.38 g_{Earth}

Orbital characteristics of Mars

Mars orbits the Sun at ~1.52 AU
Its orbital period is 687 Earth days

Mars' spin axis is tilted relative to its orbital plane,
with an obliquity of 25.2º (Earth is 23.5º)
.... Mars has seasons

Mars' orbit is highly eccentric
    i.e. the distance varies greatly between perihelion & aphelion
        which accentuates the seasons

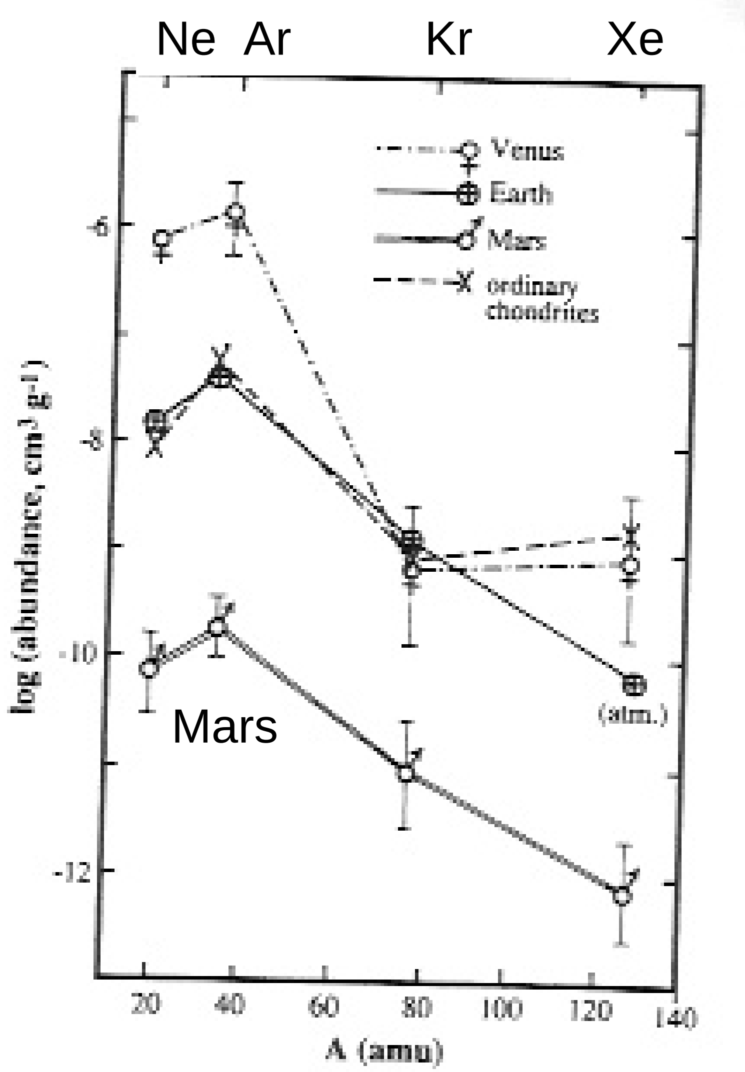


Mars' atmosphere

Mars has a very thin atmosphere with a global pressure of ~ 6 mbar

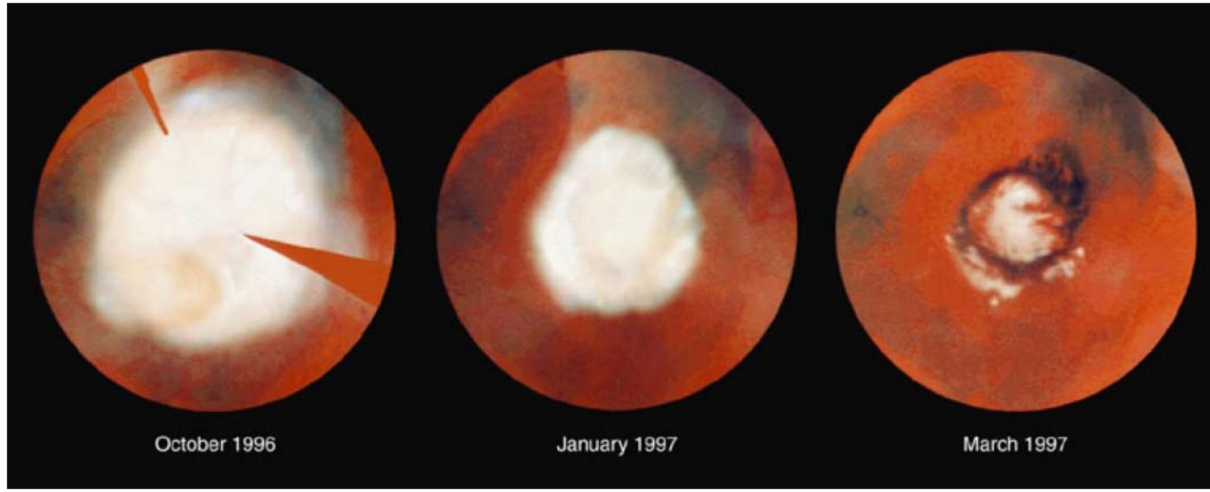
There is only one main atmospheric gas:

CO_2	**95.32%**
N_2	**2.70%**
Ar	**1.60%**
O2	**0.13%**
CO	**0.08%**
H2O	**0.03%-trace**



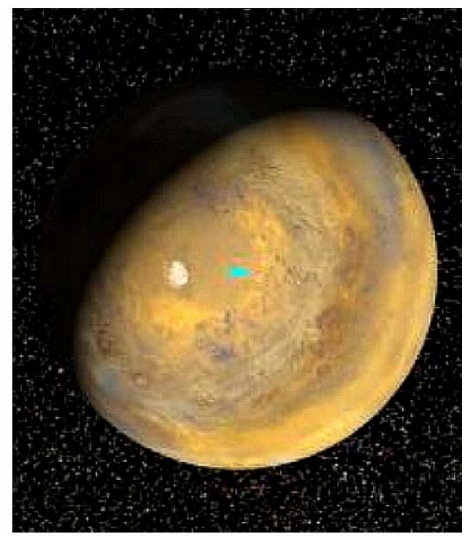
Seasonal changes on Mars

NORTH POLE -
Winter to summer
CO_2 polar cap receeds leaving residual H_2O polar cap



NASA HST

SOUTH POLE -
Winter to summer
Large CO_2 polar cap receeds, leaving CO_2 polar cap

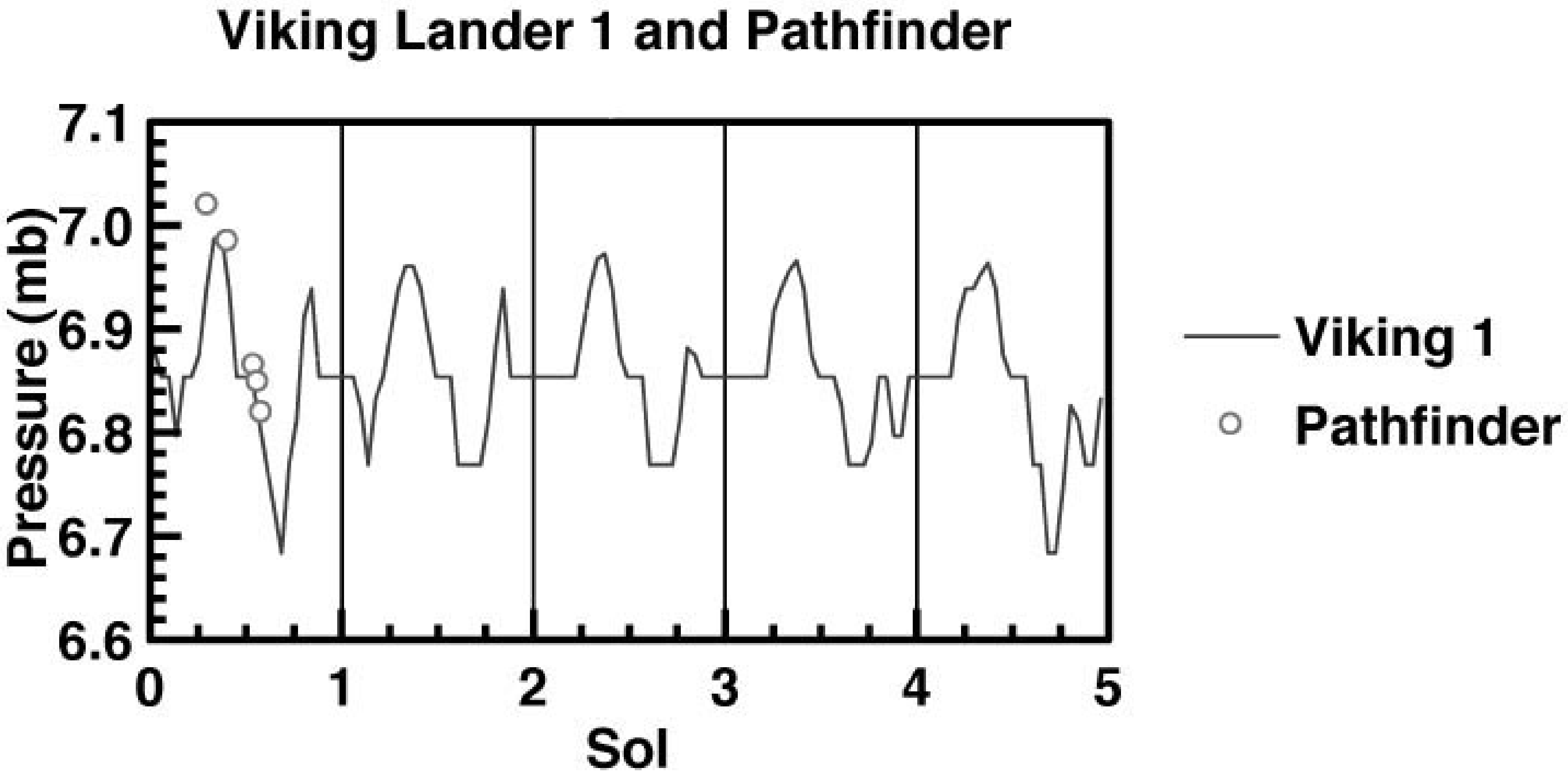


Transfer of CO_2 between north & south poles

NASA/JPL/MSSS

Daily variation in atmospheric pressure on Mars

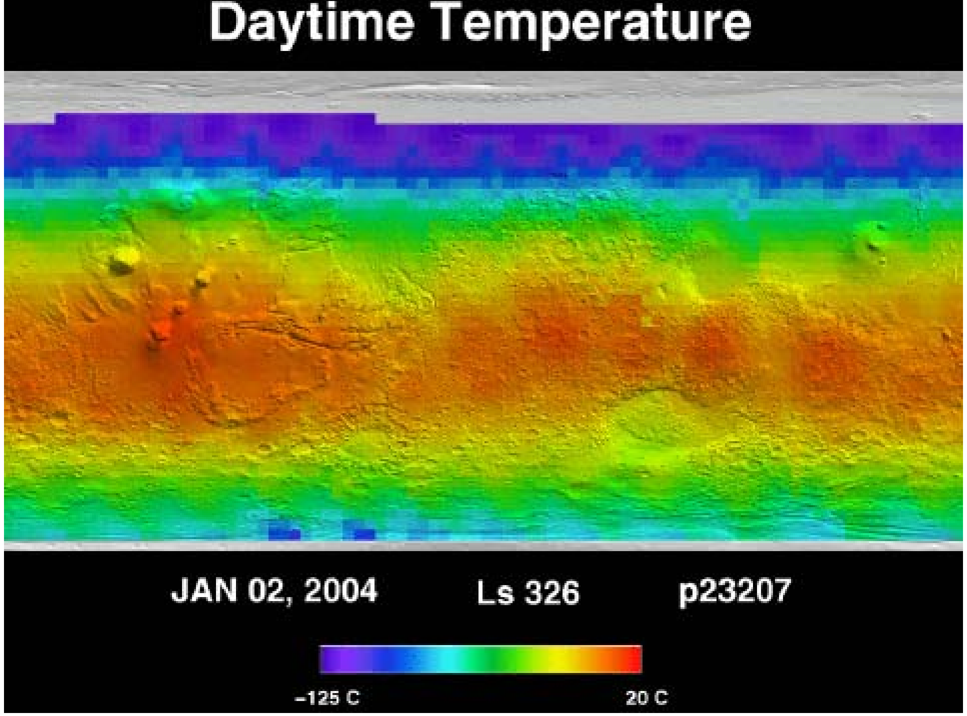
Thin atmosphere is CO_2-rich & ~6 - 7 mbar

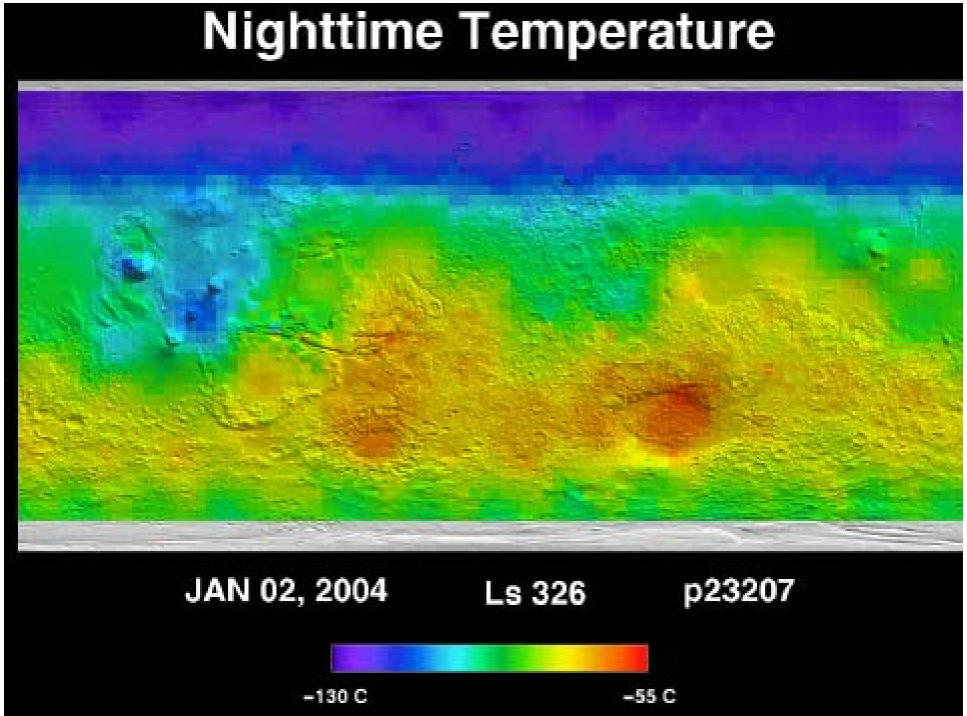


Daily variation in temperature on Mars

Average T ~ -60 deg. C
but T varies 150K to 290K

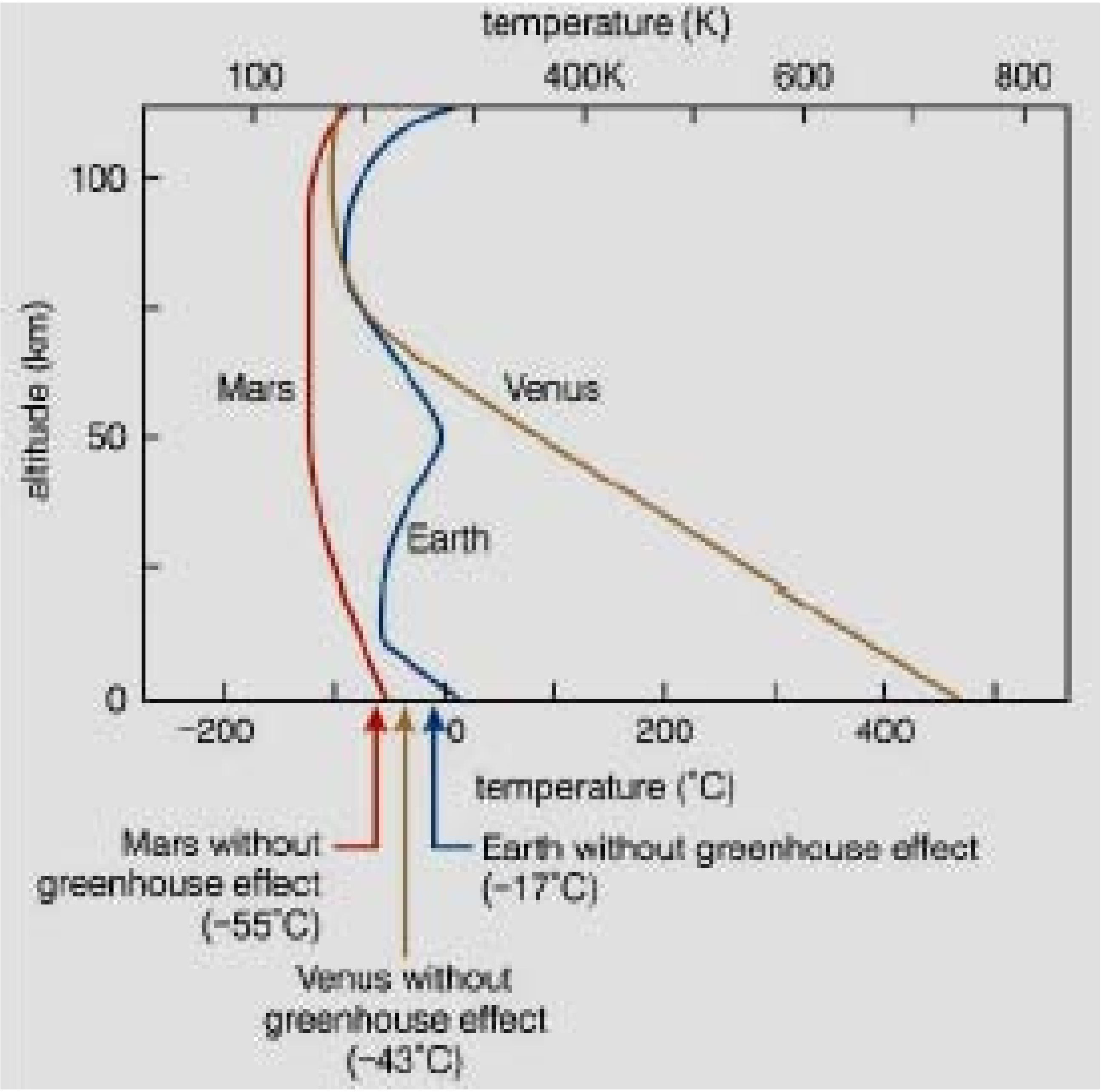
The large variations in temperature are (in part) due to the thin atmosphere that heats up & cools down quickly





