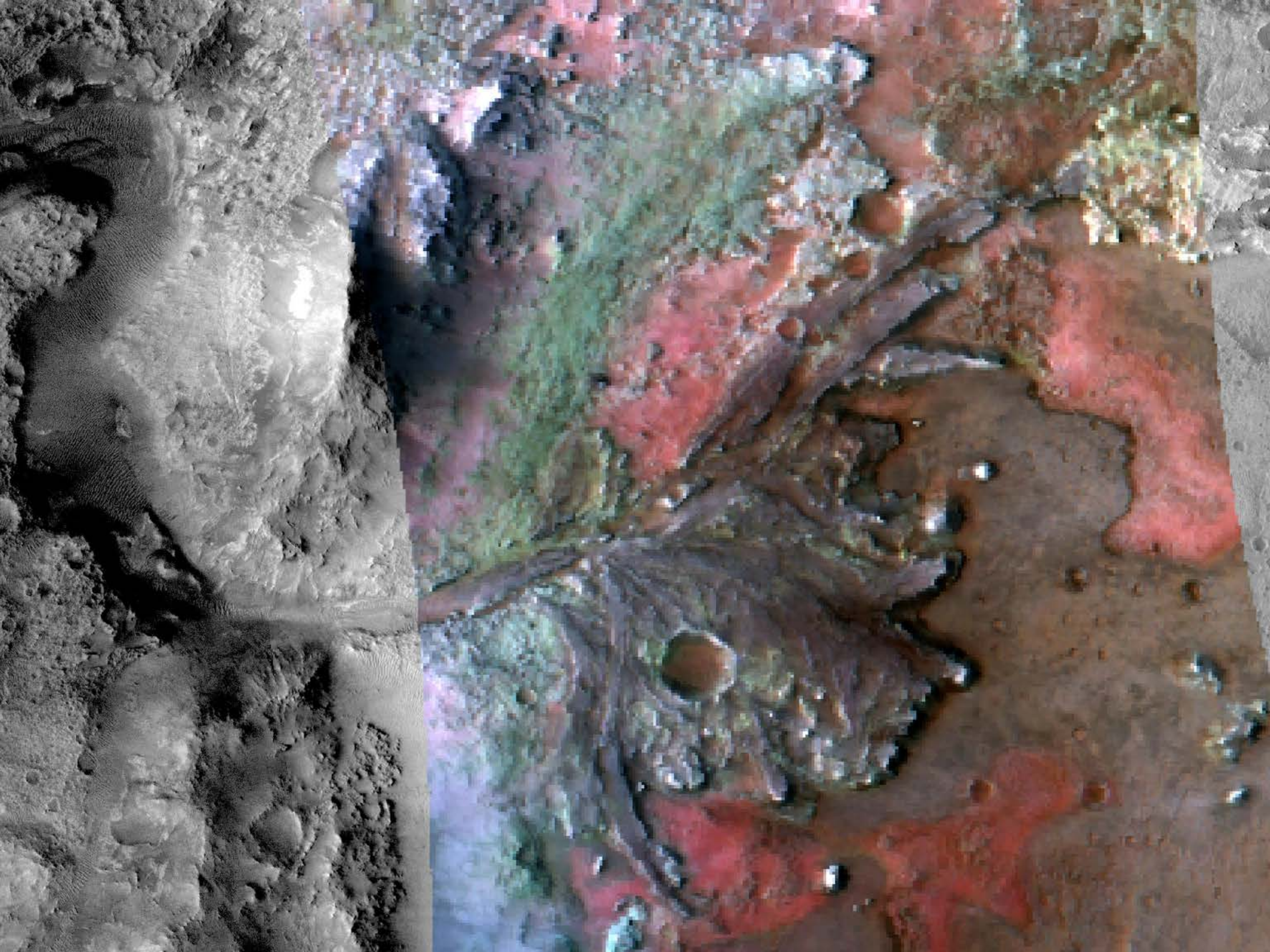
The University of Texas at Austin
Environmental Science Institute

