ASTR/GEOL-2040: Search for life in the Universe: Lecture 23

- Fossils in ALH 84001?
- Martian meteorites
- Methane on Mars

Axel Brandenburg
(Office hours: Mondays 2:30 – 3:30 in X590 and Wednesdays 11-12 in D230)

ALH 84001's History

- 4.1 Gyr solidified from molten rock in southern highlands
- 4.0 – 4.1 Gyr: affected by nearby impact, but not ejected (shock metamorphism)
- 3.9 Gyr: infiltrated by water → carbonate grains at +18°C, according to oxygen isotope
  01 – 0.2 mm
- 0.016 Gyr = 16 Myr: blasted into space
- 0.013 Myr = 13,000 yr: fell in Antarctica
- 1984 found, 1993 recognized as Martian, → 1996

ALH 84001

- Contained carbonate rocks (not known < 1997)
  - Layered structure: magnesium-rich → iron-rich → calcium-rich: on Earth typical of biology
- Carbonate grains contain complex hydrocarbons
  - Polycyclic aromatic hydrocarbons (PAHs)
  - On Earth: produced by decay of dead organisms

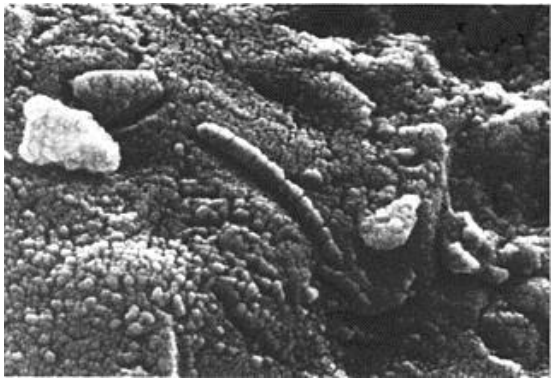
Magnetite in ALH 84001

- Size, purity, shape of Fe_3O_4 typical of bacteria
  - Remember: iron-reducing bacteria:

hematite → magnetite

$$3Fe_2O_3 \rightarrow 2Fe_3O_4 + \tfrac{1}{2} O_2$$

- Carbonate, FeS, Fe_3O_4 not stable in equilibrium
- Rod-shaped structures



Objections include

- Fossil structures plausibly nonbiological
- Convincing fossils at 3.9 Gyr age rare on Earth
- Melts from impacts produce carbonate globules like those in the meteorite

Further objections

- Pulses of hot water with dissolved elements could also produce layered structure
- Other meteorites also have PAHs
- Abiological magnetite crystals (but no details)
- Rod-shaped structures 200x small than on Earth (similar structures also in other meteorites)

20 yr later: general consensus

- 2011, Marocco, also organics, etc
  - Scientists skeptical
- Magnetite crystals hard to explain abiotically
  - Case for past Martian life not made by ALH84001

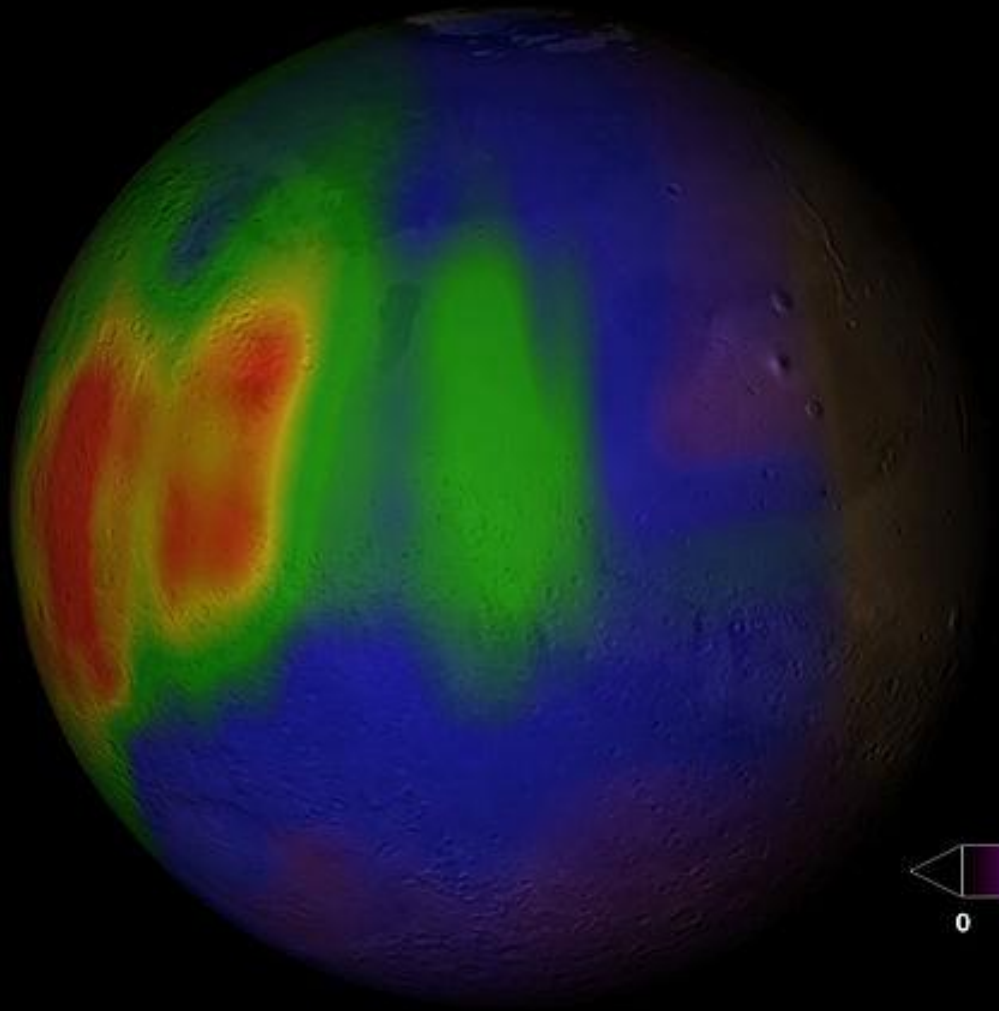
Search for Past Life on Mars: Possible Relic Biogenic Activity in Martian Meteorite ALH84001

David S. McKay, Everett K. Gibson Jr.,
Kathie L. Thomas-Keprta, Hojatollah Vali,
Christopher S. Romanek, Simon J. Clemett,
Xavier D. F. Chillier, Claude R. Maechling, Richard N. Zare

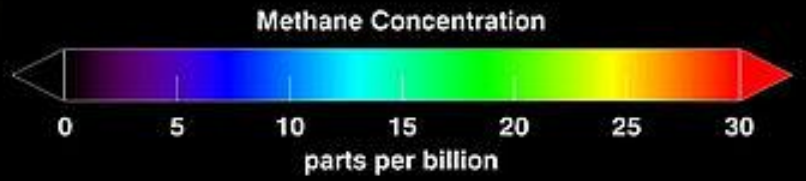
Martian life claims: 3 categoroies

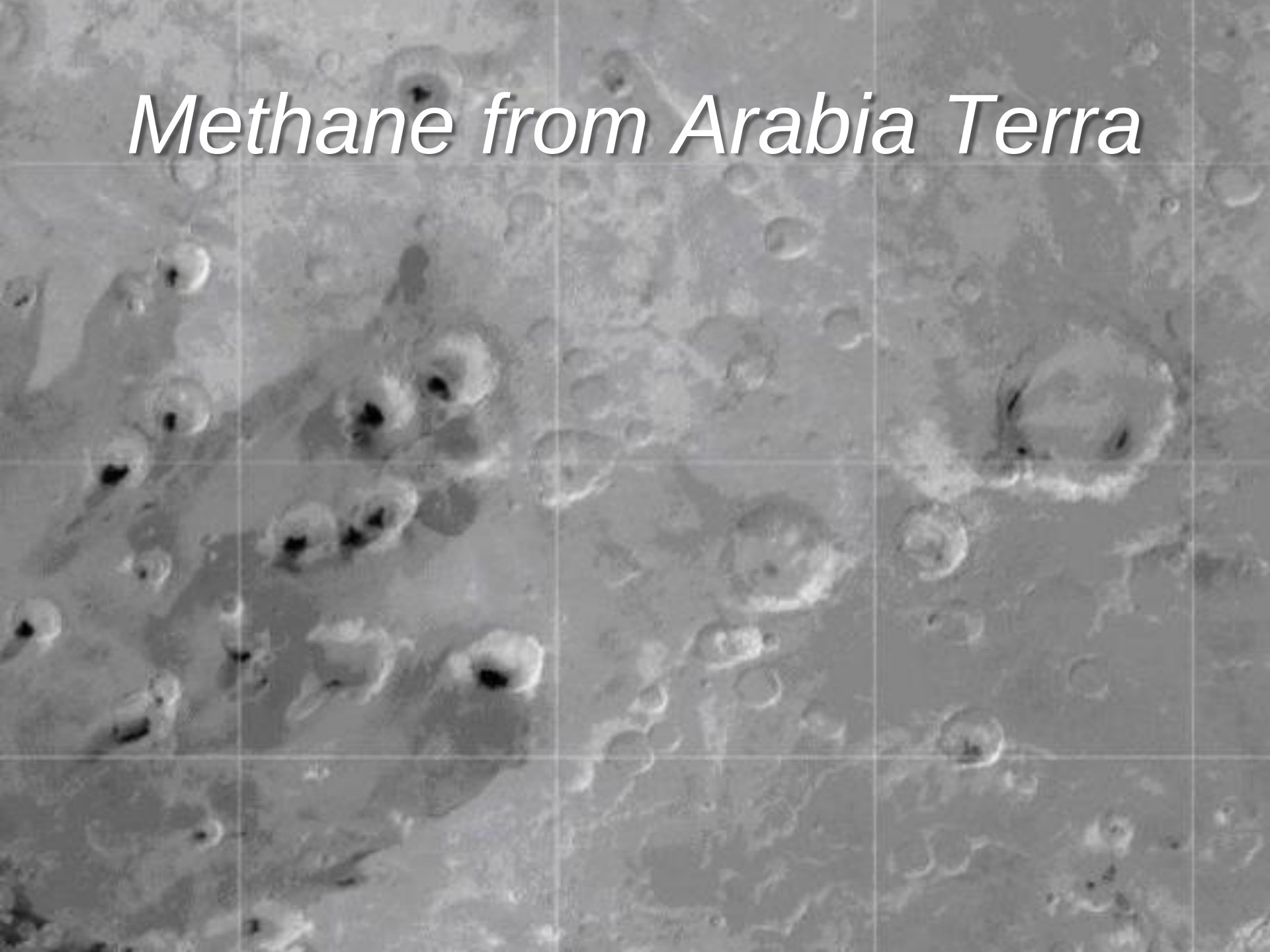
- Viking 1+2 landers
  - Microbes in the soil perform metabolism on supplied organics
- Methane in martian atmosphere
  - Methanogenes?
- Martian meteorites
  - Fossil evidence