Temperature of Mars' atmosphere

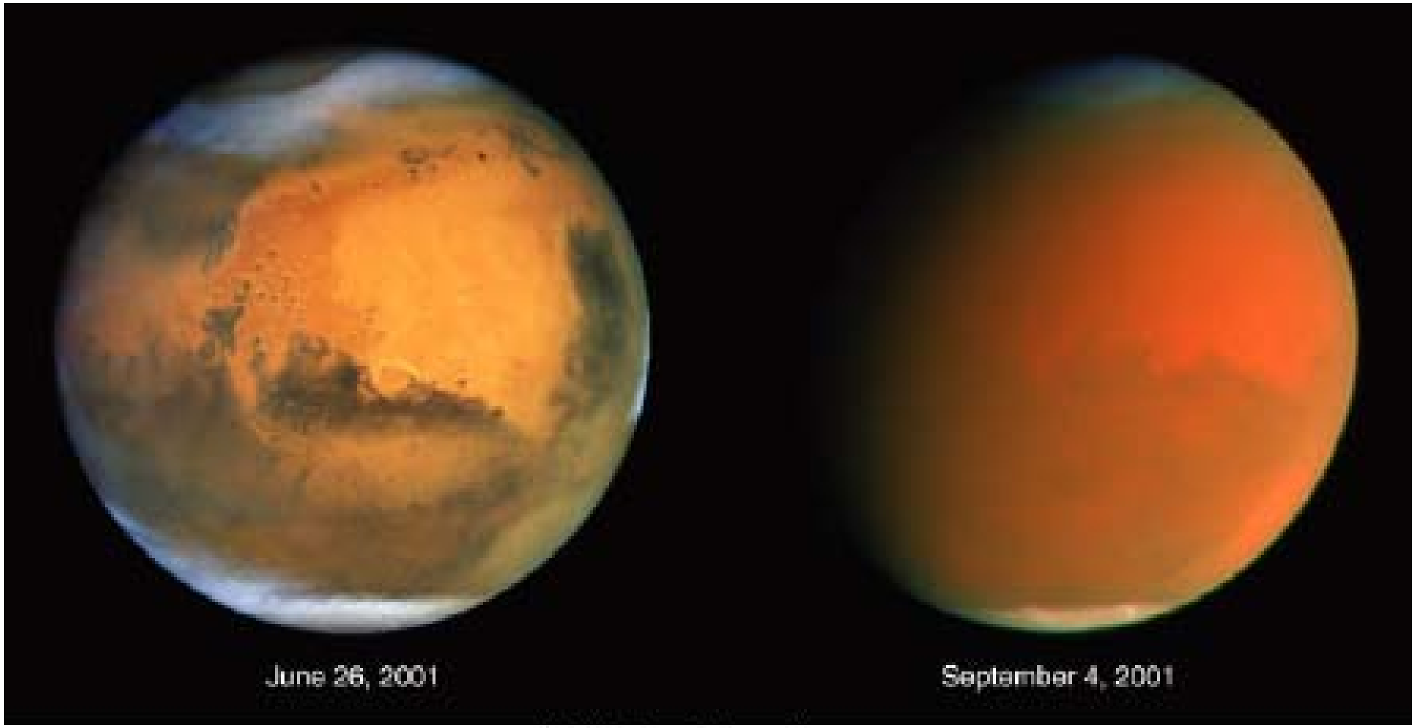
The greenhouse effect is very small on Mars (~5K) because it has a very thin atmosphere



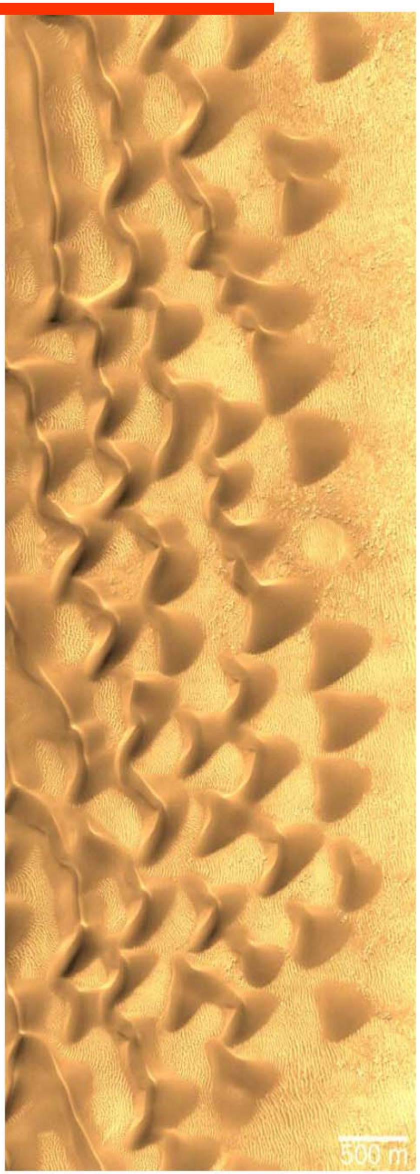
Martian wind & dust storms

Although atmospheric density is low, winds may reach up to 100-150 mph on Mars. There is sufficient dynamic pressure to move dust to sand-sized particles.

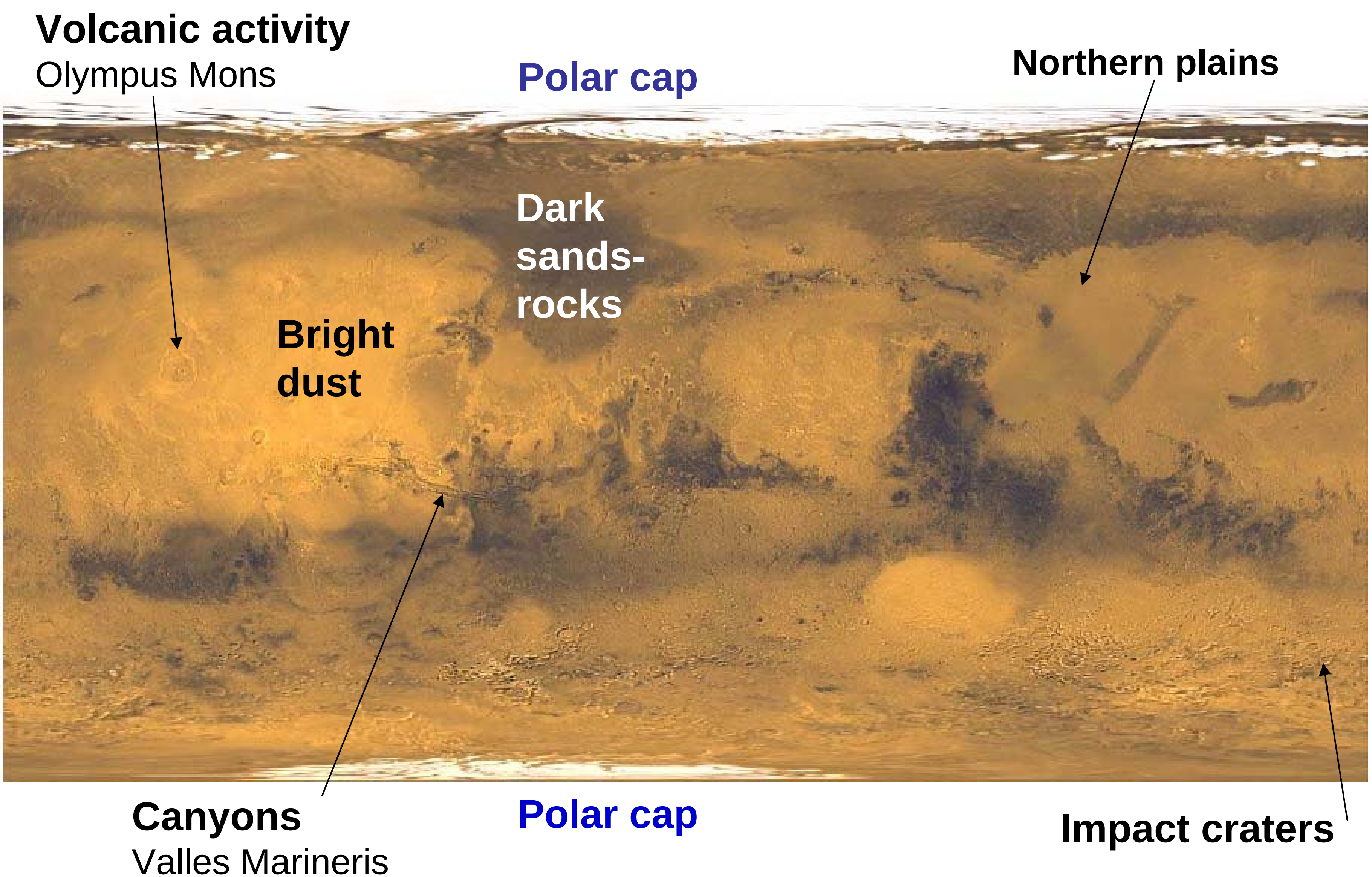
Some dust storms are global and last for months. Many originate in the S. hemisphere in summer, although active dune fields may show multiple wind directions.



Hubble Space Telescope Images



Surface of Mars

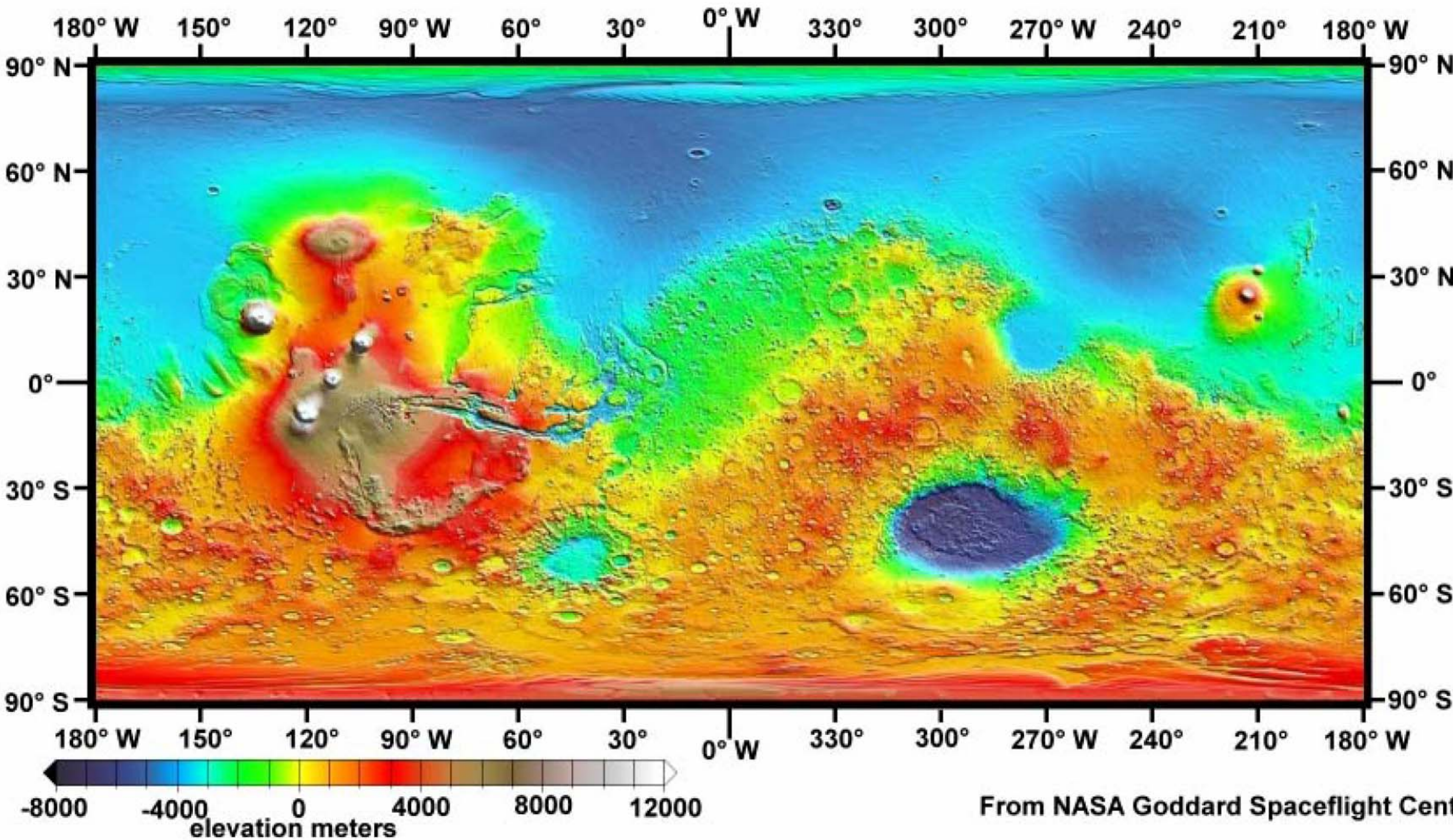


Martian crustal dichotomy

Mars has a range of elevations with two distinct areas

1. South is high overall. Highest point +27km (Olympus Mons), lowest point -7.8km (Hellas Basin)
   - heavily cratered indicating older terrain
2. North is low overall - sparsely cratered indicating younger terrain