Hot Science - Cool Talk # 123

NASA's Next Mission to Mars: Searching for life on the Red Planet

Dr. Tim Goudge
February 28, 2020

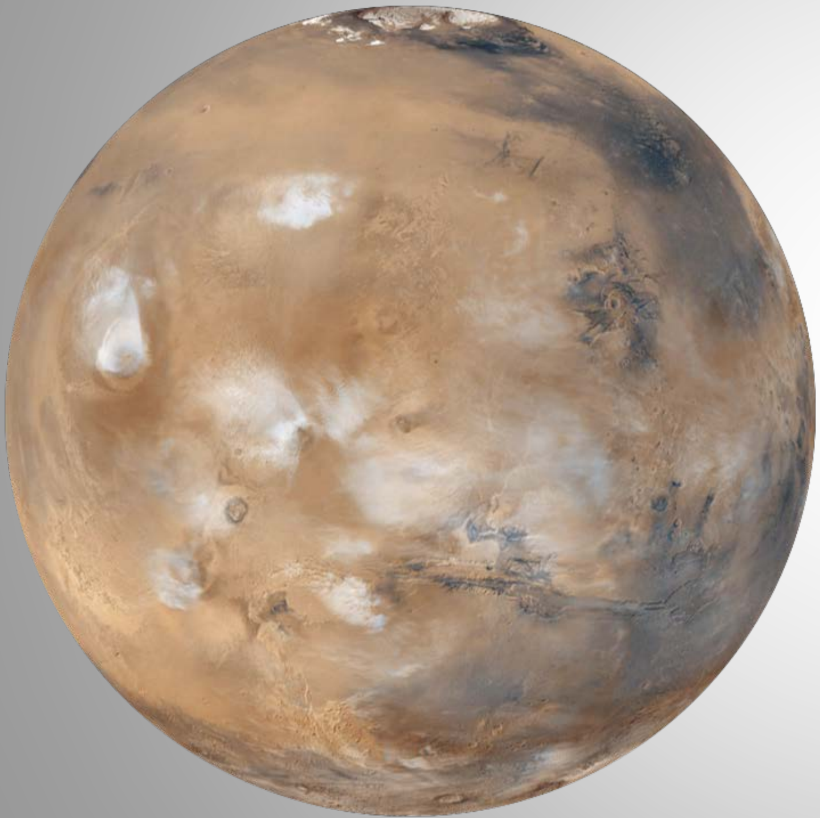


NASA's Next Mission to Mars:
Searching for Life on the Red Planet

Tim Goudge
Dept. of Geological Sciences, UT – Austin
Pronouns: he/him
@timgoudge

Hot Science Cool Talks **2/28/2020**

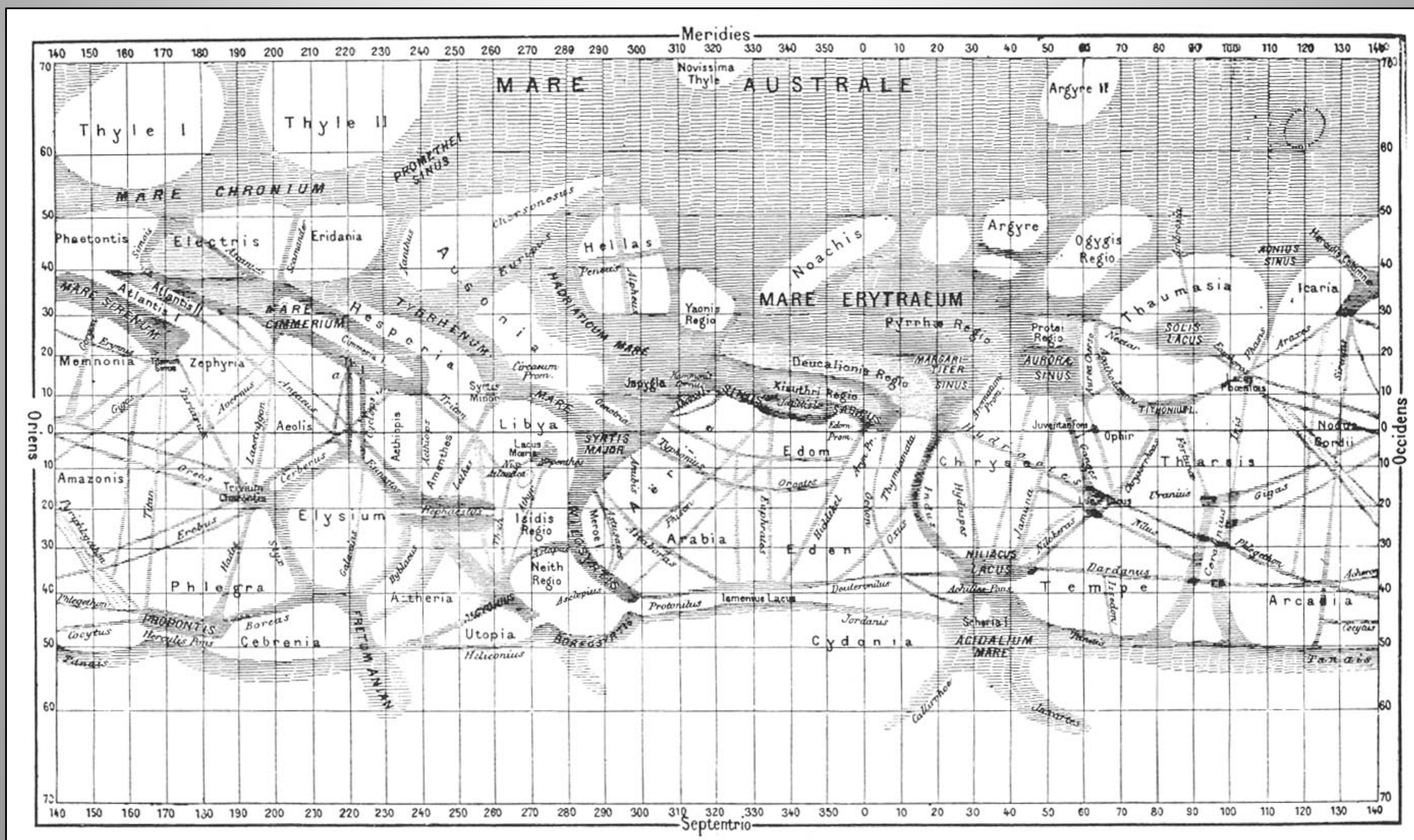
Mars 101



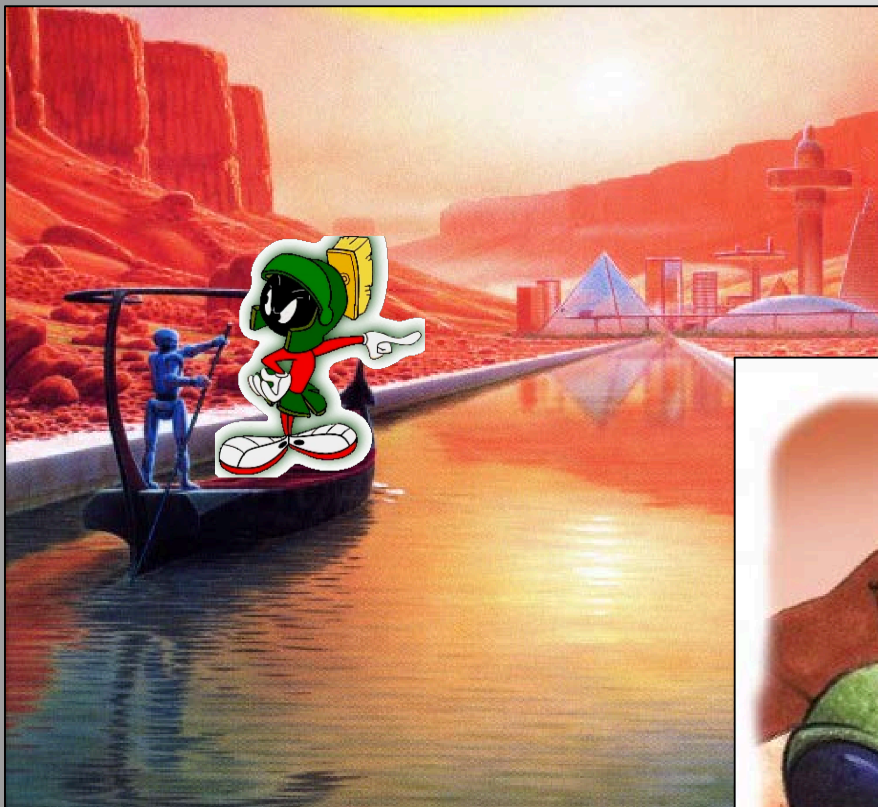
- Avg. Distance from Sun = 1.5 AU
- Day Length = 24.7 h = 1 'sol'
- Orbital Period (year) = 687 d = 669 sols
- Avg. Radius = 3390 km (~0.5 Earth radii)
- Surface Gravity = 3.71 m/s^2 (~0.4 Earth gravity)