Localized Methane release

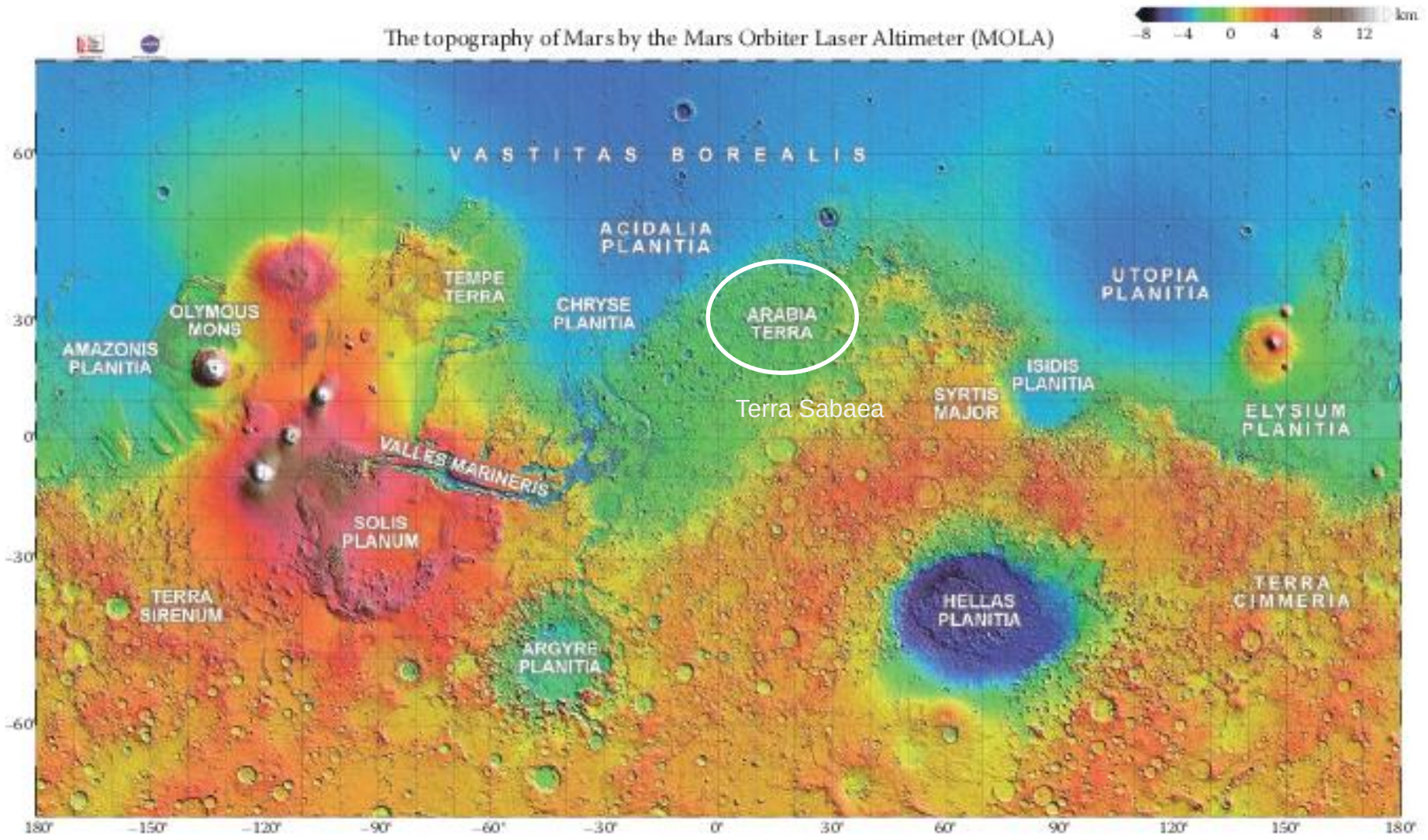


Methane release:
Northern summer

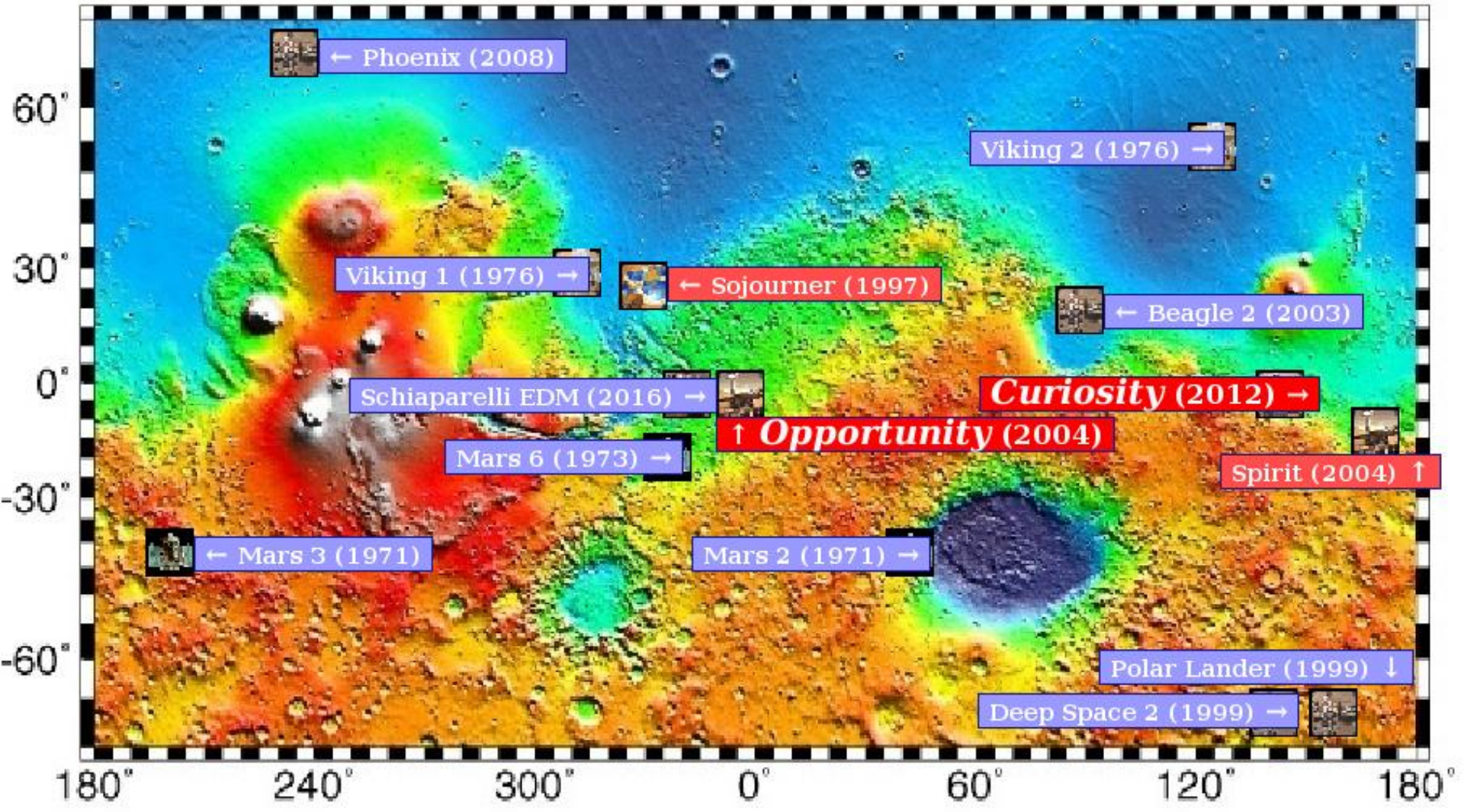



Methane from Arabia Terra

Amazonis Planitia



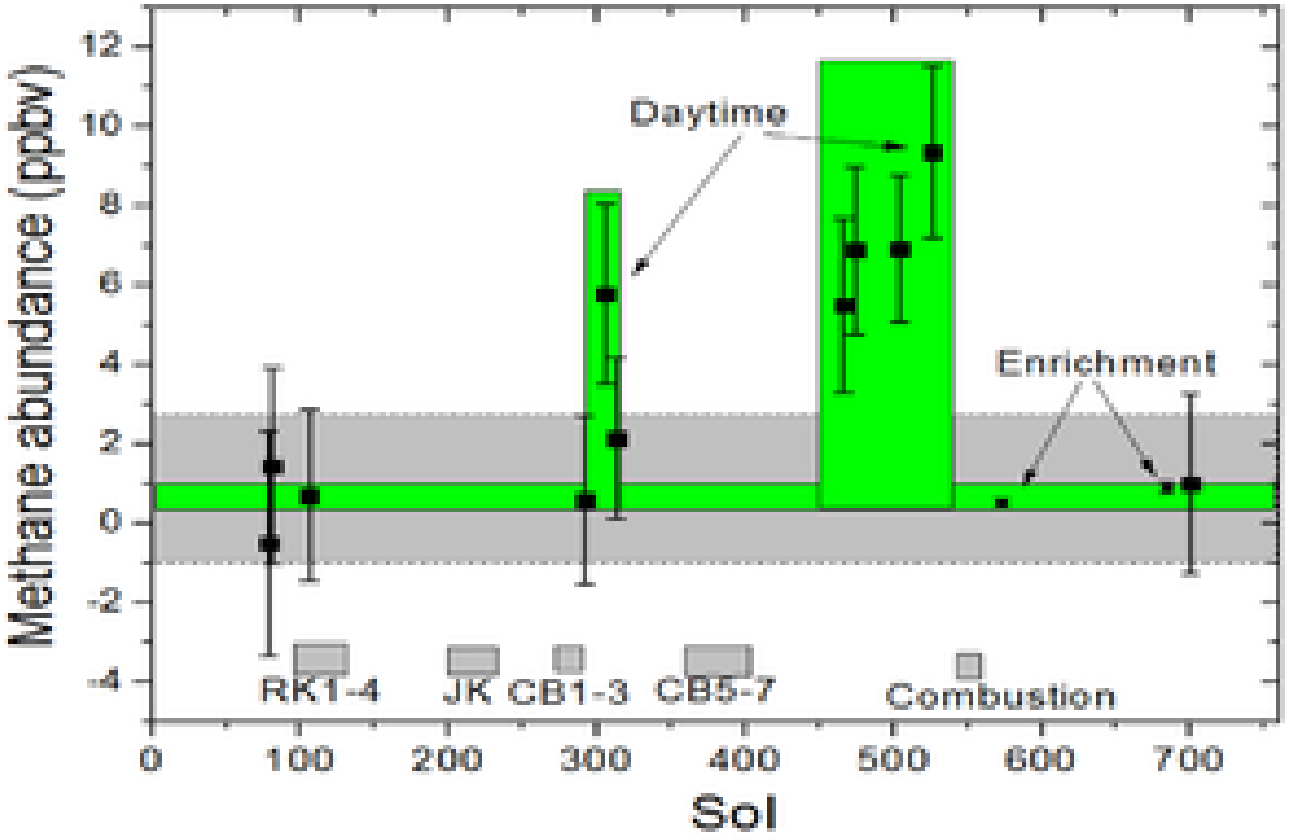
Modern topographic map of Mars



Curiosity to the right of Arabia Terra

Curiosity measures CH_4

- Episodic releases