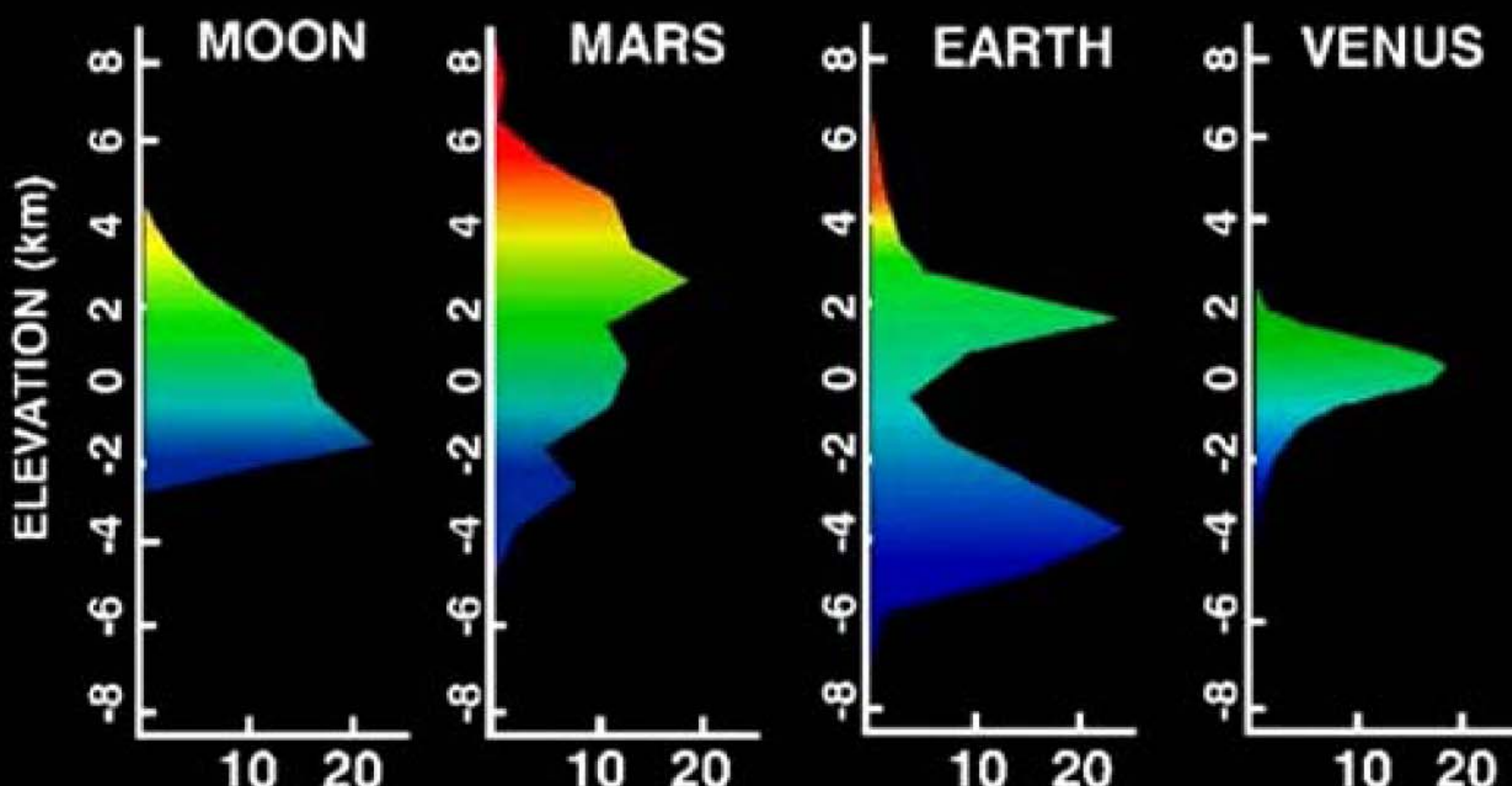
Color-coded Elevations on Mars, MOLA Altimeter, MGS Mission



From NASA Goddard Spaceflight Center

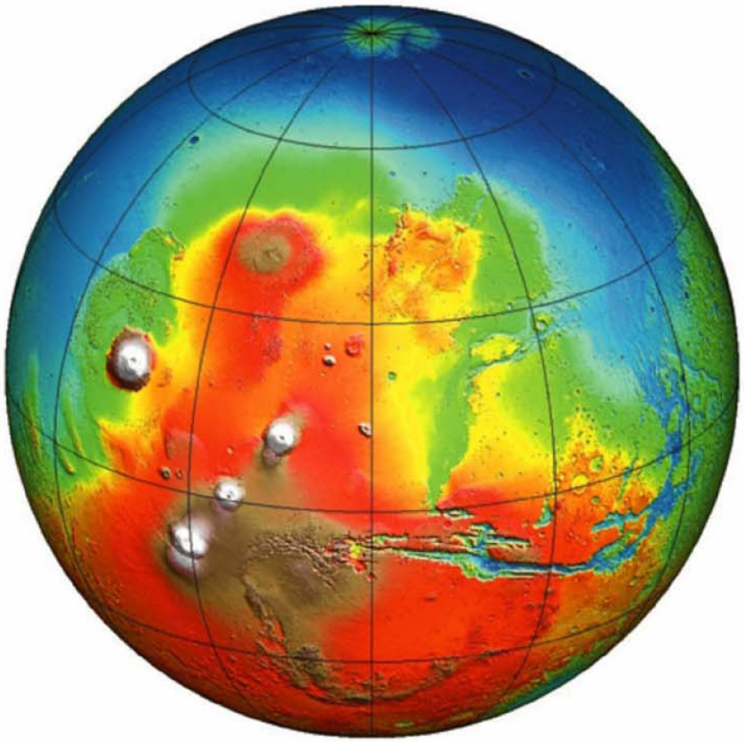
Terrestrial Planets: Topography

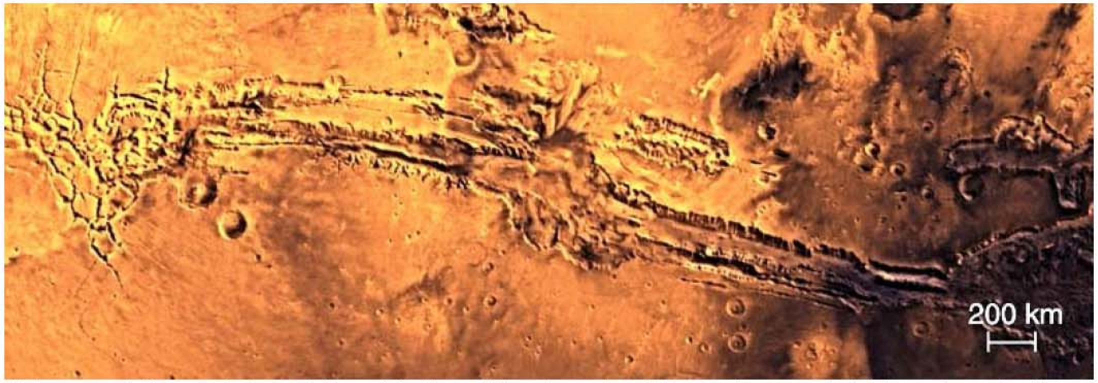
The Terrestrial Planets have different topography distributions (given in % below). The Earth's is ***bimodal*** and is a consequence of ***plate tectonics.*** Those of Venus, Mercury, Mars and the Moon are ***unimodal*** because of the lack of plate tectonics. Mars has a wide topography range ***because*** it is small yet geologically quite active.



Mars: Tectonics

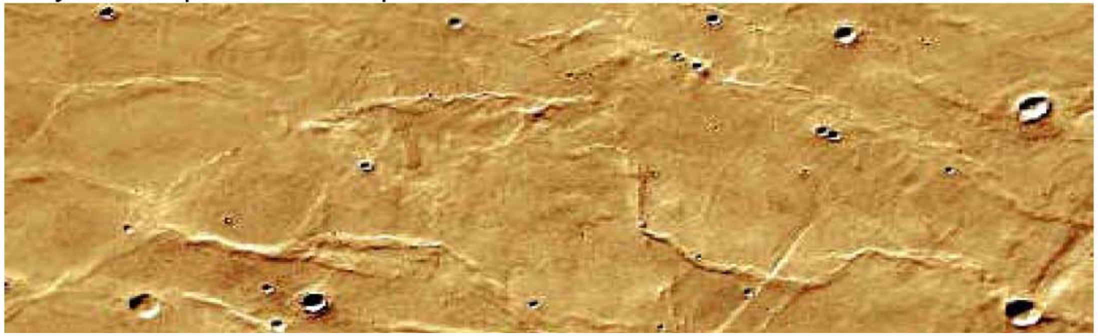
Extensional tectonics: Martian crust is ***rifted*** ("split") on broad regional scales**.**
Largest rift: ***Valles Marineris*** canyon system: 5000 km long, 100 km wide, 7 km deep.
Compressional tectonics: Martian crust also locally compressed: ***wrinkle ridges***.
No sign of plate tectonics. Maybe earlier in Mars's history?



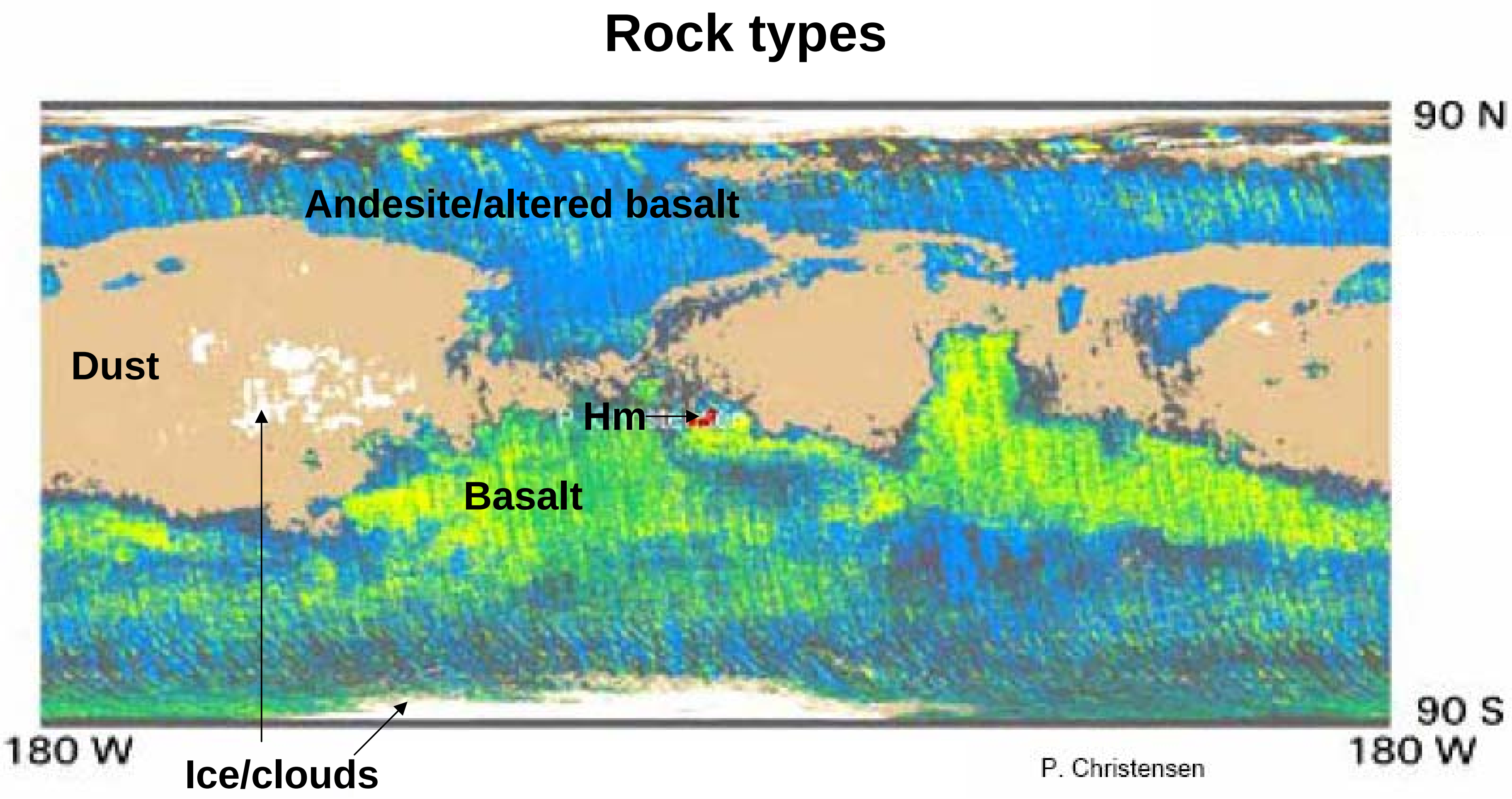


Above: The origin of the ***Valles Marineris*** rift system might be due to the formation of the Tharsis Bulge province (red at left) which bears Mars's largest volcanoes. Scale bar represents 200 km.

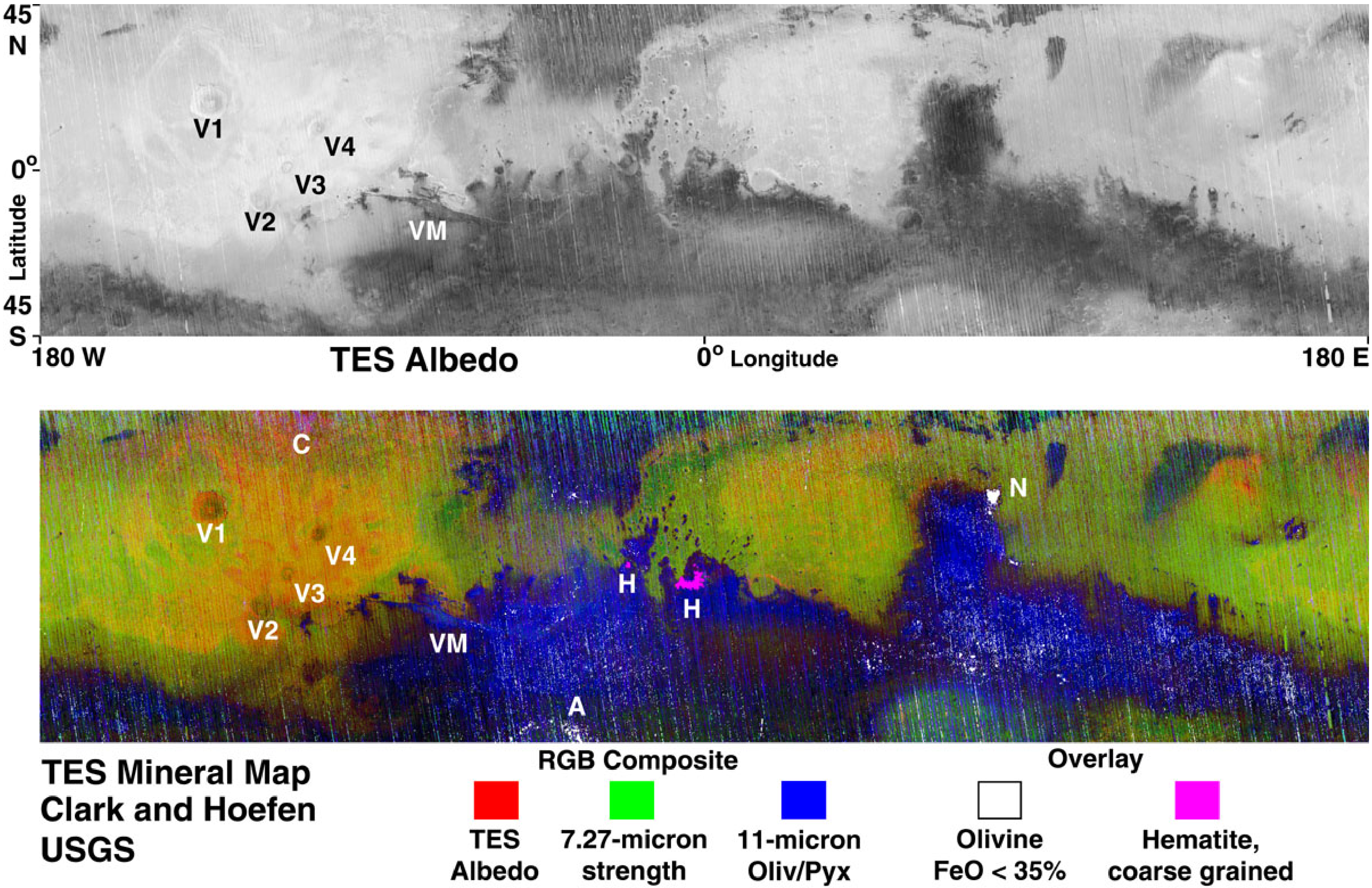
Below: ***Wrinkle ridges*** on plains are evidence that martian crust material may also experience compression. Craters shown here are 20 km across.