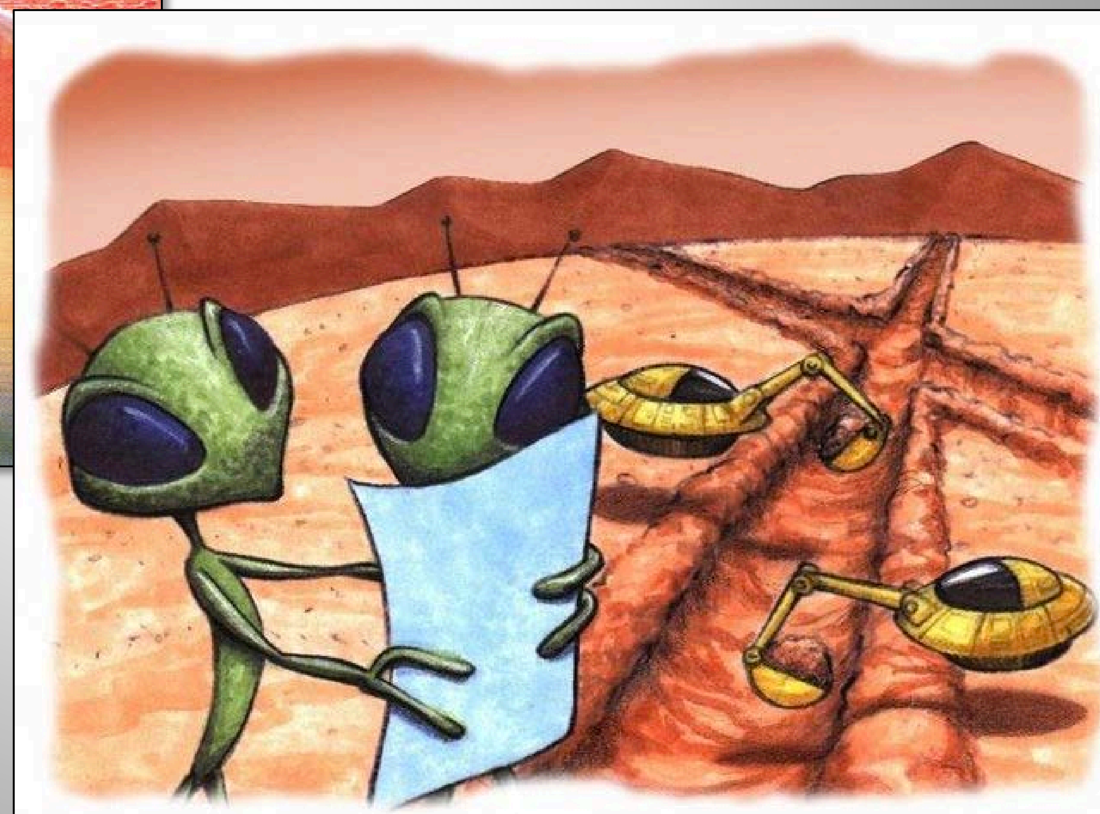
The Earliest Views of Mars

- 1877 - Giovanni Schiaparelli maps surface features on Mars, including ‘canali’.