- Spike in 2014



Is CH_4 organic or inorganic?

A. Organic

B. Inorganic

C. Too simple a molecule to tell

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A. Organic

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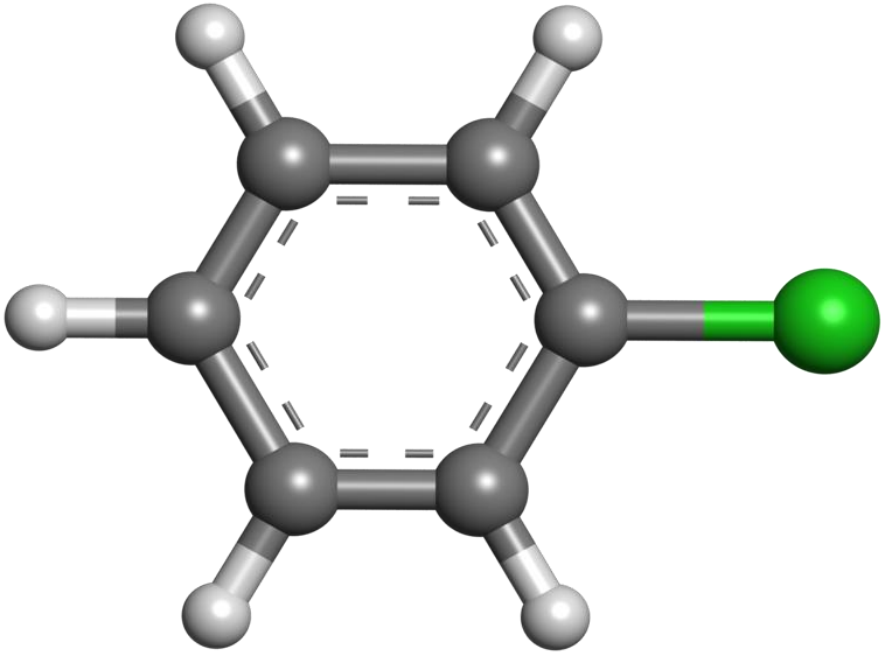
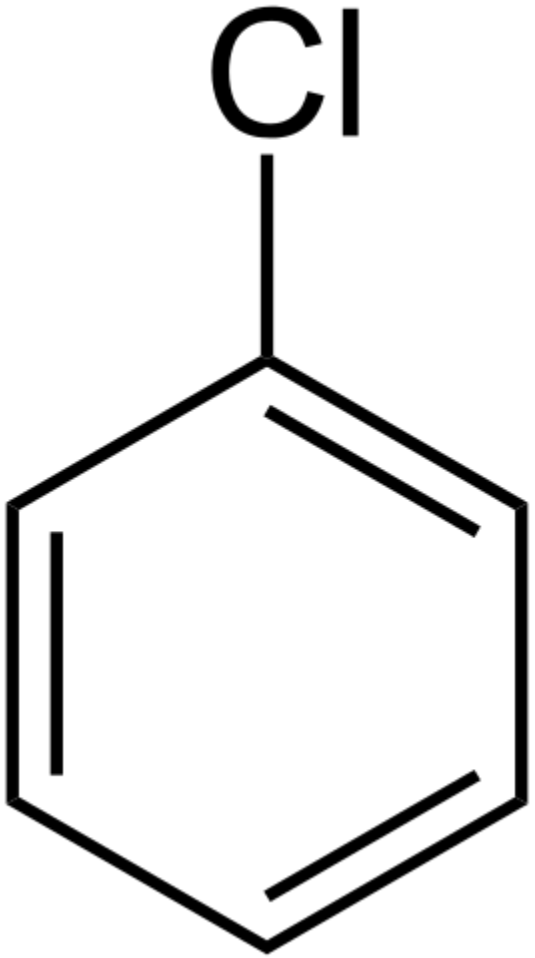
C. Too simple a molecule to tell