Geologic Map of Mars

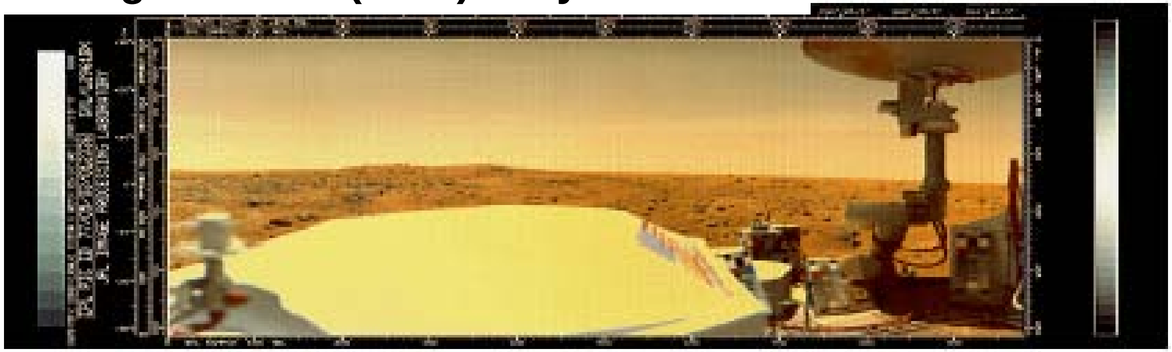


Mineralogy of the Martian surface



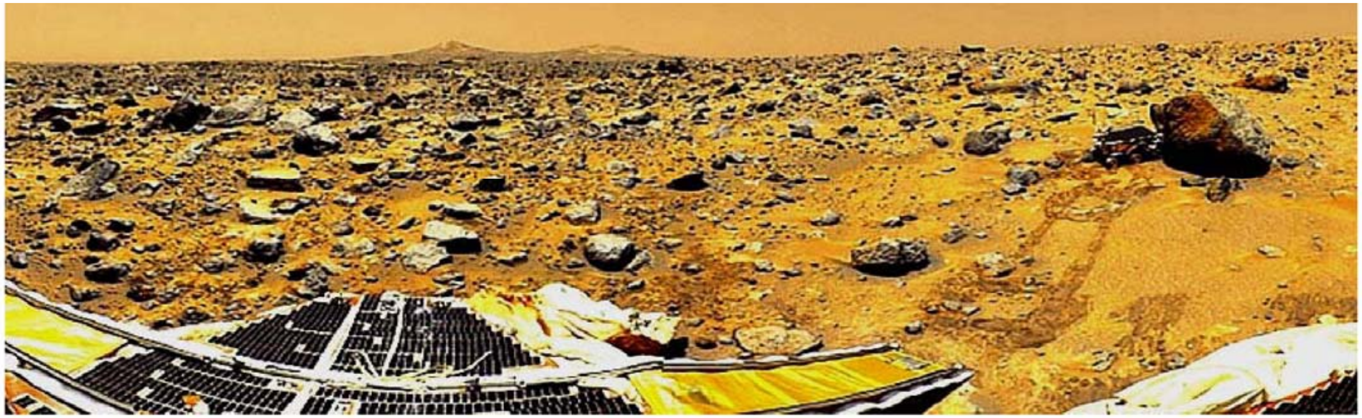
Chemistry of the Martian surface

Viking Lander 1 (1976) Chryse Planitia



Viking Lander 2 (1976) Utopia Planitia

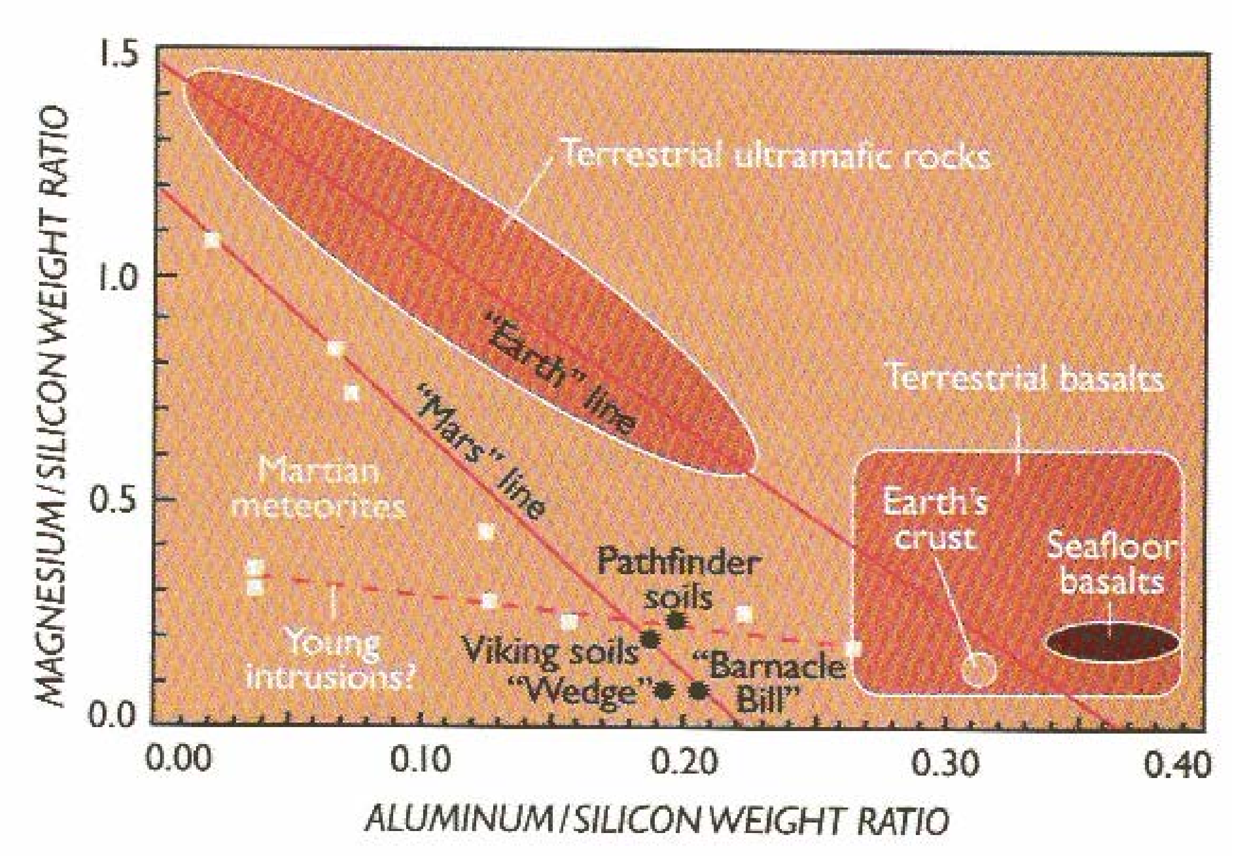
Mars Pathfinder with Sojourner Rover (1997) Ares Vallis



Chemistry of the Martian surface

1. Rocks are basaltic

likely tholeiites
possibly
alkali basalts



2. Loose material & dust is higher in Mg, S, Na & Cl than rocks
Limited weathering

Other clues to the martian crustal composition: the Martian meteorites

"Martian" Meteorites

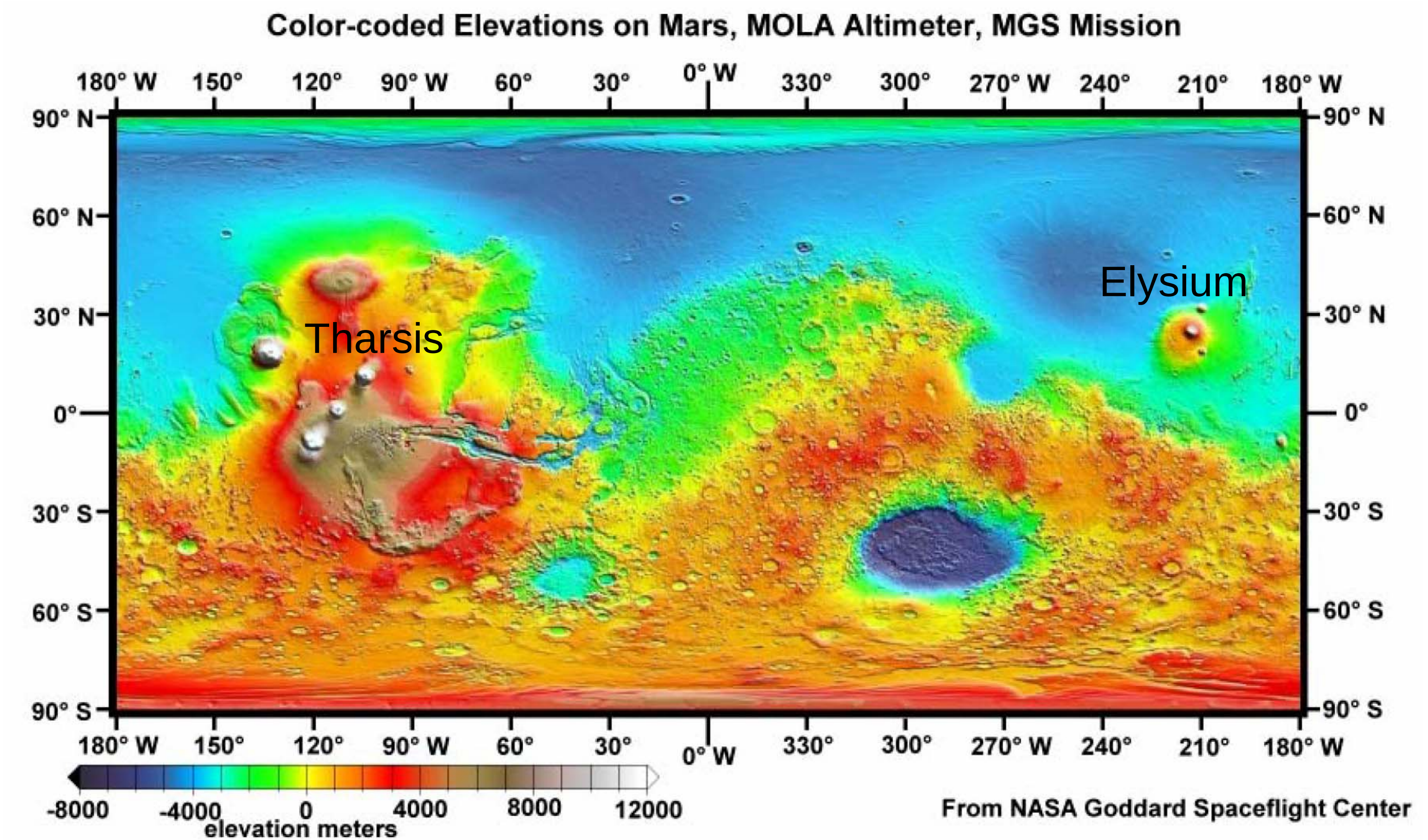
- meteorites that are distinctively young
- distinct O isotopic compositions
- noble gases in impact glasses are similar to the Martian atmosphere

Earth

Volcanic Provinces

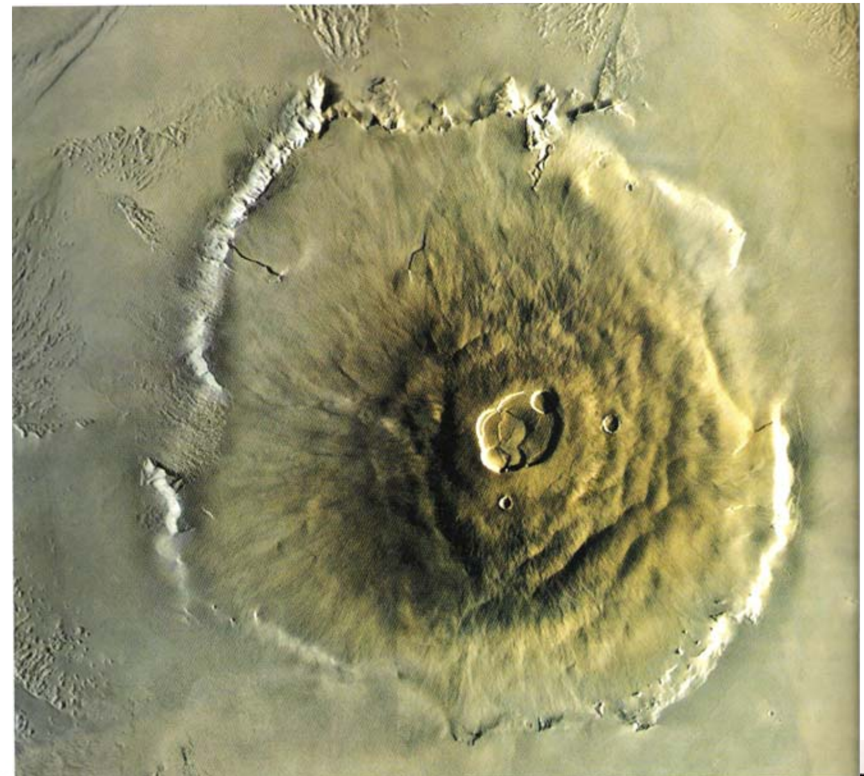
<u>Two major provinces:</u>
Tharsis: 10km-high bulge, supporting several large volcanoes, including Olympus Mon
Elysium: smaller elevated region with several cone-shaped volcanoes

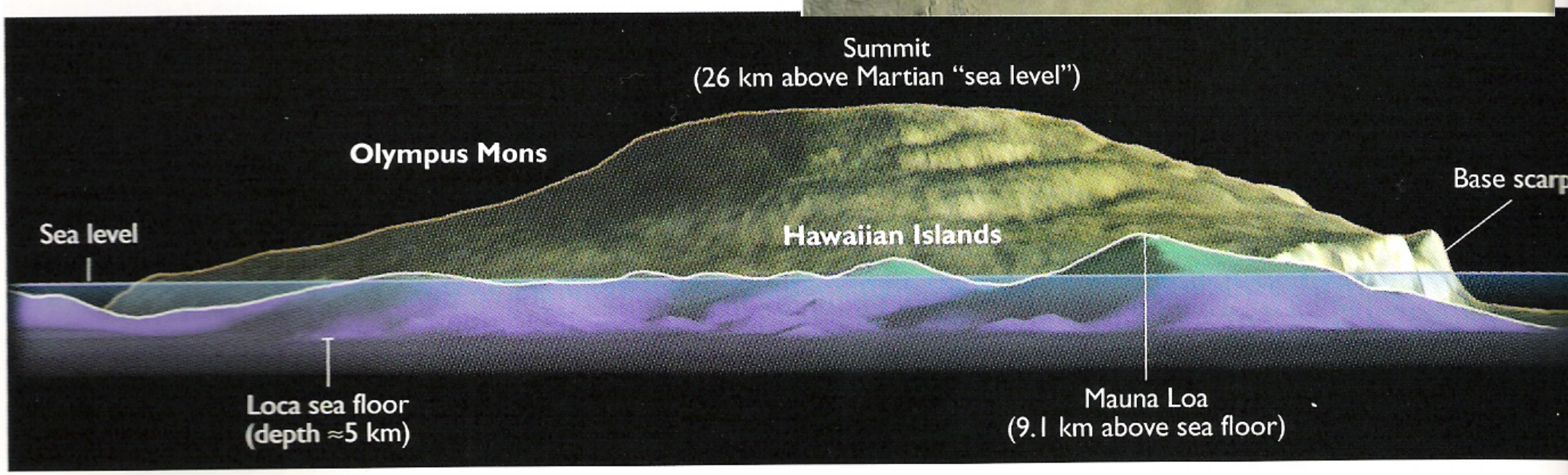
Relative age dating suggests these are young (<100Ma), may be still active,



Olympus Mons

- largest volcano (& mountain) in the solar system
- 600km diameter at base, 27km high
- Summit caldera 60km across, above Mars' atms.