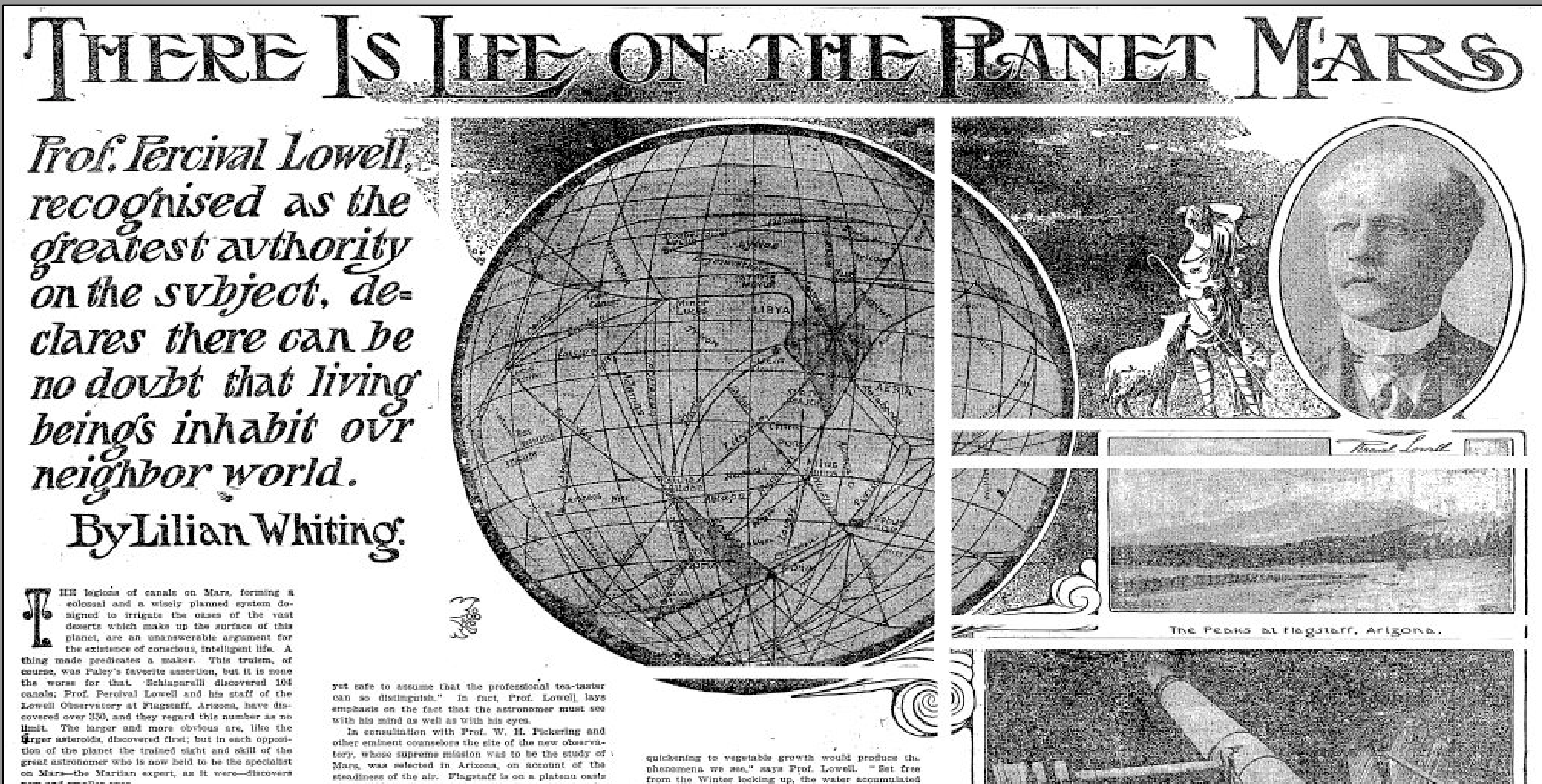


The Earliest Views of Mars





The Earliest Views of Mars



THERE IS LIFE ON THE PLANET MARS

Prof. Percival Lowell, recognised as the greatest authority on the subject, declares there can be no doubt that living beings inhabit our neighbor world.

By Lilian Whiting.

THE legions of canals on Mars, forming a colossal and a wisely planned system designed to irrigate the oases of the vast deserts which make up the surface of this planet, are an unanswerable argument for the existence of conscious, intelligent life. A thing made predicates a maker. This truism, of course, was Paley's favorite assertion, but it is none the worse for that. Schiaparelli discovered 104 canals; Prof. Percival Lowell and his staff of the Lowell Observatory at Flagstaff, Arizona, have discovered over 330, and they regard this number as no limit. The larger and more obvious are, like the larger asteroids, discovered first; but in each opposition of the planet the trained sight and skill of the great astronomer who is now held to be the specialist on Mars—the Martian expert, as it were—discovers new and smaller ones.

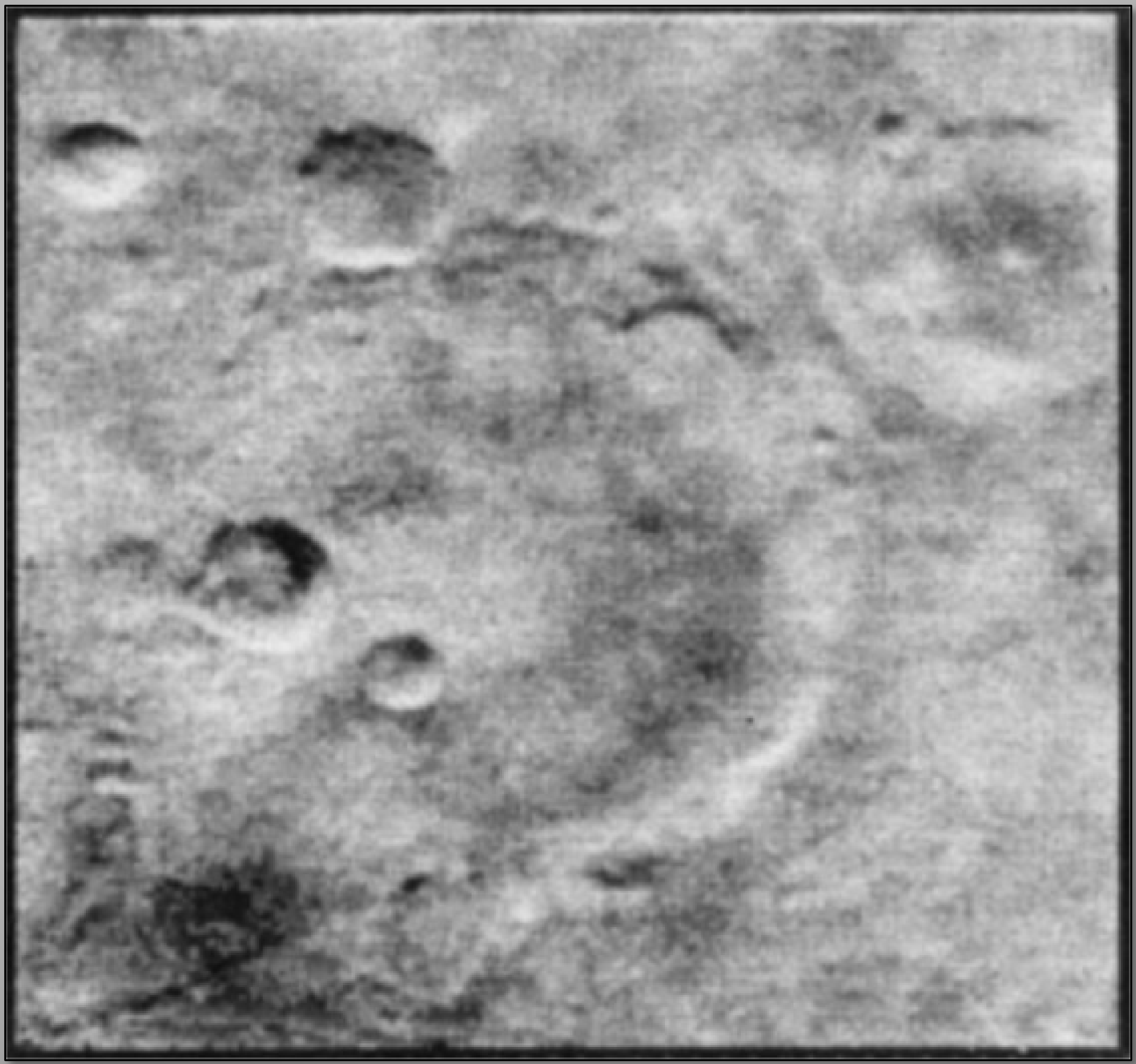
yet safe to assume that the professional tea-taster can so distinguish." In fact, Prof. Lowell lays emphasis on the fact that the astronomer must see with his mind as well as with his eyes.