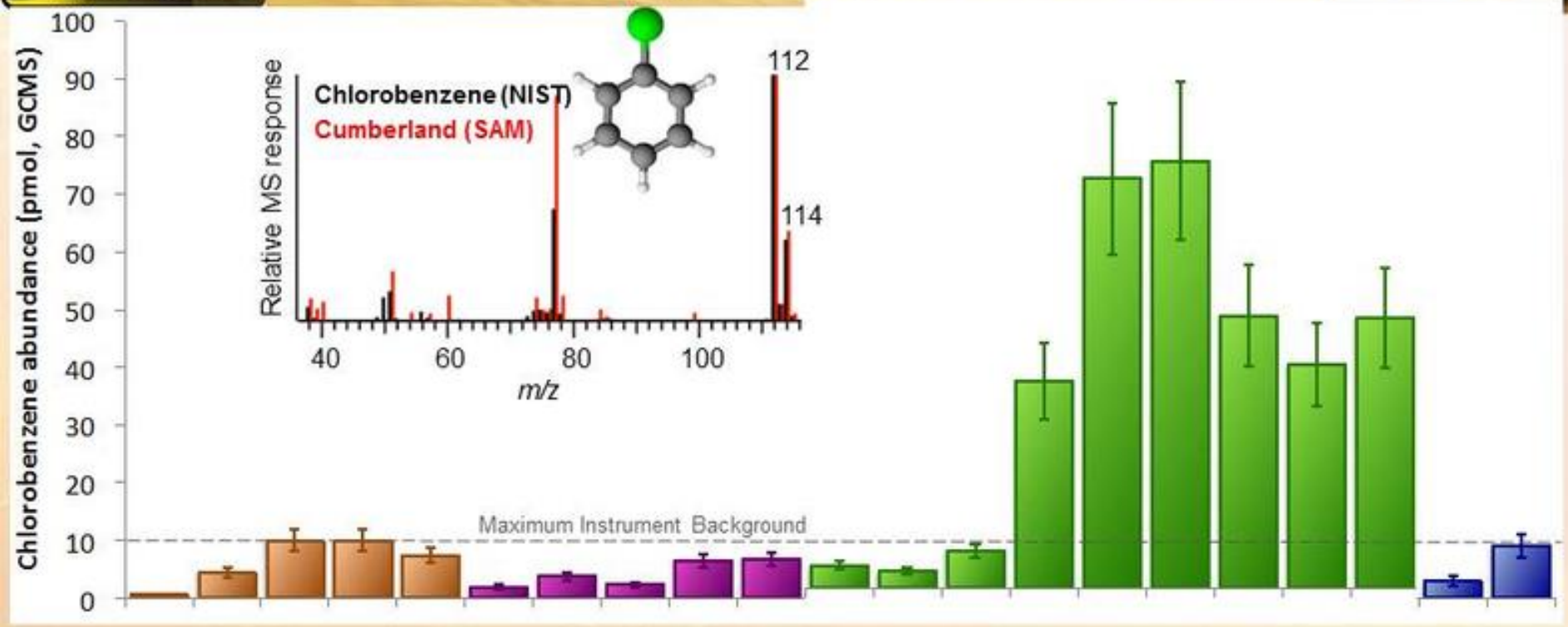
Curiosity detects C_6H_5Cl

- In sedimentary rocks



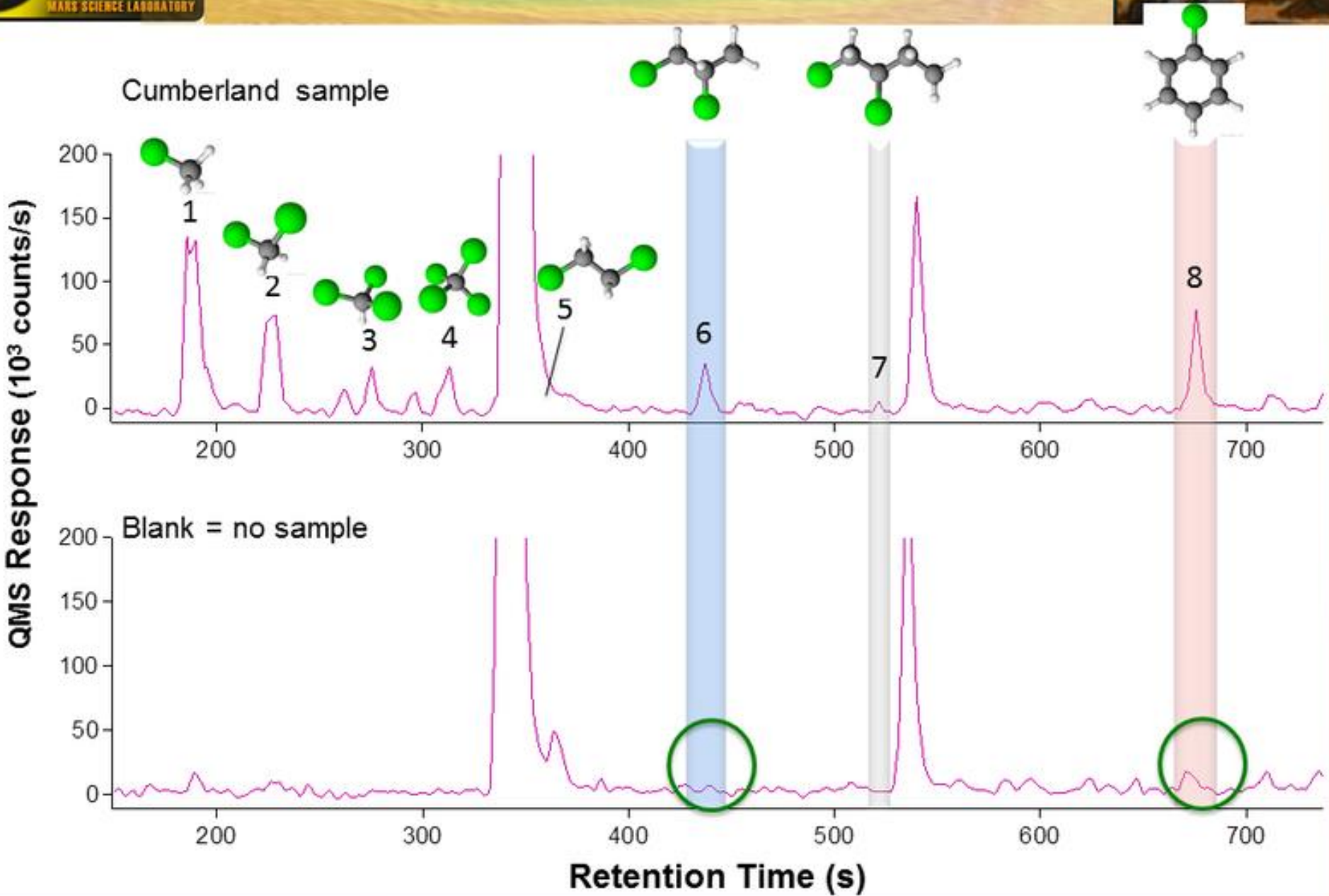


Sample comparisons reveal a compelling result

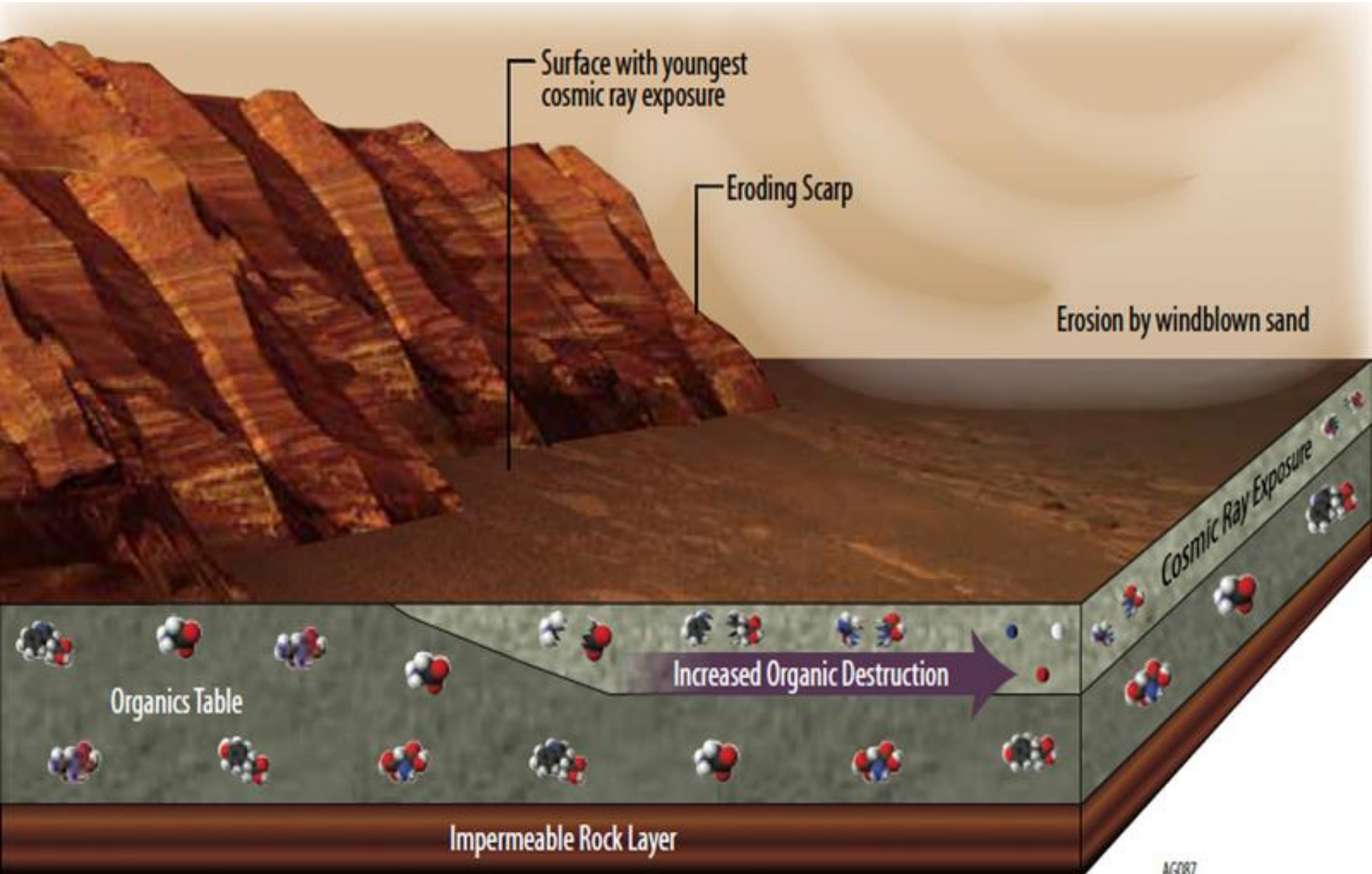


ROCKNEST | JOHN KLEIN | CUMBERLAND | CONFIDENCE HILLS

Some of the SAM Data

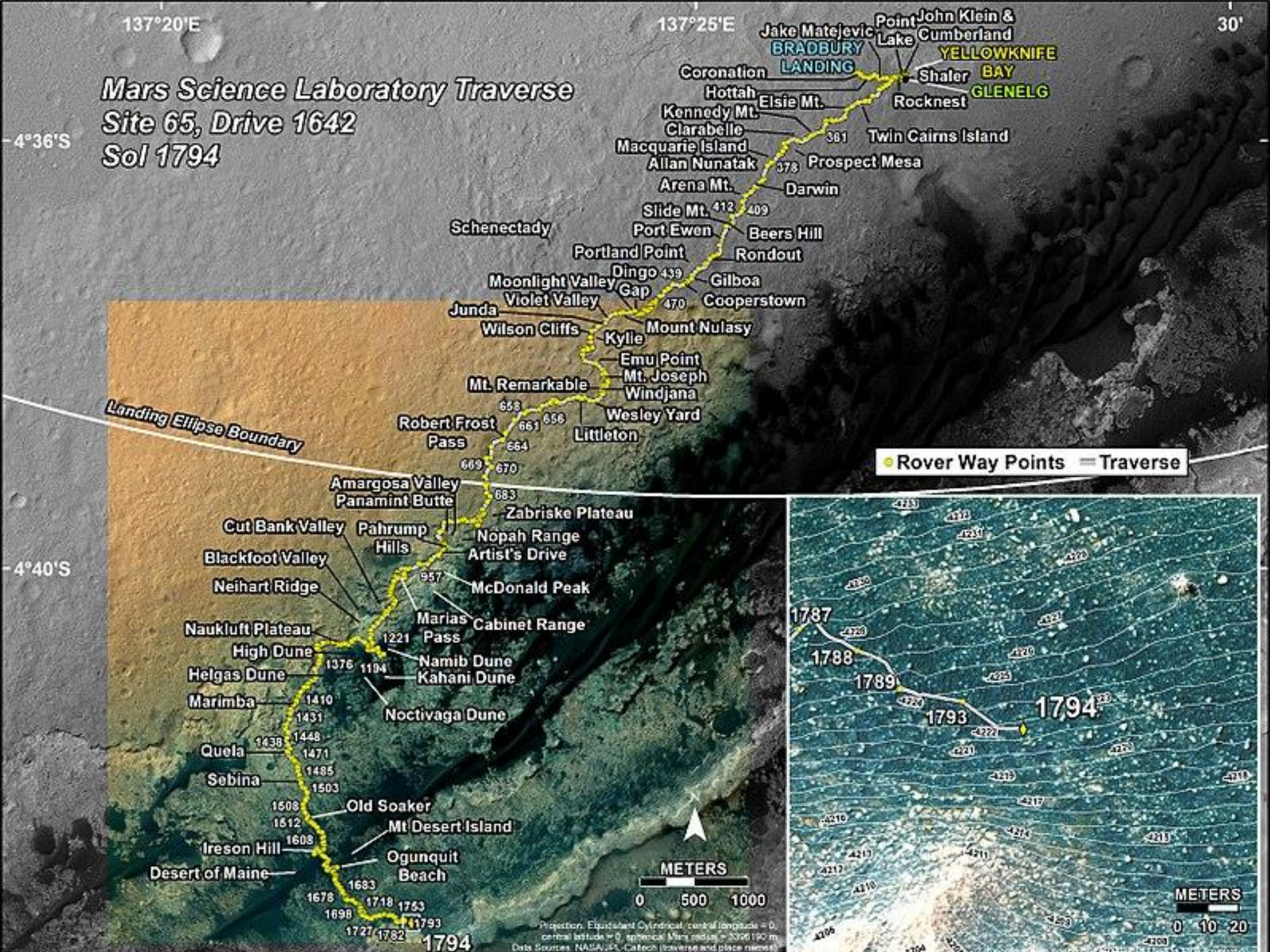


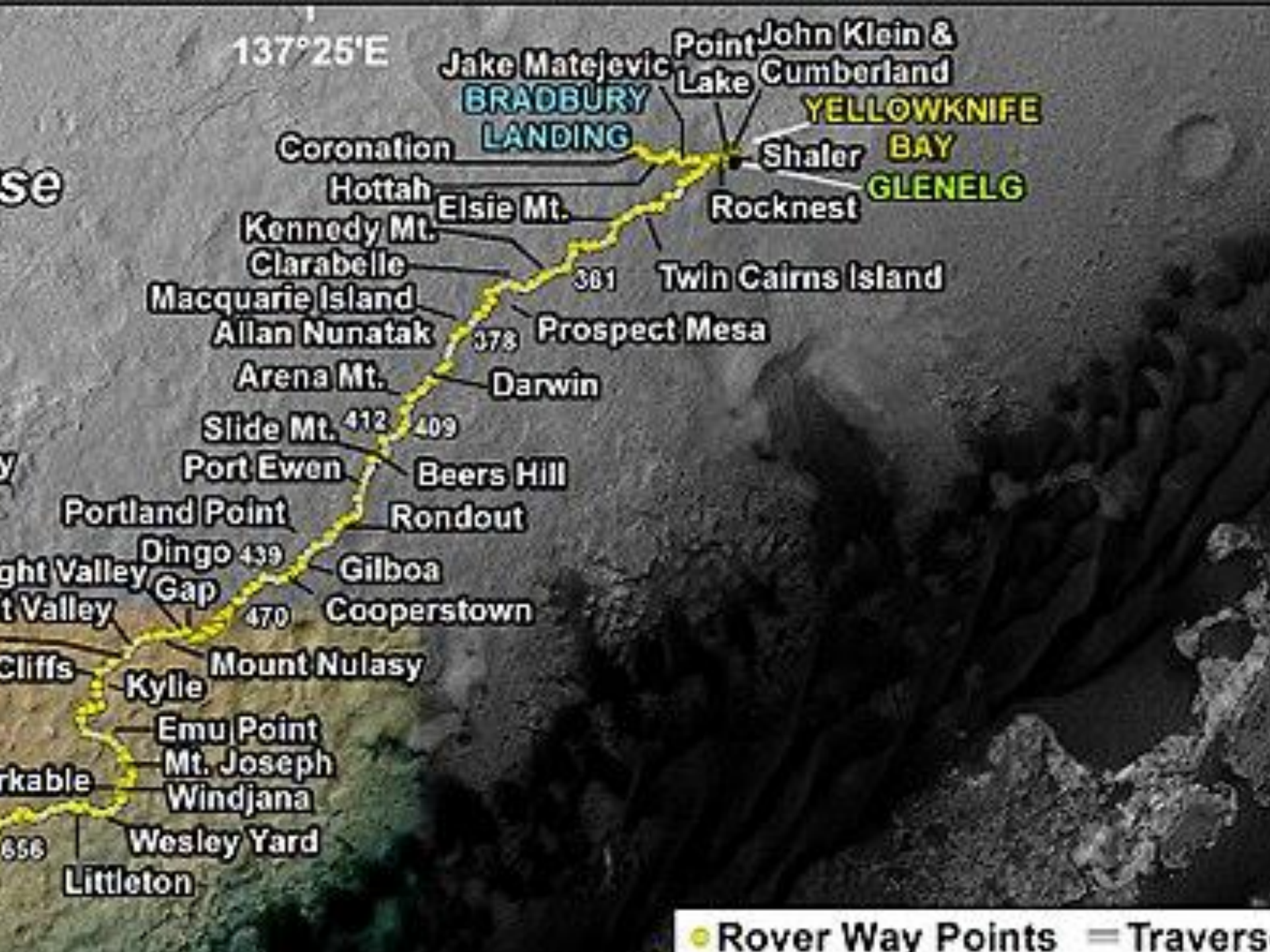
Searth for organics



Curiosity rover

- Mars Science Laboratory (MSL)
- Since August 2012 (15 km, launch Nov 2011)
- Here: Mount Sharp (=Aeolis Mons, Sep 9, 2015)


Mars Science Laboratory Traverse
Site 65, Drive 1642
Sol 1794
137°20'E
137°25'E
30'
4°36'S
4°40'S
Jake Matejevic
Point Lake
John Klein & Cumberland
BRADBURY LANDING
YELLOWKNIFE BAY
GLENELG
Coronation
Shaler
Hottah
Elsie Mt.
Rocknest
Kennedy Mt.
Clarabelle
361
Twin Cairns Island
Macquarie Island
Allan Nunatak
378
Prospect Mesa
Arena Mt.
Darwin
Slide Mt.
412
409
Schenectady
Port Ewen
Beers Hill
Portland Point