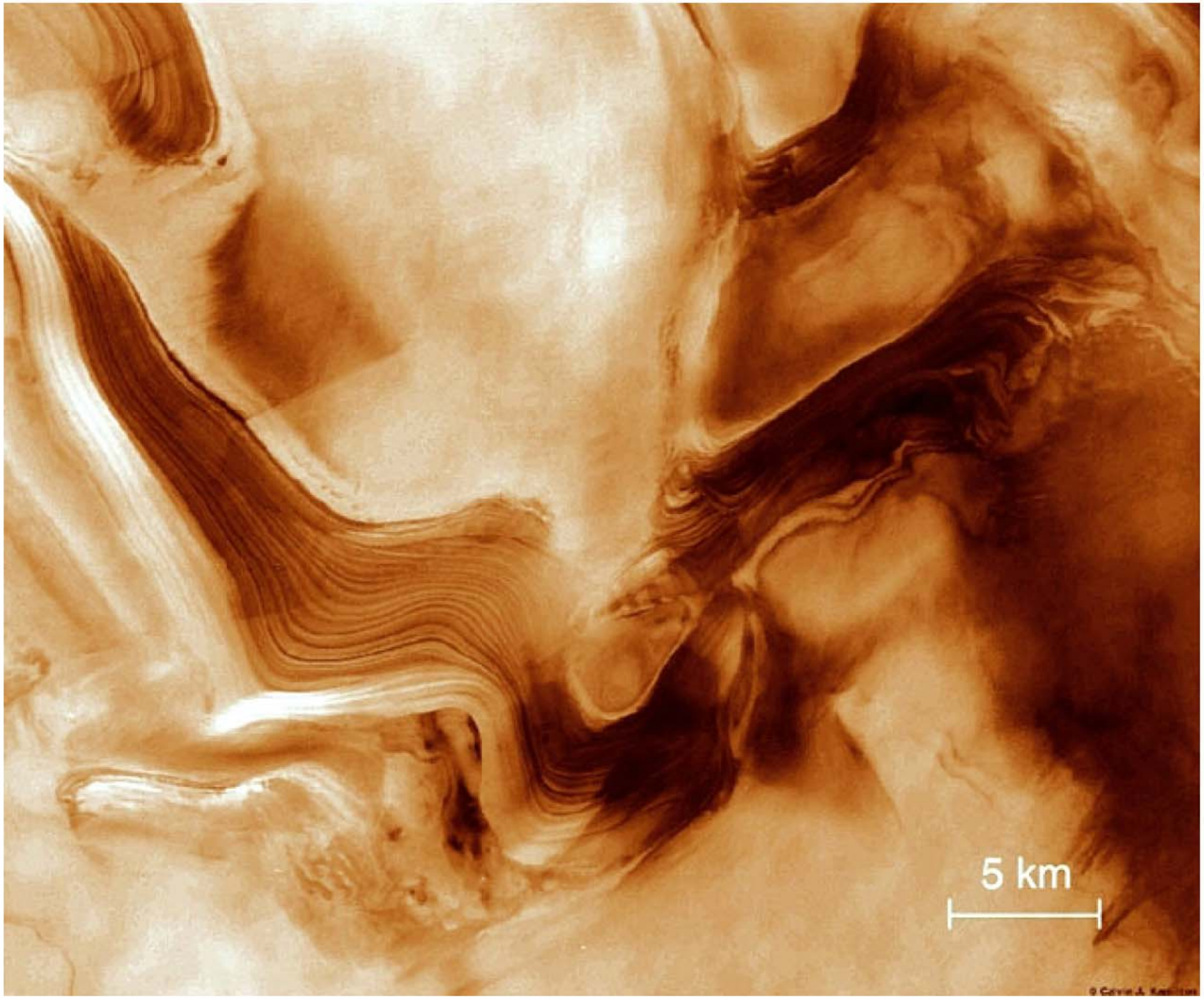
Mars Polar Layered Deposits

The terrains surrounding both residual caps present thick piles of finely layered sediments known as the ***Polar Layered Deposits*** or ***PLDs***.

PLDs might be some of the youngest terrains on Mars: perhaps 10^5-10^8 years old.

PLDs seem to be made of meter to sub-meter thick layers of ice and dust-rich sediments.

PLDs suggest ***climate change*** and might hold a record of Mars's climate Evolution in recent times.

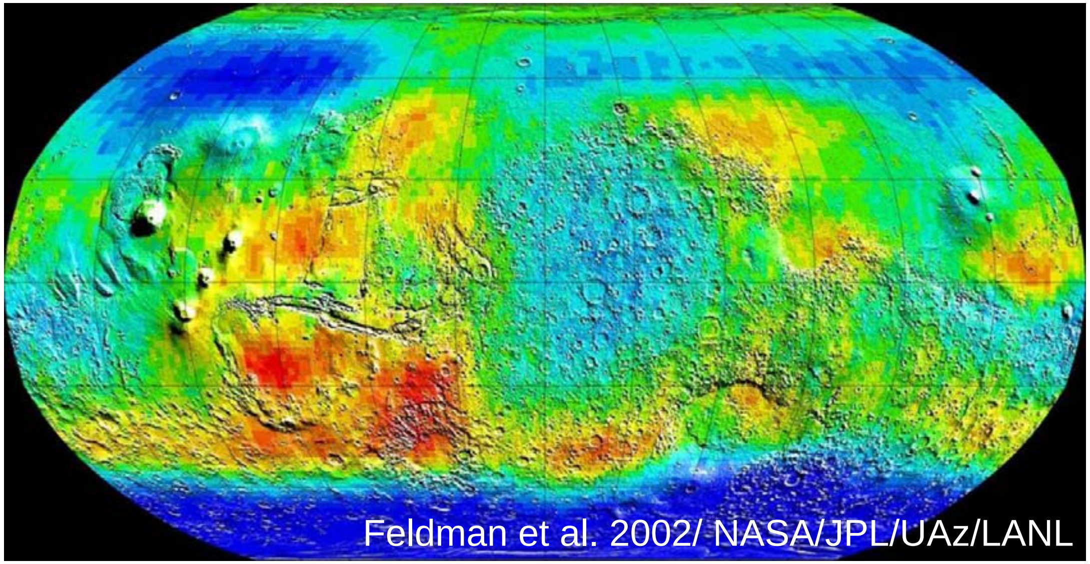


Remote detection of H on Mars

Gamma Ray spectrometer detected H in the top 1m of the surface

Dark blue <50% H_2O in ice

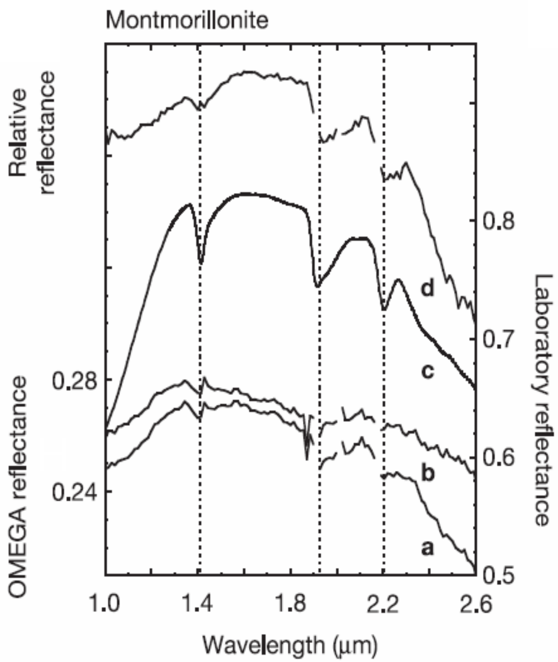
Light blue bound H in minerals

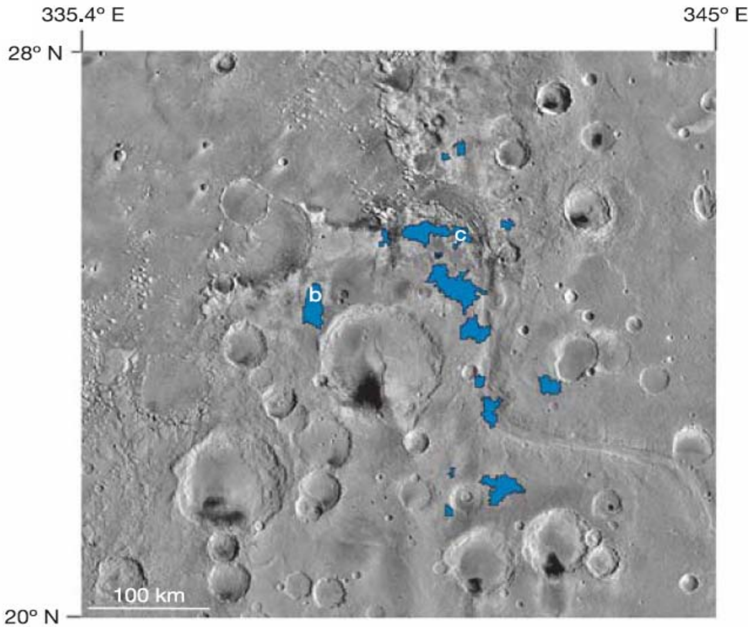


TES & OMEGA

TIR spectrometers detected minerals with H

e.g., zeolites, clays



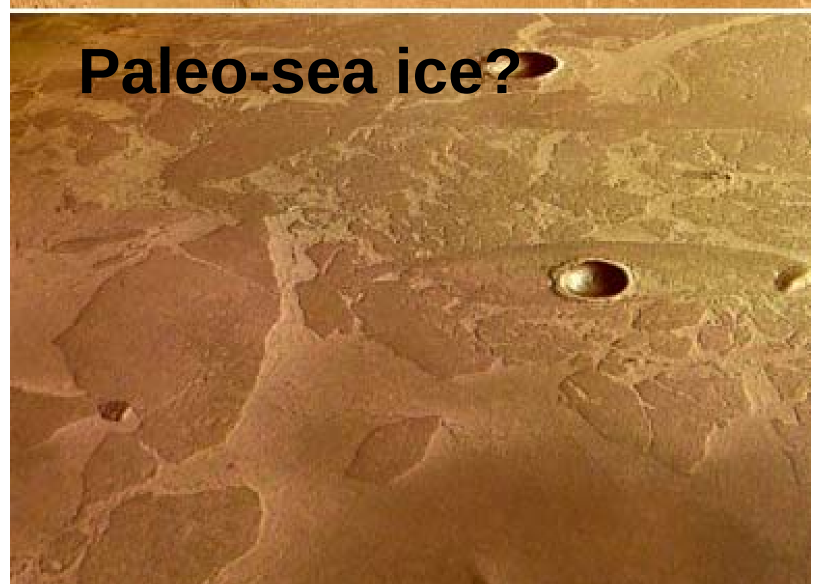


Poulet et al., 2005

Geomorphic evidence for surface water

Small valley networks

Outflow channels

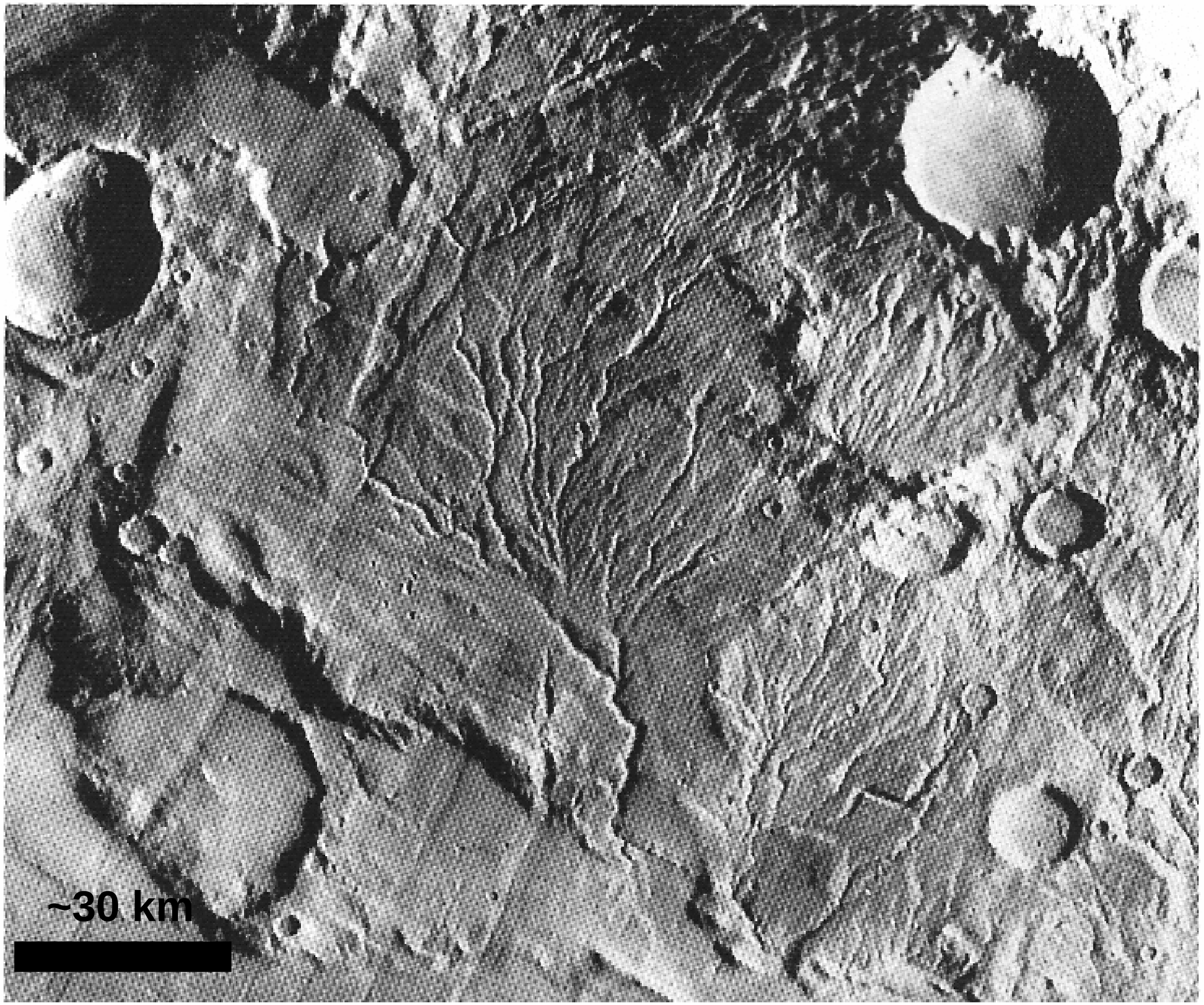


NASA/JPL

Branching, dendritic channel networks

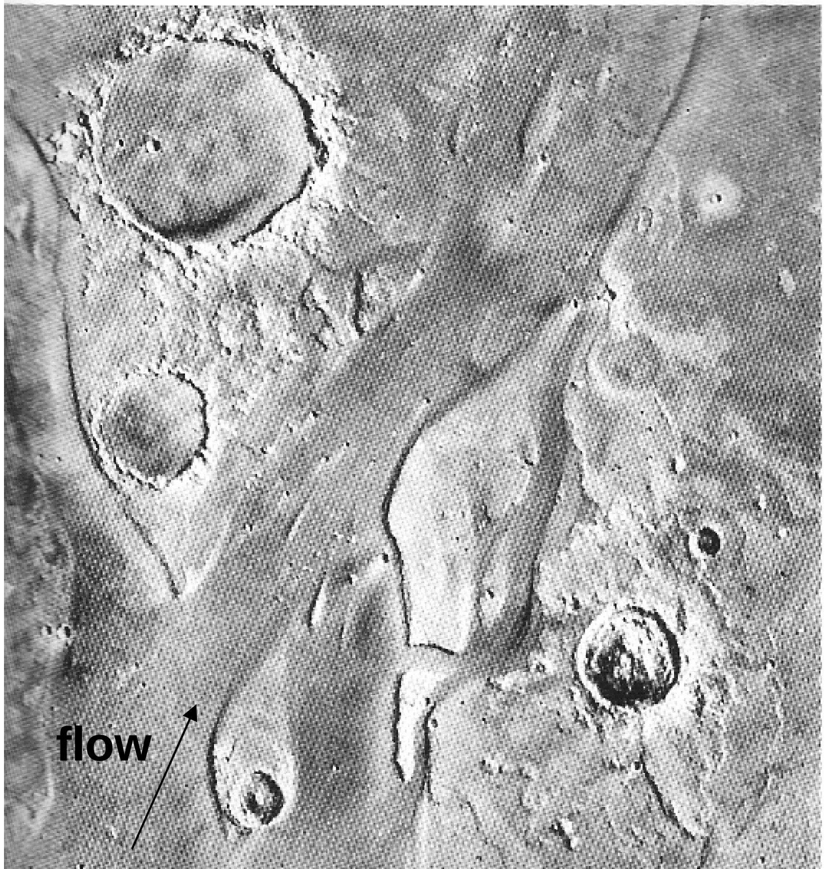
Small channel networks are ubiquitous in the older southern highlands of Mars.