In consultation with Prof. W. H. Pickering and other eminent counselors the site of the new observatory, whose supreme mission was to be the study of Mars, was selected in Arizona, on account of the steadiness of the air. Flagstaff is on a plateau oasis some 7,000 feet above sea level, with the purple peaks

quickening to vegetable growth would produce the phenomena we see," says Prof. Lowell. "Set free from the Winter locking up, the water accumulated

Article published in *The New York Times*, Dec. 9, 1906

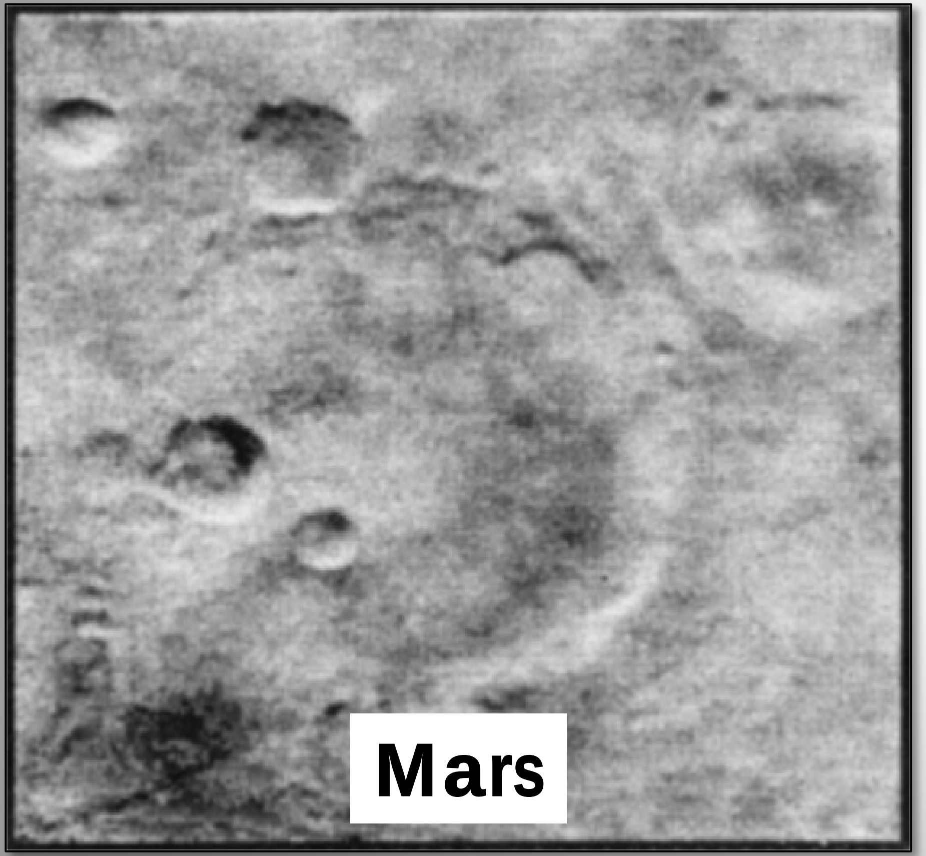
Mariner 4 – First Images of Mars

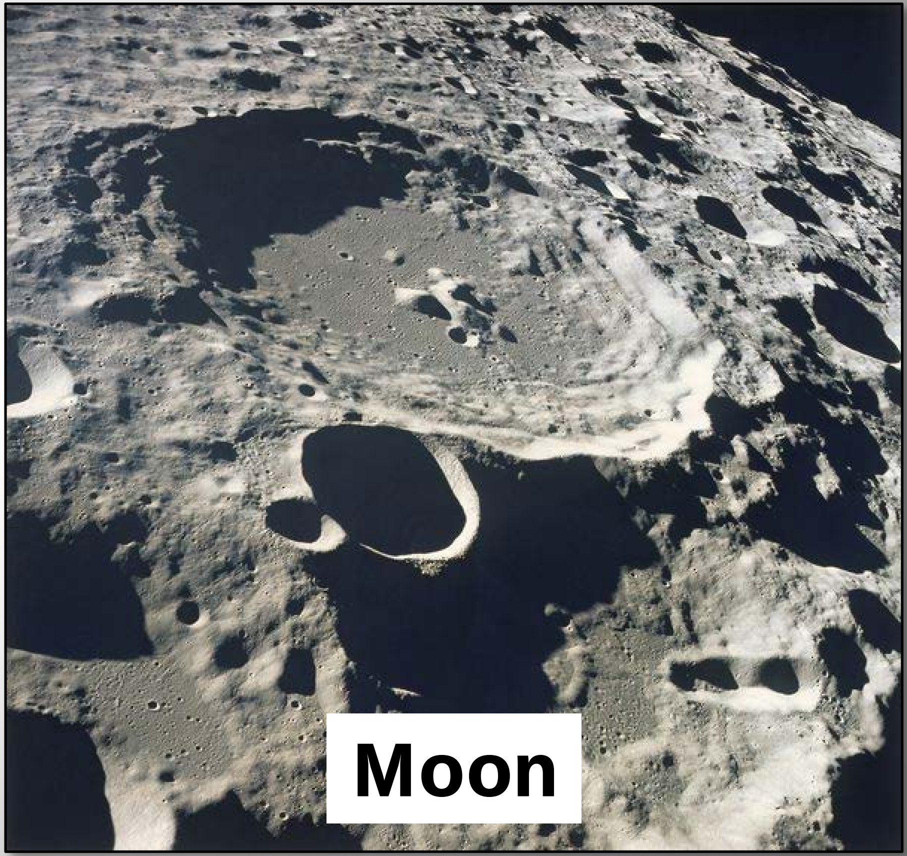


Leighton et al. [1965]