Rondout
Dingo
439
Gilboa
Moonlight Valley
Gap
Violet Valley
470
Cooperstown
Junda
Wilson Cliffs
Mount Nulasy
Kylie
Emu Point
Mt. Joseph
Mt. Remarkable
Windjana
653
Wesley Yard
Robert Frost
661
656
Littleton
Pass
664
669
670
Landing Ellipse Boundary
Amargosa Valley
Panamint Butte
683
Zabriske Plateau
Cut Bank Valley
Pahrump Hills
Nopah Range
Artist's Drive
Blackfoot Valley
957
McDonald Peak
Neihart Ridge
Marias Pass
Cabinet Range
Naukluft Plateau
1221
High Dune
1376
1194
Namib Dune
Kahani Dune
Helgas Dune
Marimba
1410
1431
Noctivaga Dune
1438
1448
Quela
1471
1485
Sebina
1503
1508
Old Soaker
1512
Mt Desert Island
1608
Ireson Hill
Ogunquit Beach
Desert of Maine
1683
1678
1718
1763
1698
1793
1727
1782
1794
Rover Way Points
Traverse
METERS
0 500 1000
1787
1788
1789
1793
1794
METERS
0 10 20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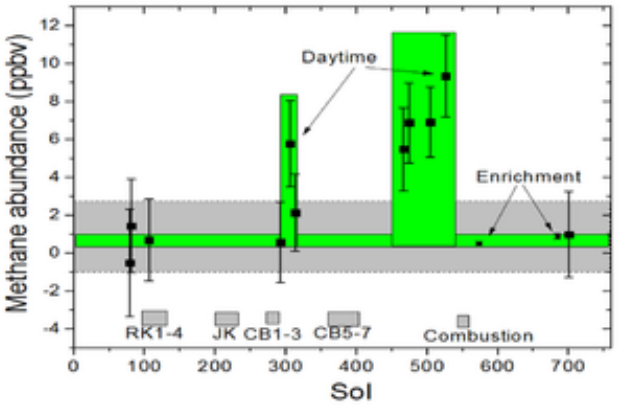
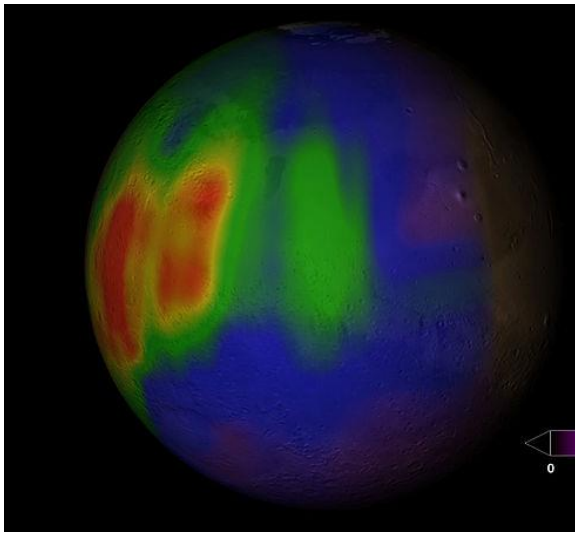
Rover Way Points
Travers