These have been used as evidence for an older warmer Mars

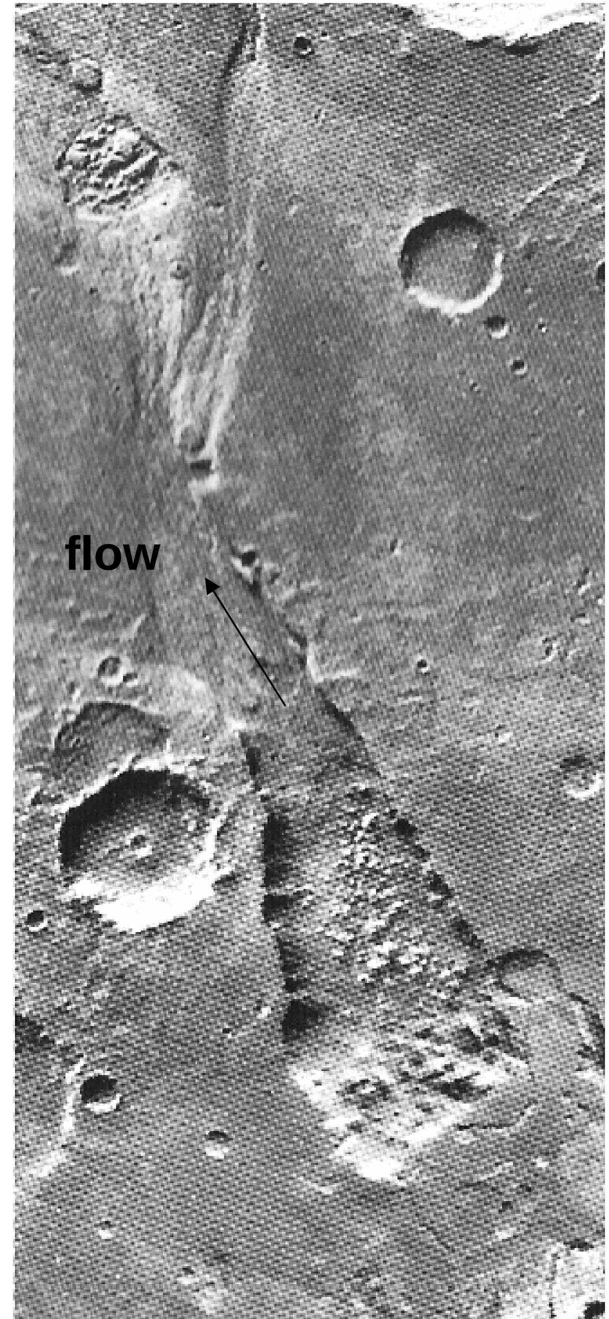


Outflow channels

Produced by the catastrophic flow of a liquid (likely H_2O). E.g. sudden release of liquid H_2O resulting from melting ground ice by localized subsurface heating.



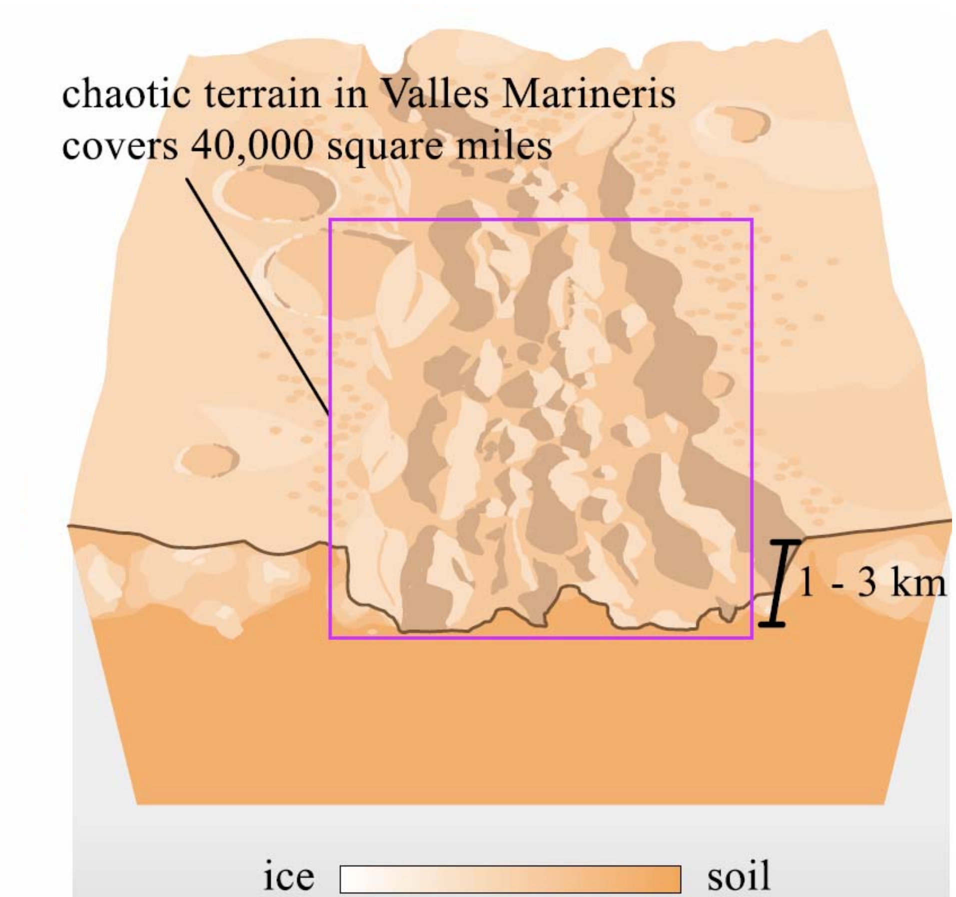
Ares Vallis, downstream of the Pathfinder site: streamlined banks, teardrop islands



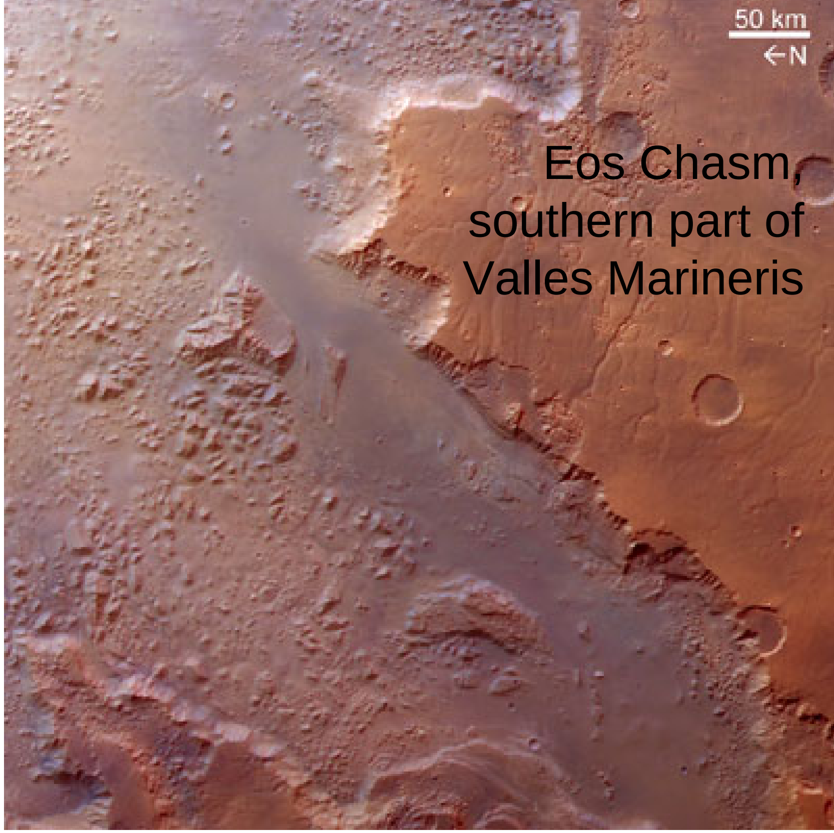
~20km wide outflow channel

Chaotic terrain

Model for chaotic terrains



http://www.marsquestonline.org/tour/floods/howtheyform/index.html



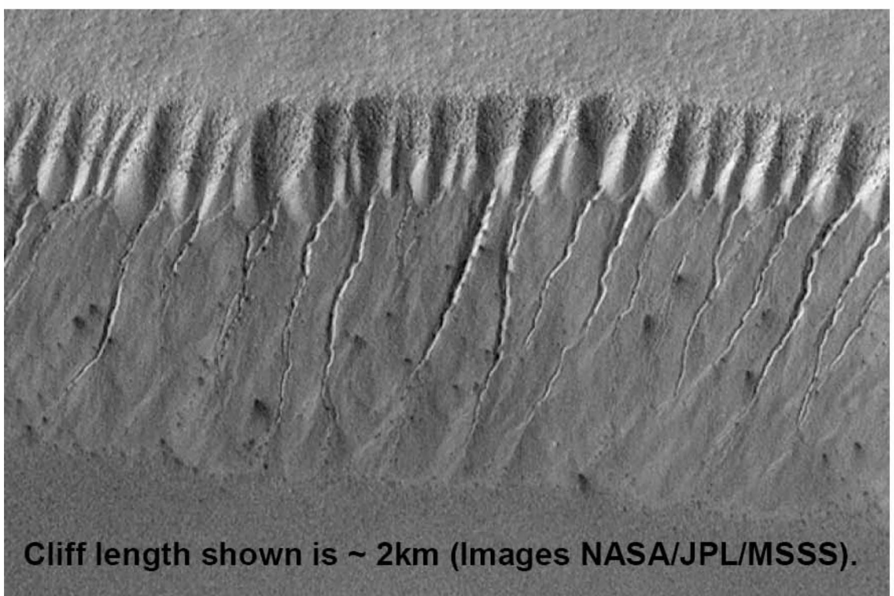
www.esa.int

Mars: Gullies

Gullies provide evidence Mars experienced liquid H_2O flow not just in the distant past but also in recent times.

Gullies must be ***young*** as they are small and are thus unlikely to survive erosional erasure over long timescales. Maybe <~100 MYa old.

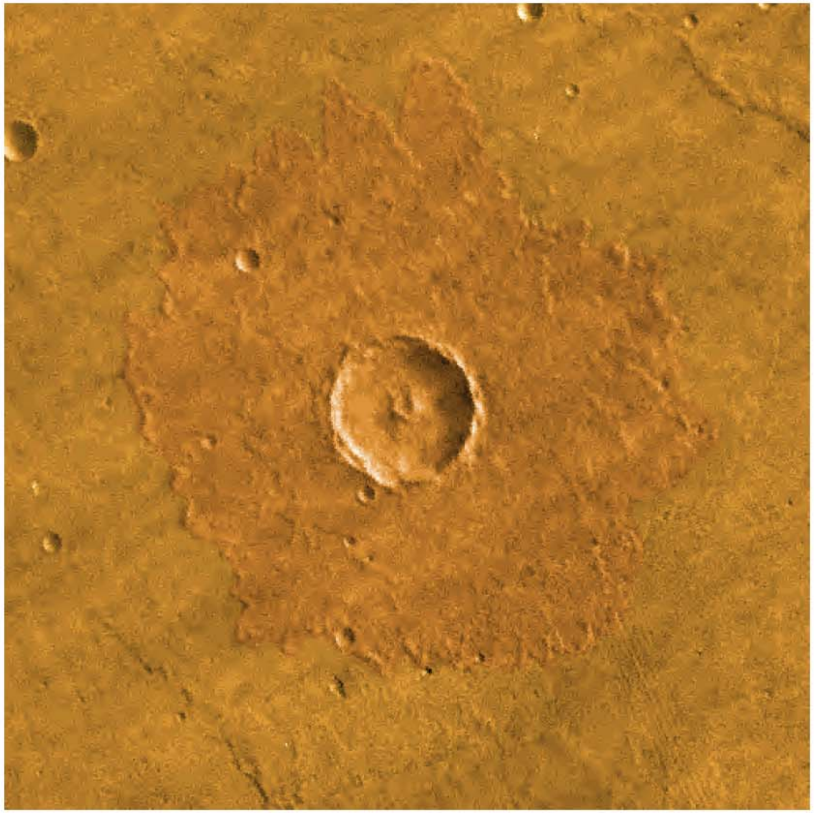
Originally thought to have involved ***seepage of groundwater***, there is growing evidence they formed instead by ***snow & ice melting***.



Cliff length shown is ~ 2km (Images NASA/JPL/MSSS).