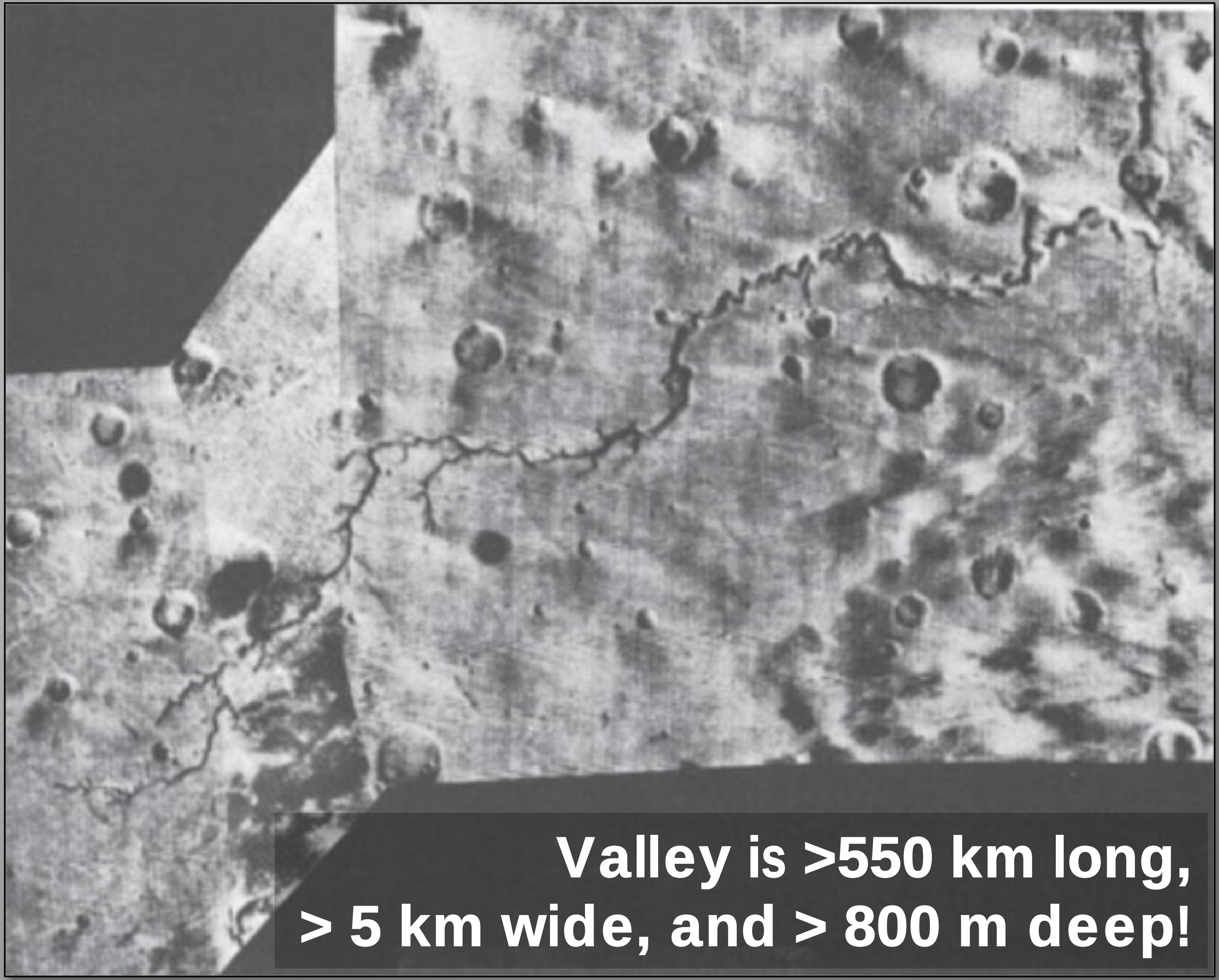
Mariner 4 – First Images of Mars

Maybe Mars looks more like the Moon than Earth??