Curiosity measures CH_4

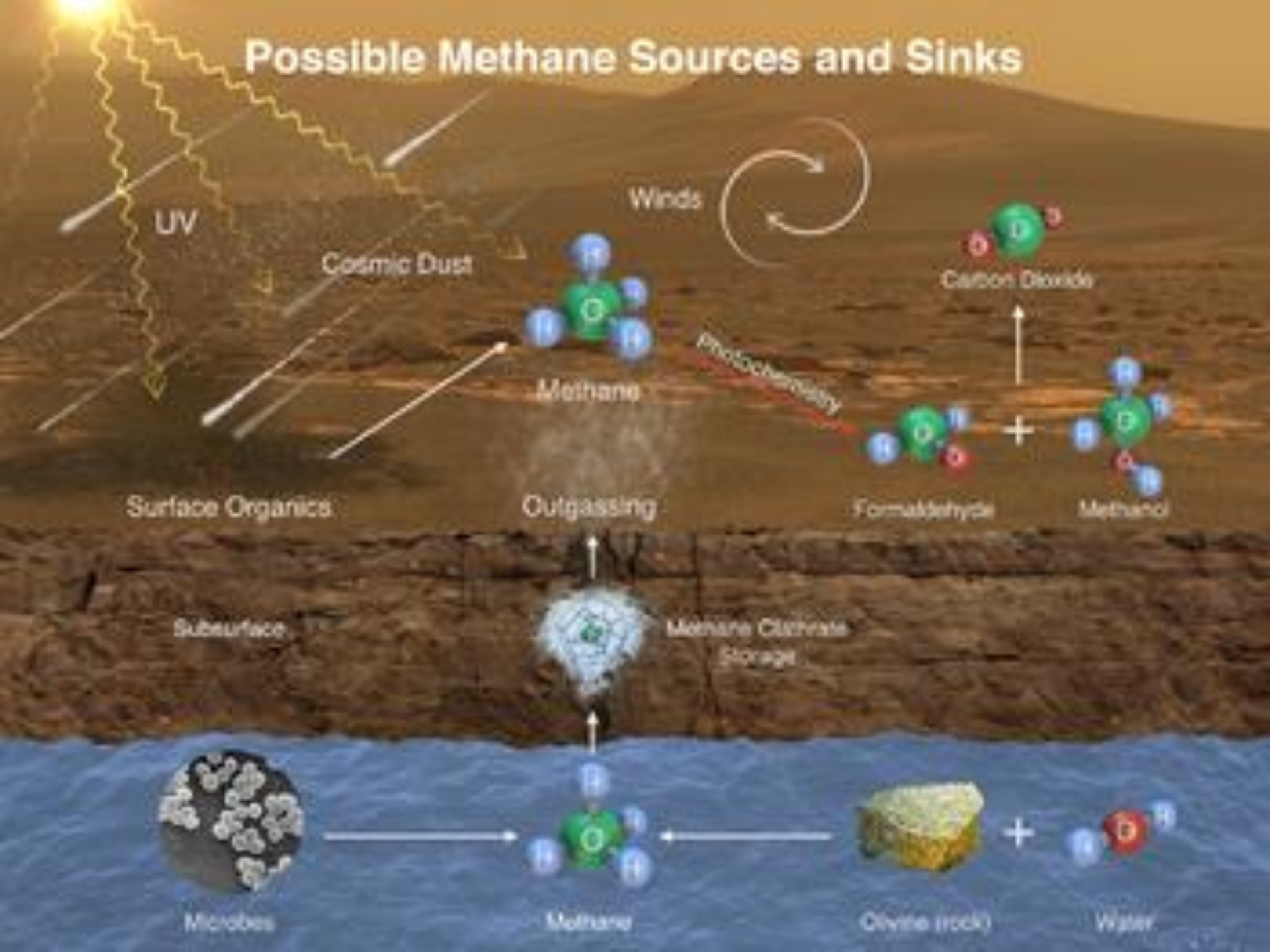
- ppbv part/billion volume
  - 0…30 detected since 2003 using IR at Hawaii
  - Quickly oxidized (~1 yr)
- Outgassing from volcanoes would be surprising
  - $3H_2 + CO \rightarrow CH_4 + H_2O$
- Methanogens: a possibility
  - $4H_2 + CO_2 \rightarrow CH_4 + 2H_2O$





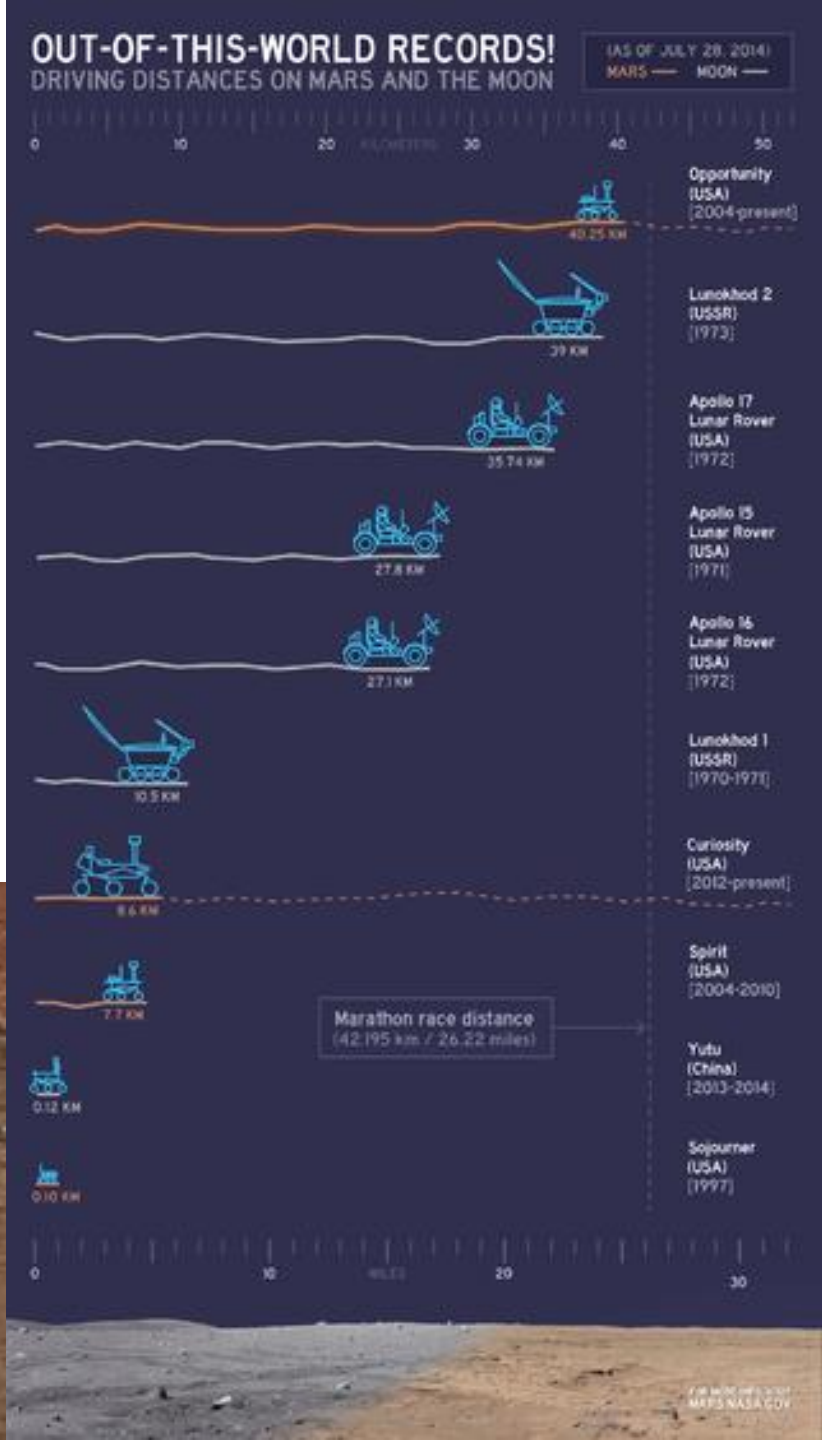
Fischer-Tropsch reaction

- Non-biological methane production
- $3H_2 + CO \rightarrow CH_4 + H_2O$
- Nickel as catalyst
- Was attempted during wartime for fuel…


Possible Methane Sources and Sinks
UV
Cosmic Dust
Winds
Methane
Photochemistry
Carbon Dioxide
Formaldehyde
Methanol
Surface Organics
Outgassing
Subsurface
Methane Clathrate Storage
Microbes
Methane
Olivine (rock)
Water