Lobate Ejecta Features

- Indicate near-surface water or ice

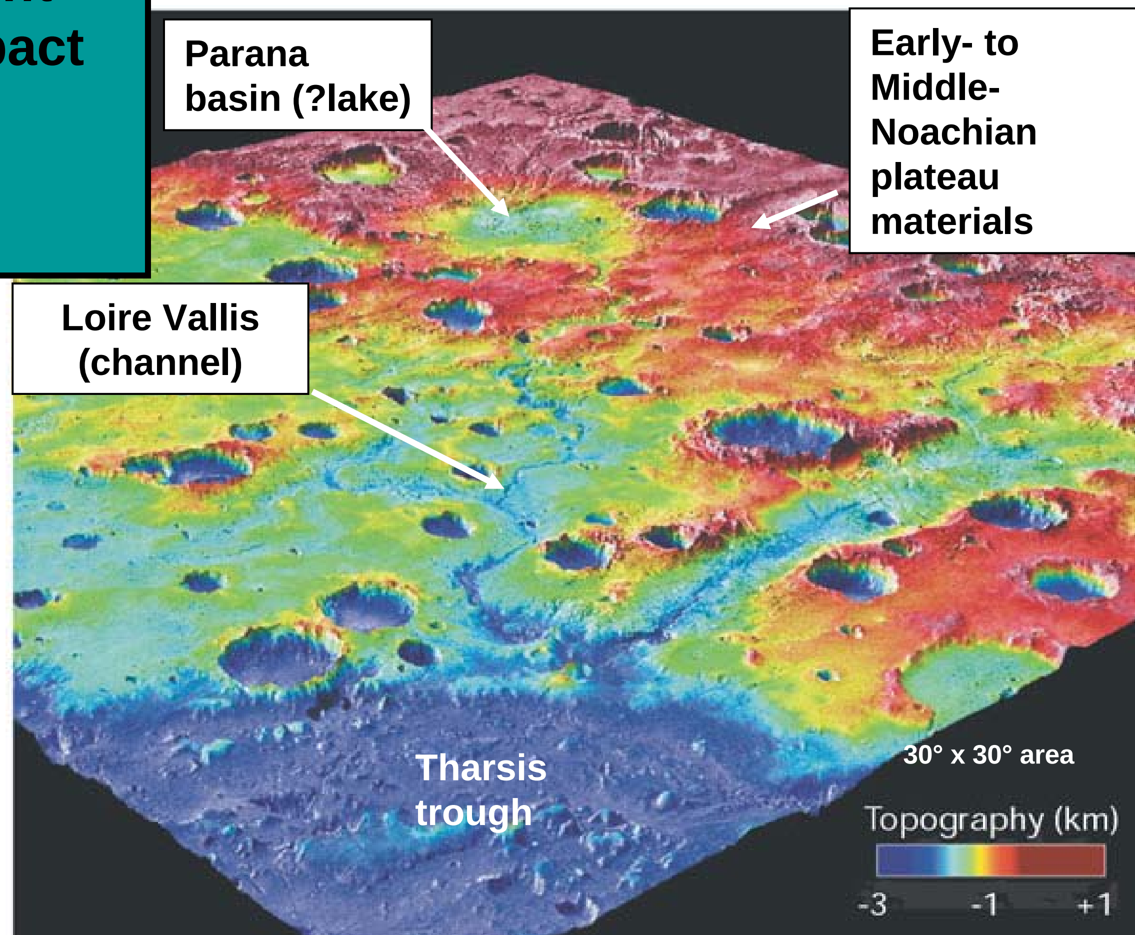


V. early "primordial" H_2O-solute transport on Mars

Major impact basins

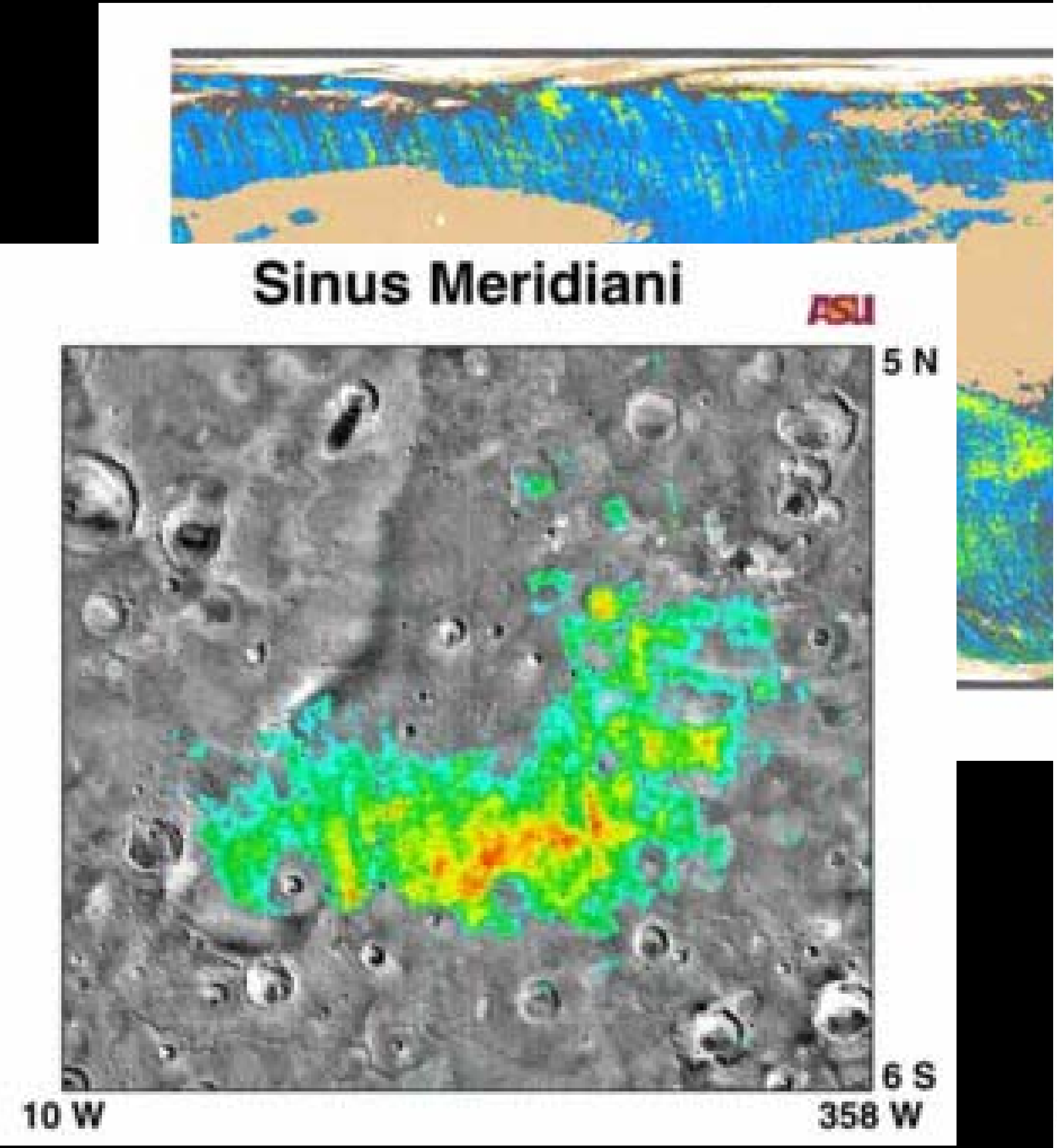
Heavy bombardment

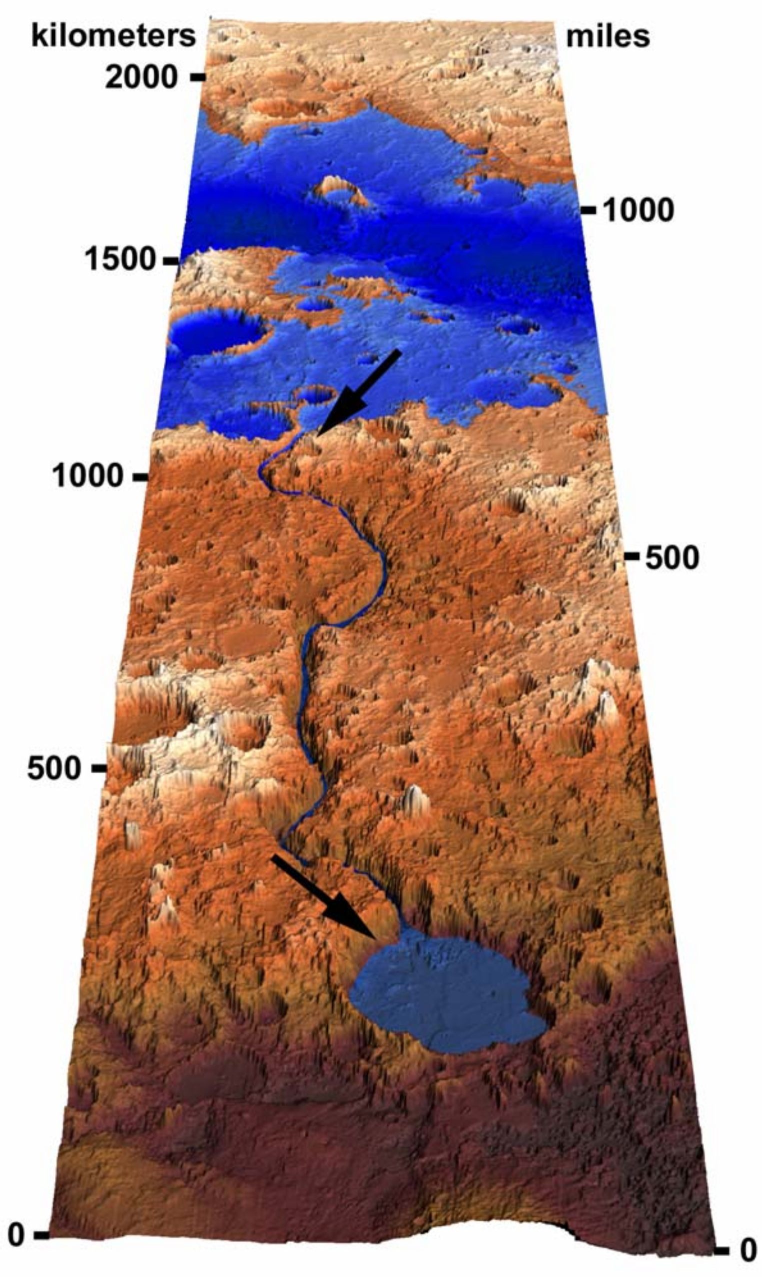
- **Volatiles from impact & volcanism**
- **High erosion & valley networks**



Modified after
Jakowsky & Phillips, 2001;
Phillips et al. 2001

Mars Exploration Rovers- Follow the Water!

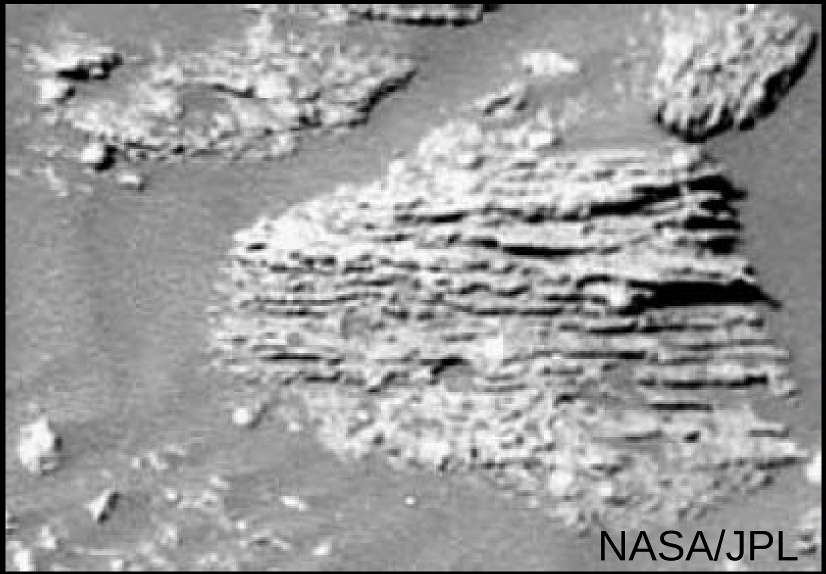




There is water!