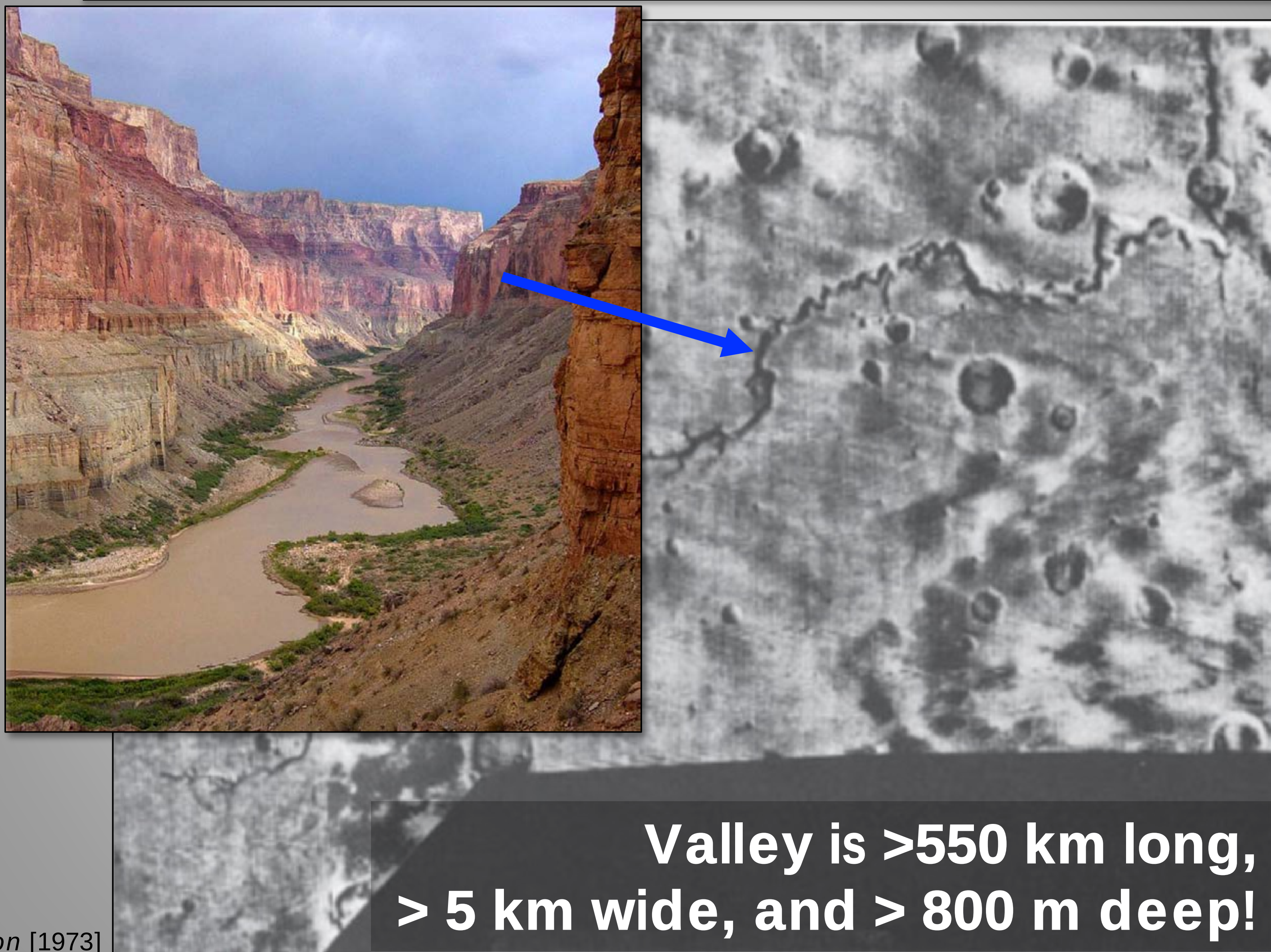


Mariner 9 – First Evidence of Water!



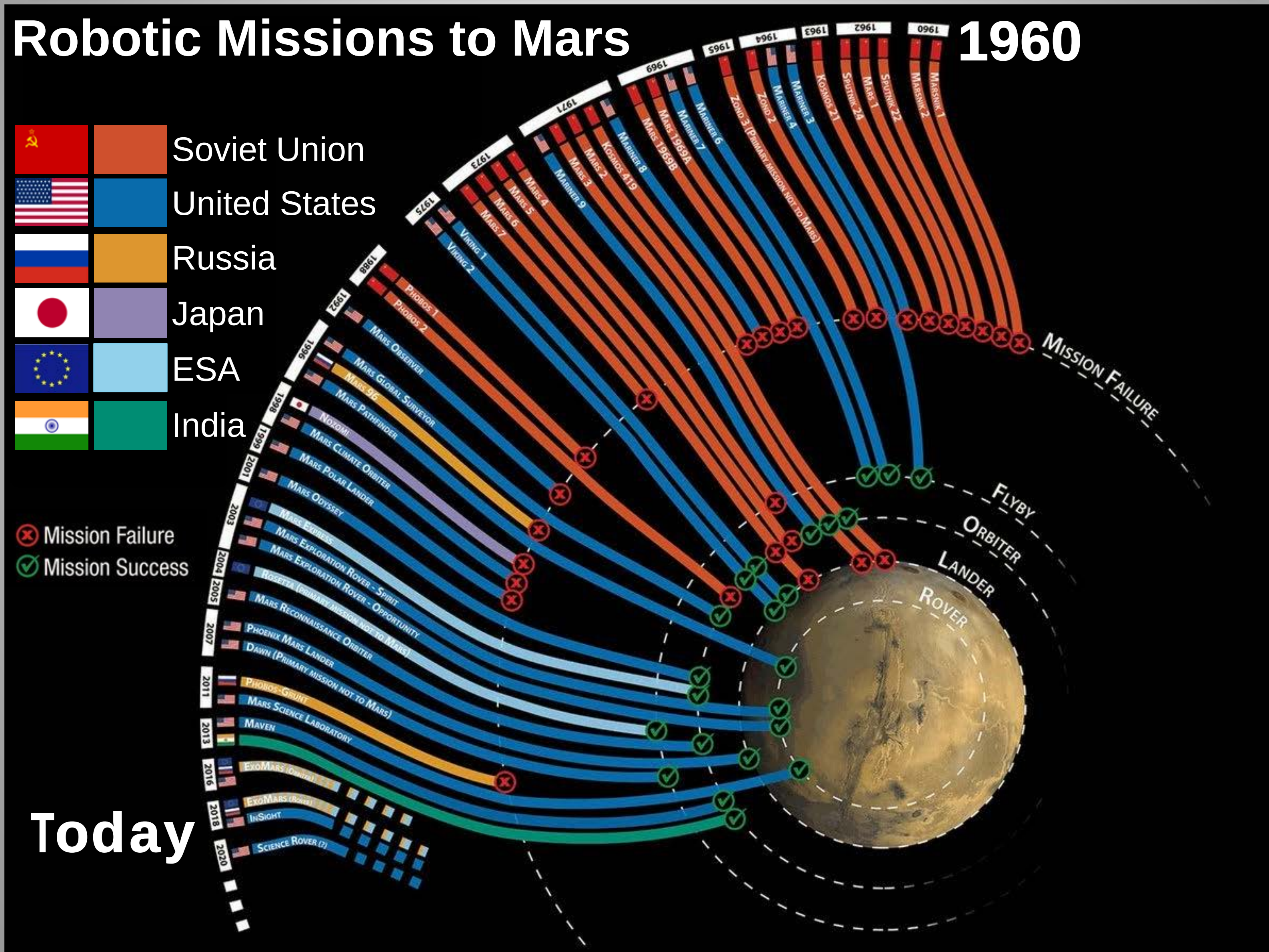
Milton [1973]

Mariner 9 – First Evidence of Water!