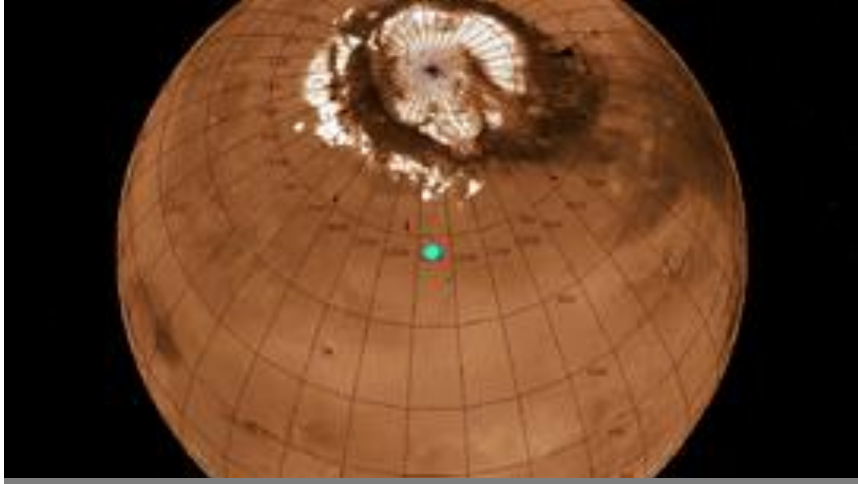
Rovers

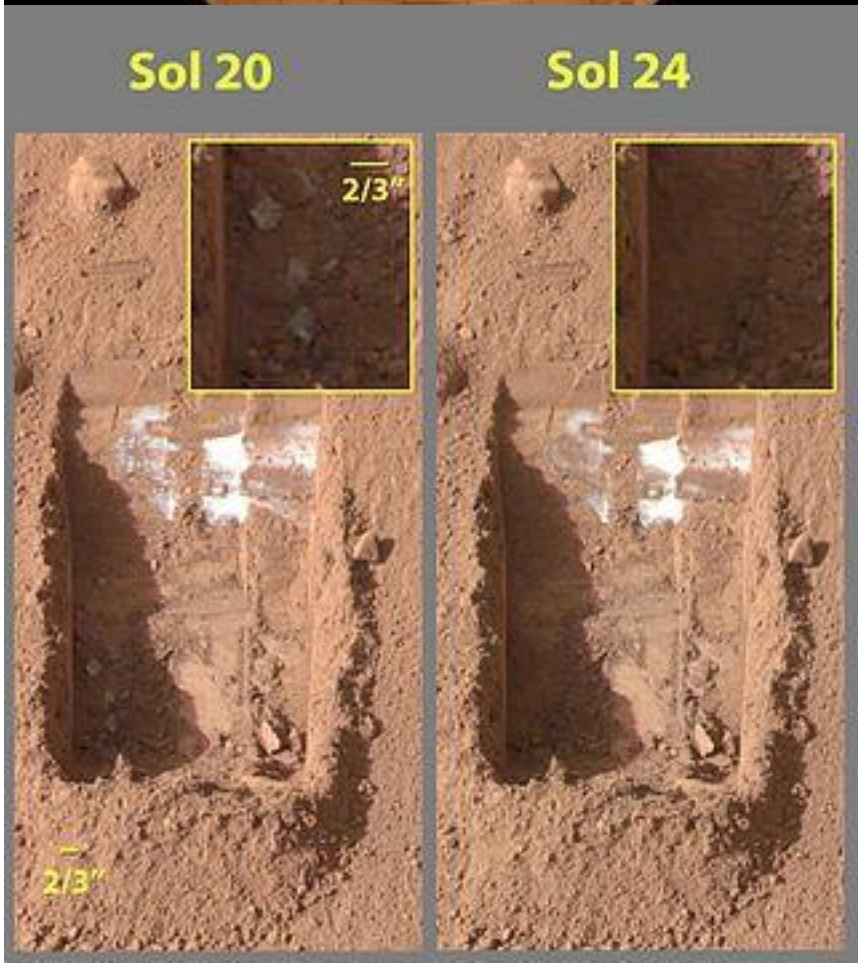
- Opportunity (2004-…)
  – 42 km after 11 yr!
- Apollo 17, 36 km
- Curiosity 15 km



Other missions

- 43 missions, 55% loss
- Pathfinder (1997), first success after 1976!
- Odyssey Orbiter (2001)
- Mars Reconnaissance orbiter (2005)
- Phoenix (2008)
- MAVEN (2012)





Organics detected on Mars?

A. Yes, as known from meteorites
B. Yes, found in martian meteorites
C. Some organics found
D. Nothing at all

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What have we learned?

- Old ideas that Mars had plants and inhabitants were disproved by the first space missions
  - Viking experiments failed to detect life: positive results from chemistry, not biology
  - but only looked for Earth-like life
  - Curiosity: methane variations, life indicator?
- *Next time*: Mars had much more liquid water
  - too cold for liquid water on the surface now
  - water today? minimal and very salty: frozen at poles, buried as permafrost; the rest lost to space

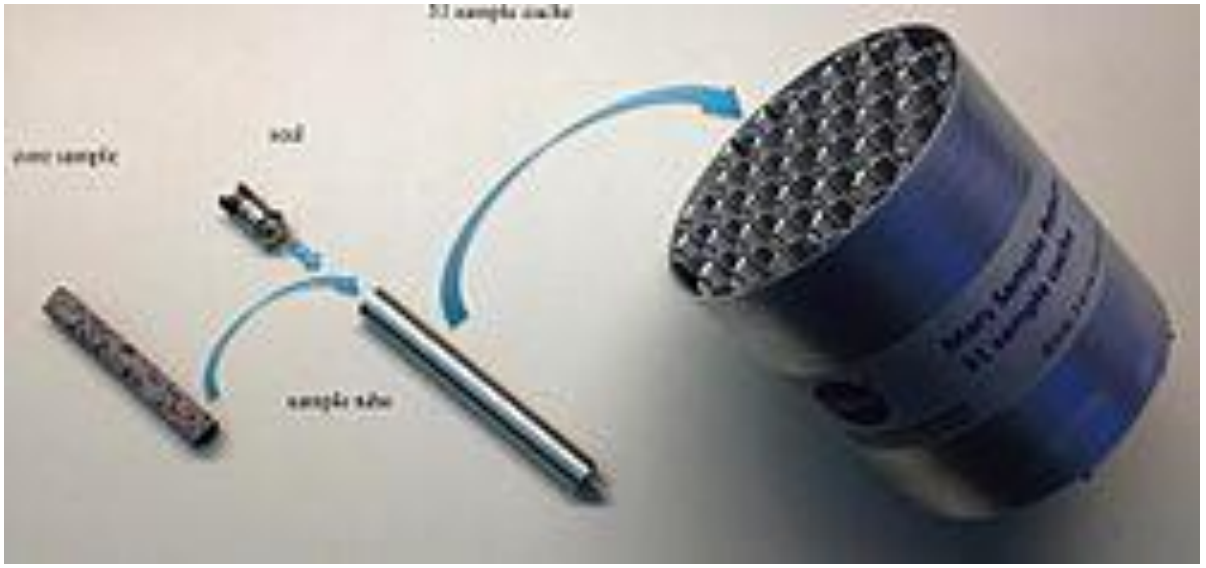
Future Mars Research

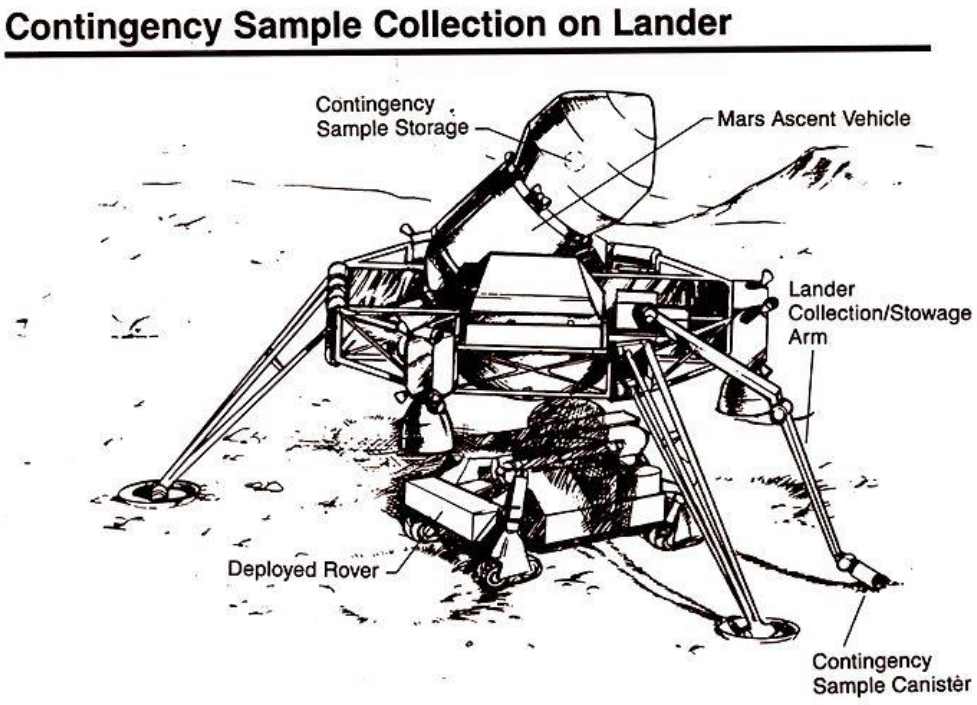
- Sample return
  - Study in detail
  - Mars 2020 Rover: to store for later pick-up