Salt weathering

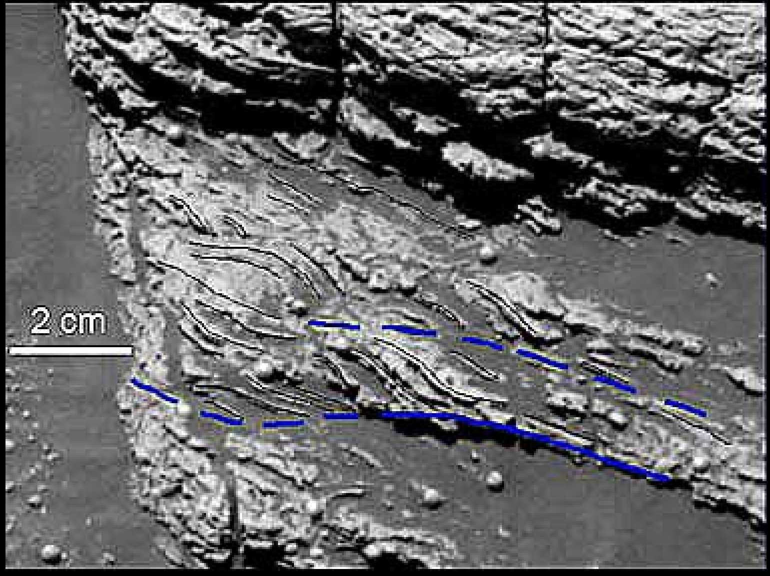
Mars



Earth

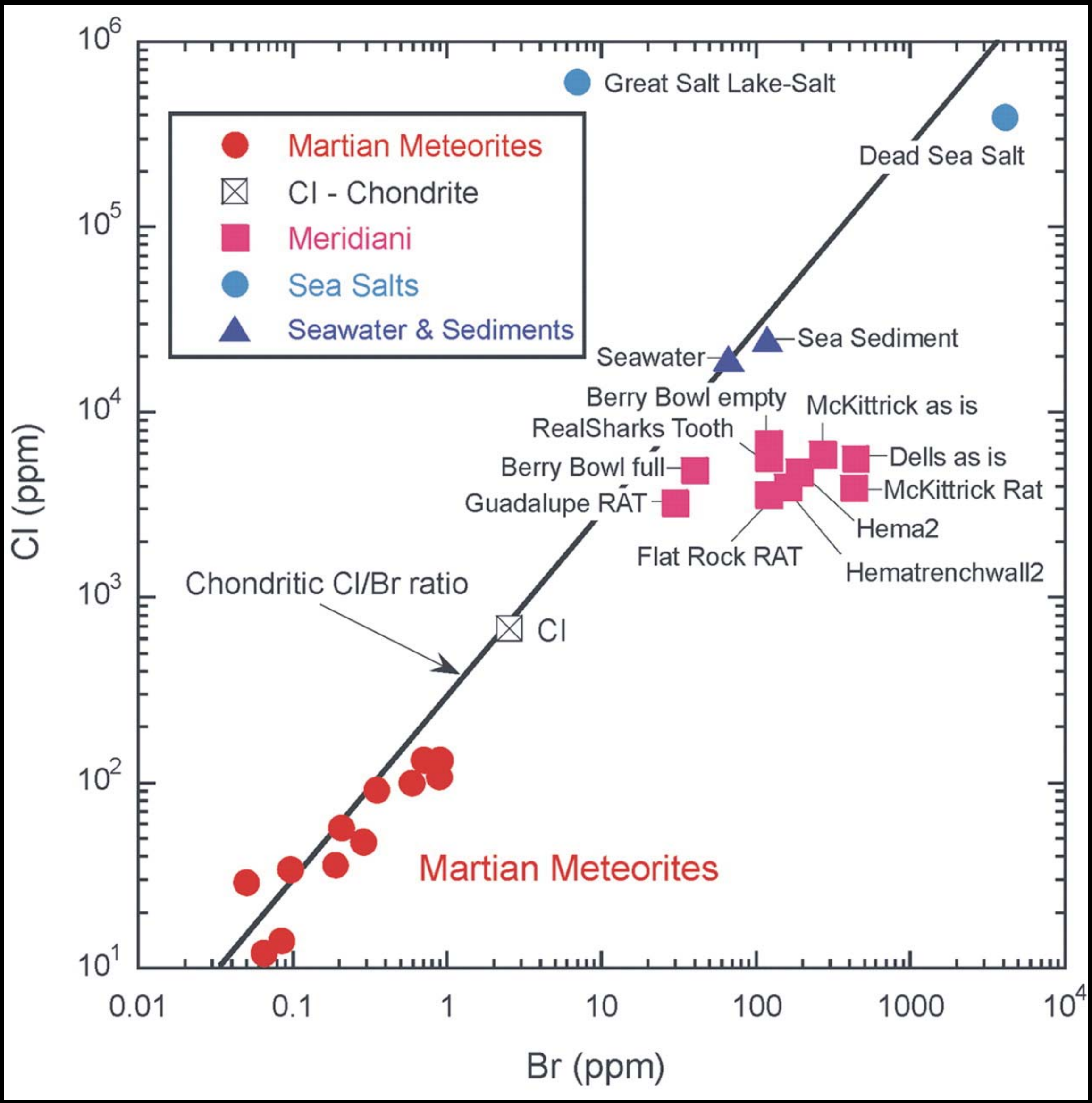
Salt vein

Salt vugs



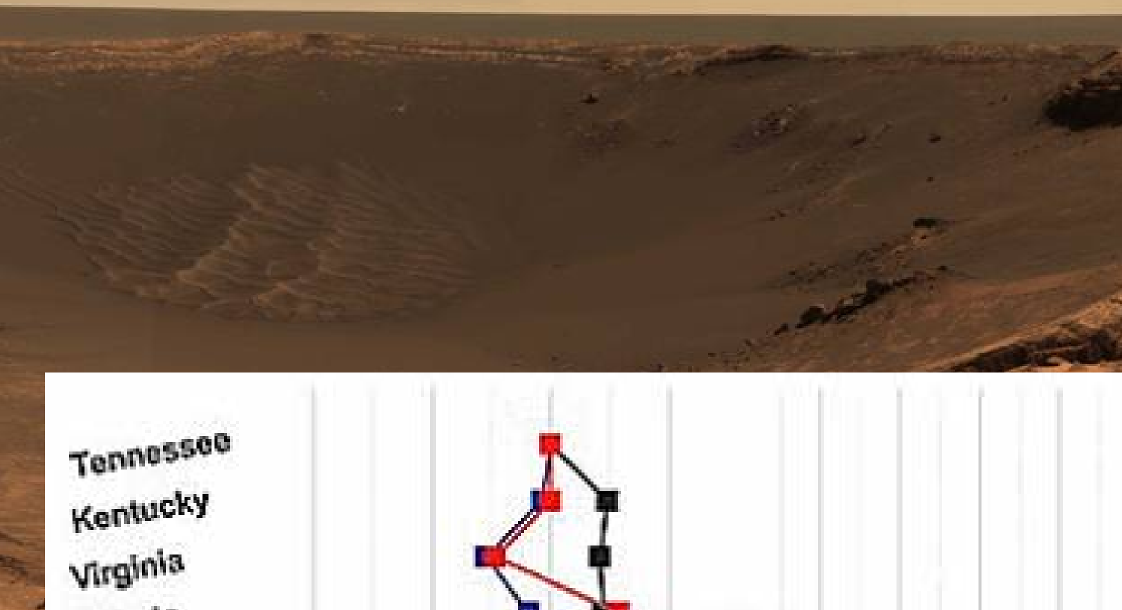
Cross-bedding indicating flow

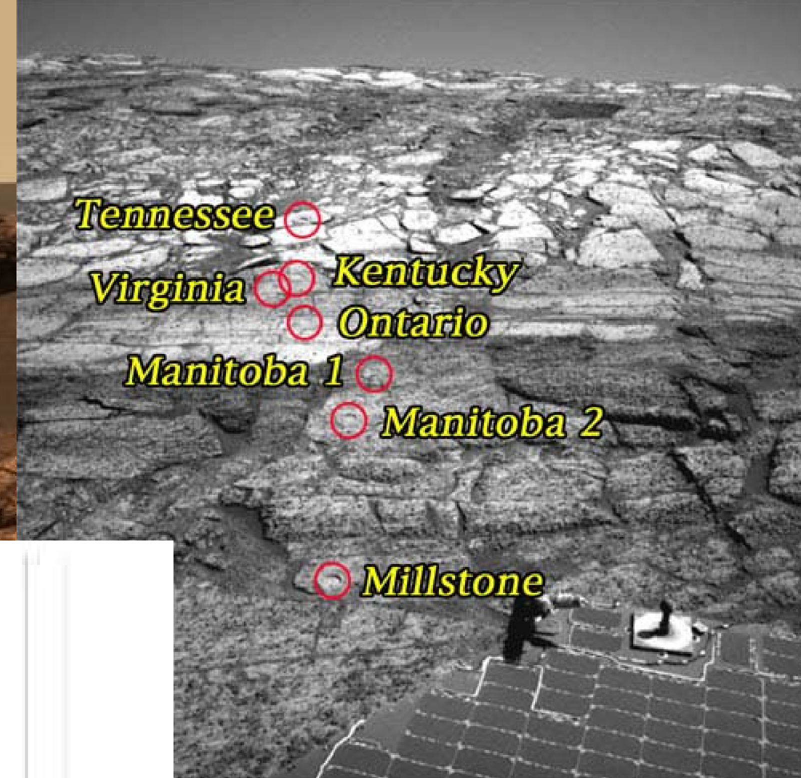
APXS chemistry of Mars

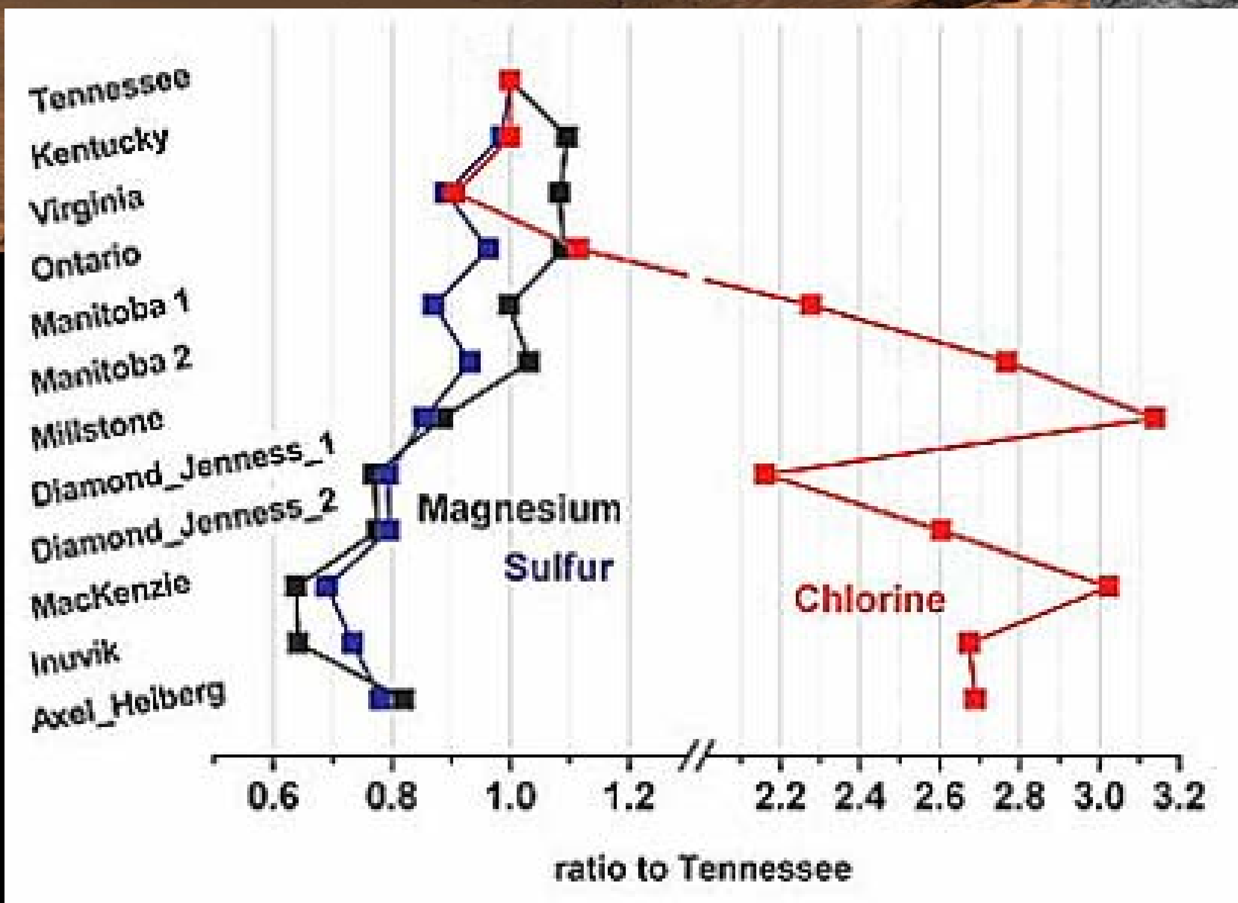


Rieder et al. (2004)

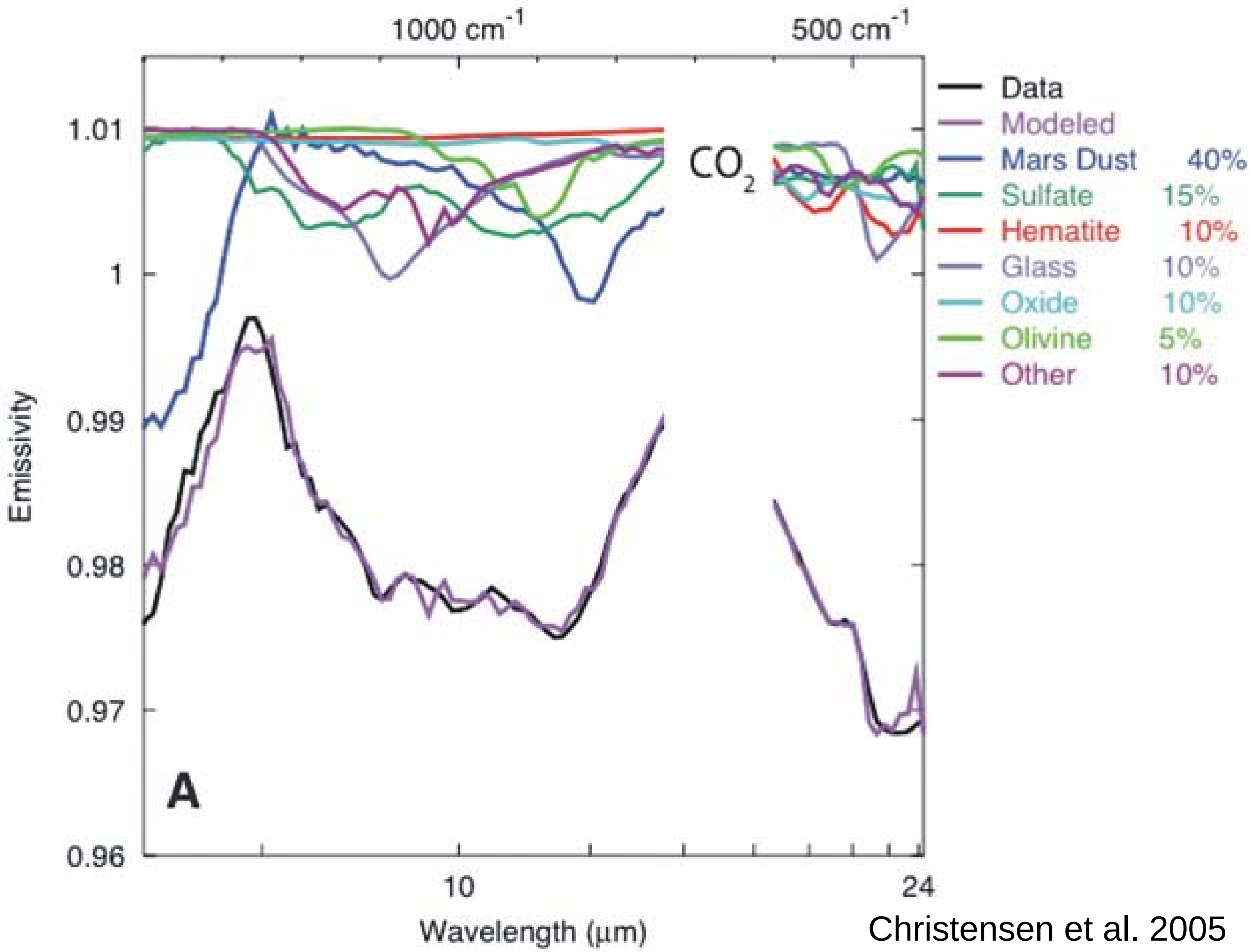
Endurance Crater





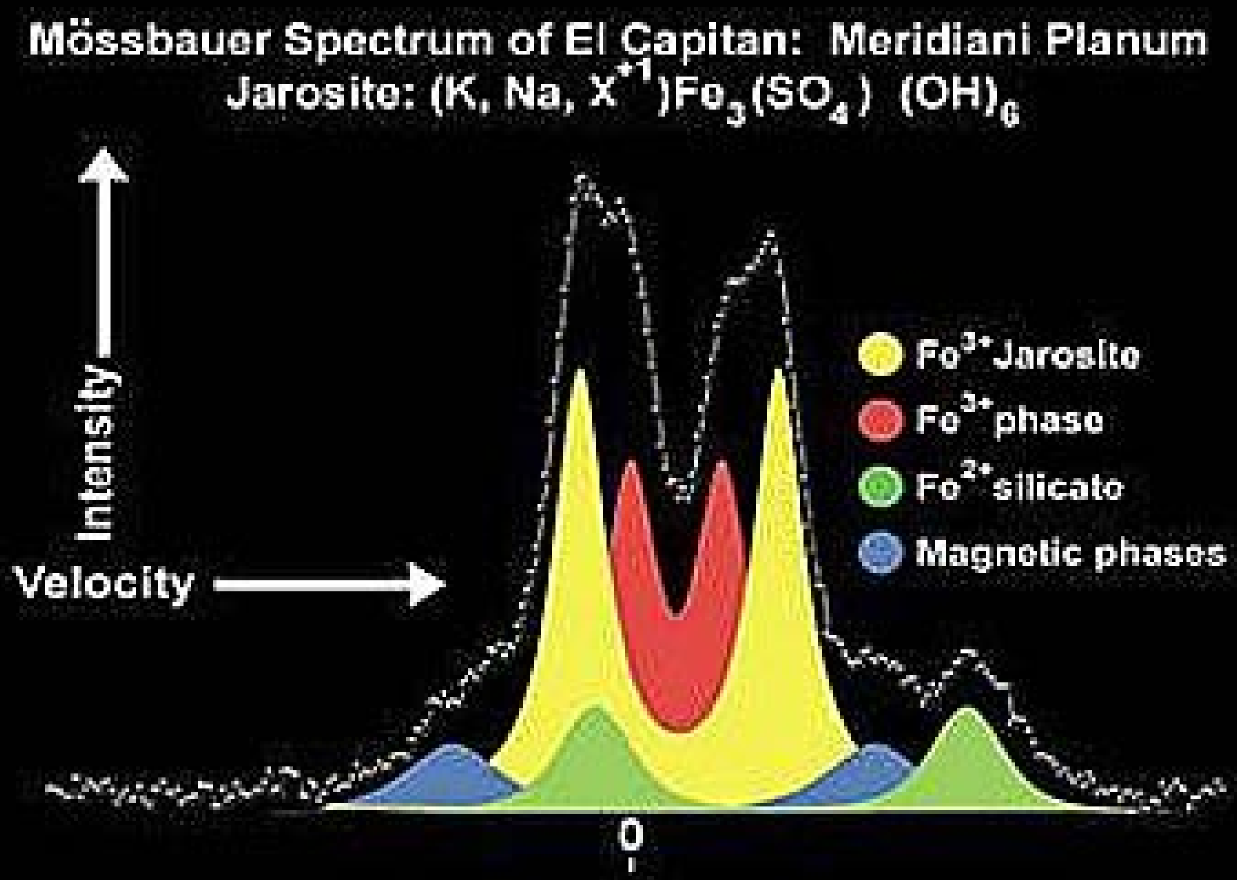


IR spectroscopy suggests that Mg-Ca-sulfates are present on Mars



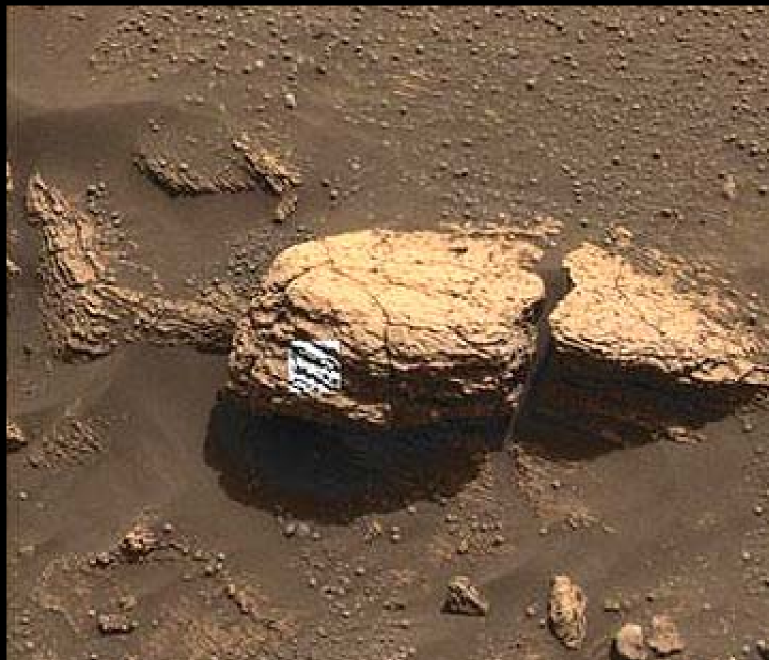
Christensen et al. 2005

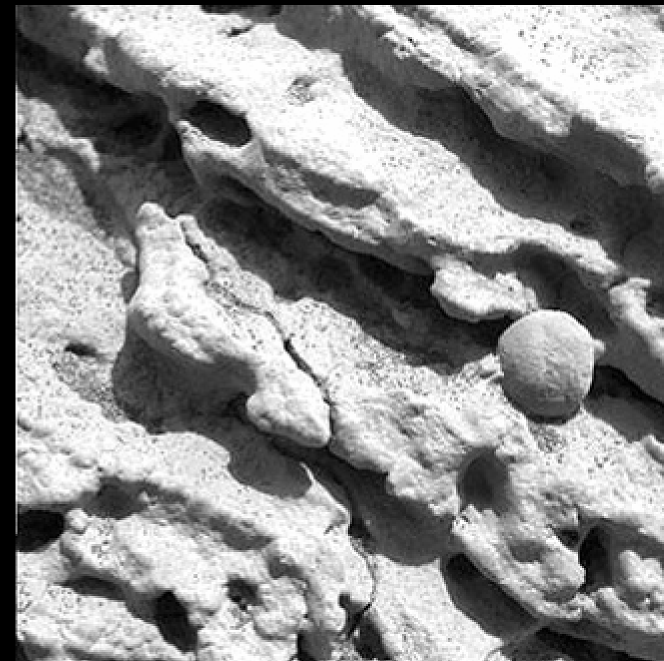
Meridiani Planum Mössbauer data



Klingelhoefer et al. 2004

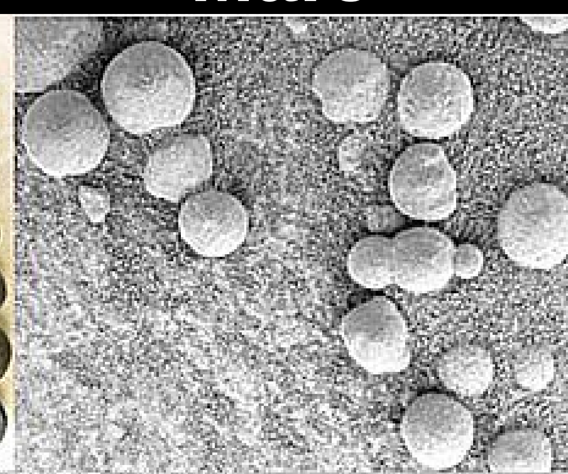
Hematite 'blueberries'





Earth

Mars



Predicted salt sequence – all pH values

Fe-rich secondary minerals

(i) melanterite or pyrite/marcasite

Sequence of

(ii) dehydration

(iii) oxidation

(iv) neutralization

Ca-Mg-Na-rich salts

(a) phosphates

(b) Fe-Mg-Ca-carbonates

(c) Ca-sulfates (gypsum)

(d) Magnesite

(e) $MgSO_4.xH_2O$

(f) Na,(Mg) sulfates

(g) Na,K halides (e.g. halite)

(h) Mg halides (e.g. bishofite)

Low pH

e.g. Meridiani Planum
- Limited water
- Stays acidic
- Acid stored in sulfates like rhomboclase that are reworked

e.g. Gusev Crater
OMEGA sites
martian meteorites
- More water
- More weathering
- Clay minerals + silica

Mod-High pH

King & McSween 2005

Summary

- Interior features
- Atmosphere
- Seasonal + daily T & P
- Surface features, topography & composition
- Missions & martian meteorites
- Volcanism & polar deposits
- Search for water – surface geomorphology (valley networks, channels, gullies etc.)
- MER mission results – salts, chemistry, mineralogy