Ideas…

- Later pickup
- 2 step
- 3 step

- etc





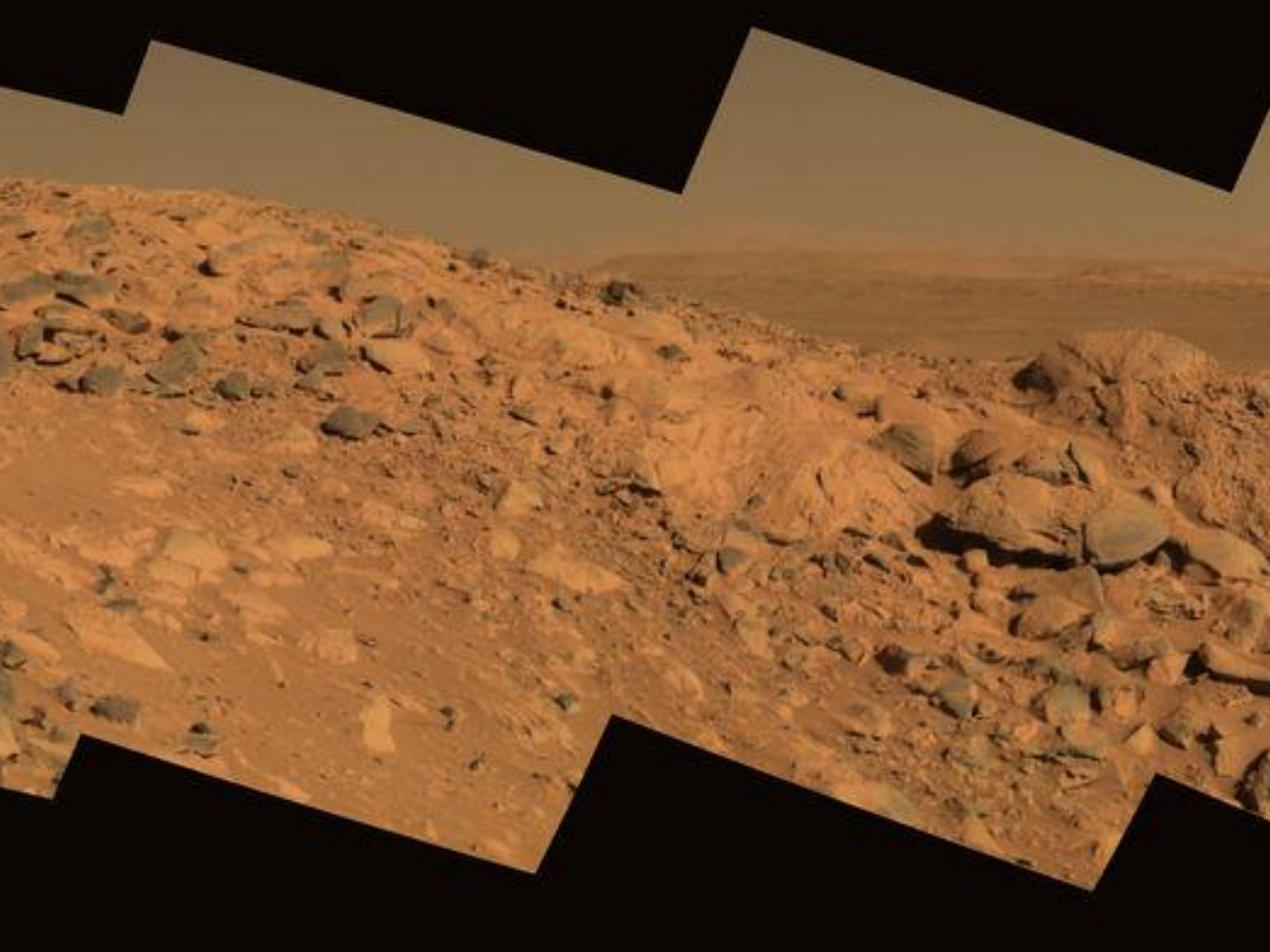
Contingency Sample Collection on Lander

Mars 2020 Rover: landing sites

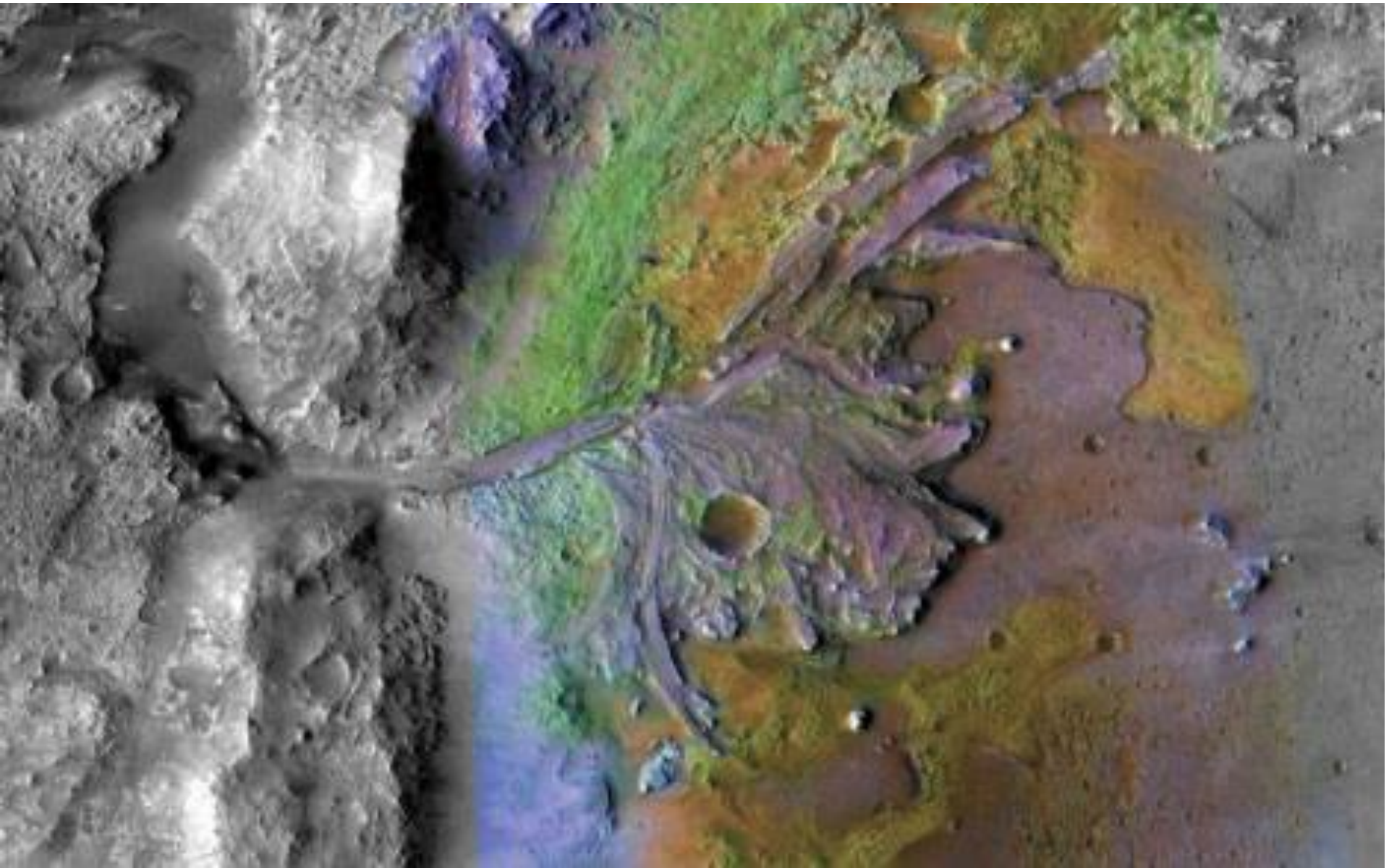
Mars 2020 Rover: landing sites

http://mars.nasa.gov/mars2020/mission/timeline/prelaunch/landing-site-selection/

- Gusev crater: Rover Spirit found hot springs
  - But only at one site; rest was lava
- Jezero crater: wet → dry → wet …
  - Water filled crater, then drained away
  - Then rivers spilled over crater walls → picture….
- NE Syrtis: underground heat sources
  - Microbial life flourished here?



Jezero



NE Syrtis

Mission timeline

- 2018: InSight (**In**terior Exploration using **S**eismic **I**nvestigations, **G**eodesy and **H**eat **T**ransport.)
- 2020: Red Dragon (on Falcon Heavy) = pathfinder for Mars colonization
  - 2020 Mangalyaan 2 (India)
  - 2020 Emirates Mars Mission
  - 2020 Mars 2020 (NASA)
  - 2020 Exomars (ESA, with 2m drill)
  - 2020 Chinese Mars Mission

Planetary protection

- Forward protection
- Backward protection

Levin & Straat (2016)

In summary, in the absence of a nonbiological agent that satisfies all Viking findings, and in view of environmental evidence that Mars may well be able to support extant life, it seems prudent that the scientific community maintain biology as a viable explanation of the LR experimental results. It seems inevitable that astronauts will eventually explore Mars. In the interest of their health and safety, biology should be held in the forefront of possible explanations for the LR results. Plans for any Mars sample return mission

Forward contamination

- Viking probes
- Dry – Heat (oxidation)
  - 135C for 8 hours
  - Hydrogen peroxide plasma
  - Gamma radiation
- Max 300,000 microbes per Martian Lander
- Human sneezing: 10^6 microbes!

Planetary protection

- Why important?
  - Don’t want to detect terrestrial life
- What to consider?
- And what is meant?

Ethical issues

- Terrestrial life outcompete Martian
- Do we have the right to do this?

Or

- Unleash dangerous Martian microbes
- Unprepared
- Outcompete Terrestrial life
  - Unlikely: highly adapted
  - Species jumping very rare
  - Example HIV chimpanzee (SIV) → human
- Natural contamination (reach Earth already)
- Cautious: high stakes involed

To survive crash …

- Columbia disaster….
- Astrobiology experiment survived

Should we send humans?

- 3 – 4 months travel time
  - Food, air, water, radiation
- Humans more capable
  - Complicates issue of finding life
  - Check your mouth
- Human travel not driven by science
- Terraforming
  - Greenhouse gases from CFCs

chlorofluorocarbons

Axel Brandenburg Thu Mar 16, 10:04 PM
NORDITA - Nordic In... Boulder Links Publications Meeting Room Book... Google Trans Boulder Links Google Scholar
List of missions to Mars - Wik...

Proposals [edit]

Mission	Launch	Notes	Country or Space Agency
NASA 2022 orbiter	2022	Telecomm orbiter[28]	NASA, USA
	2024	Crewed mission to Mars[*citation needed*]	SpaceX, USA
Mars One	2026[29]	Orbiter, lander, rover, Human Colony	Mars One, USA
	2030[30]	Sample return phase of the Chinese Mars exploration program	CNSA, PRC
	2036[27]	Crewed phase of the Chinese Mars exploration program	CNSA, PRC
	2040–45	Crewed phase of the Russian Mars exploration program[31]	Роскосмос (Roscosmos), Russian Federation
Mars to Stay		Settlement[*citation needed*]	United States

Missions to the moons of Mars [edit]

Friday

- Venus
  - https://en.wikipedia.org/wiki/Life_on_Venus
  - BS pp. 339 – 345
- Icy words: our south pole