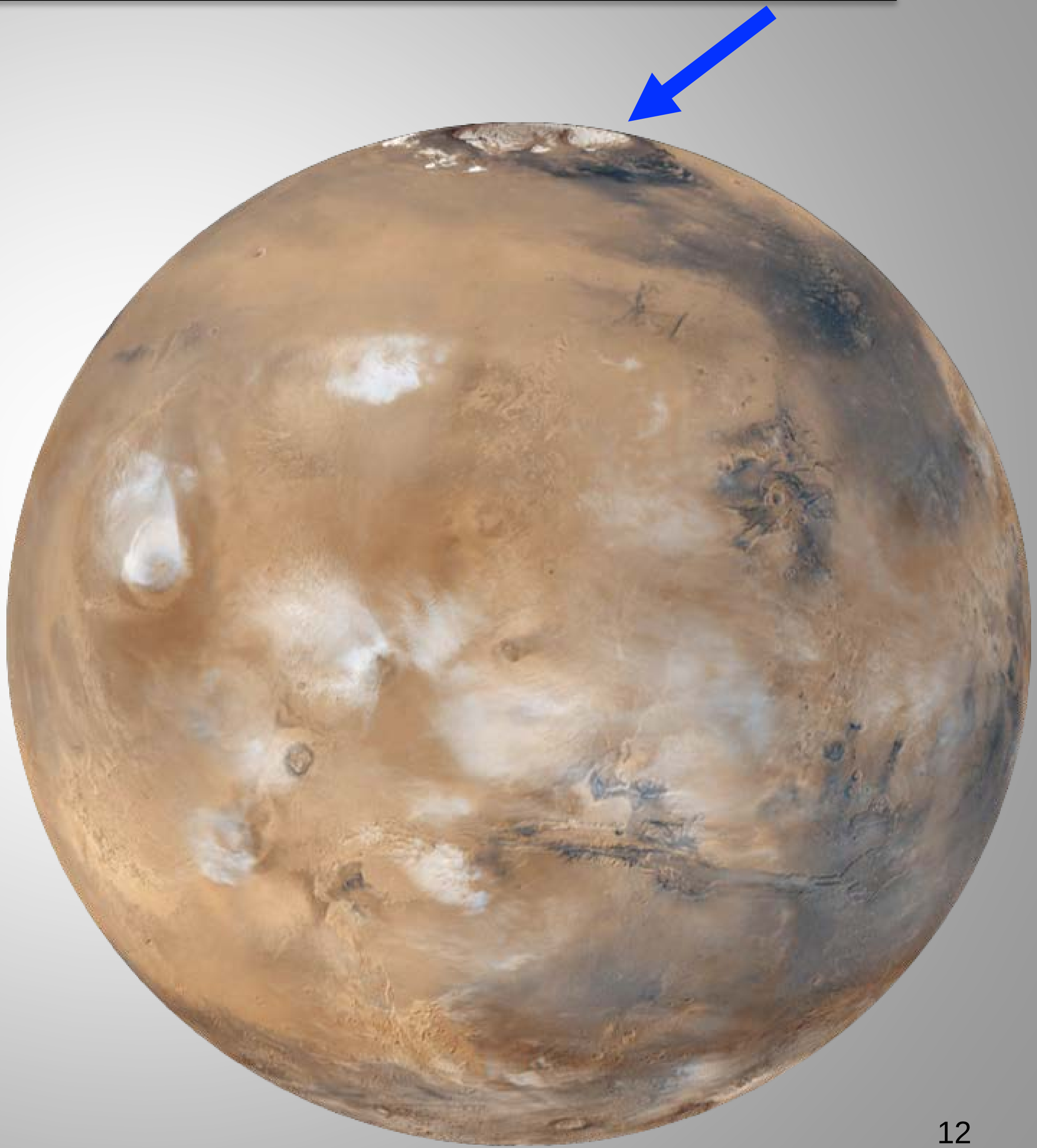
Milton [1973]

Long History of Mars Exploration



Mars Today = Cold and Dry

- **Average Surface T = -63° C *(-81° F)***
- Atmospheric Pressure = 6 mbar (Earth – 1013 mbar)
  - **~10's of precipitable microns of water (Earth is ~cm's)**
- **Large polar ice caps.**

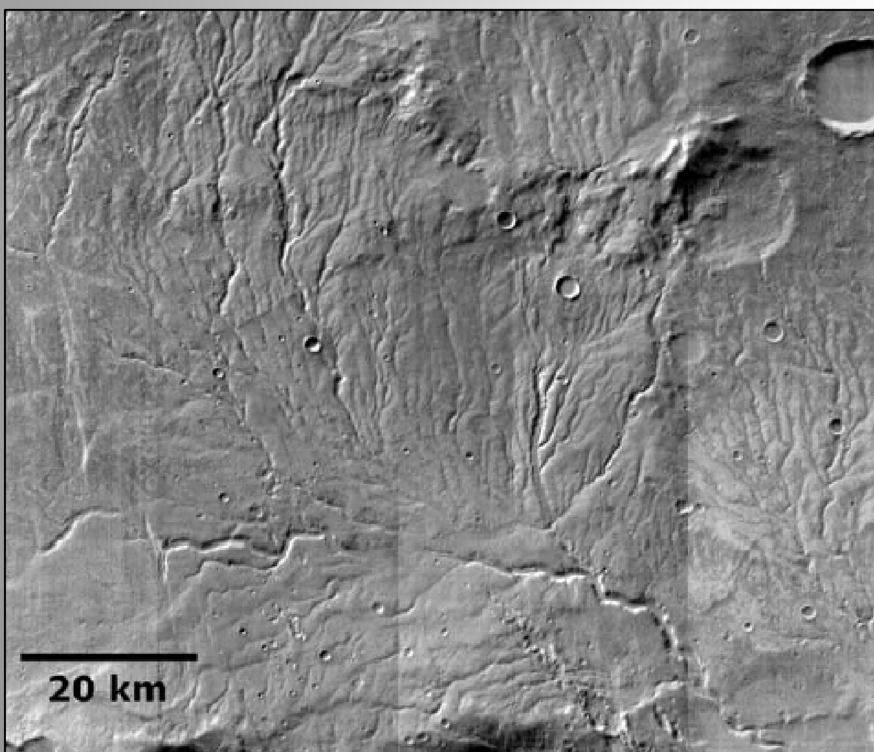


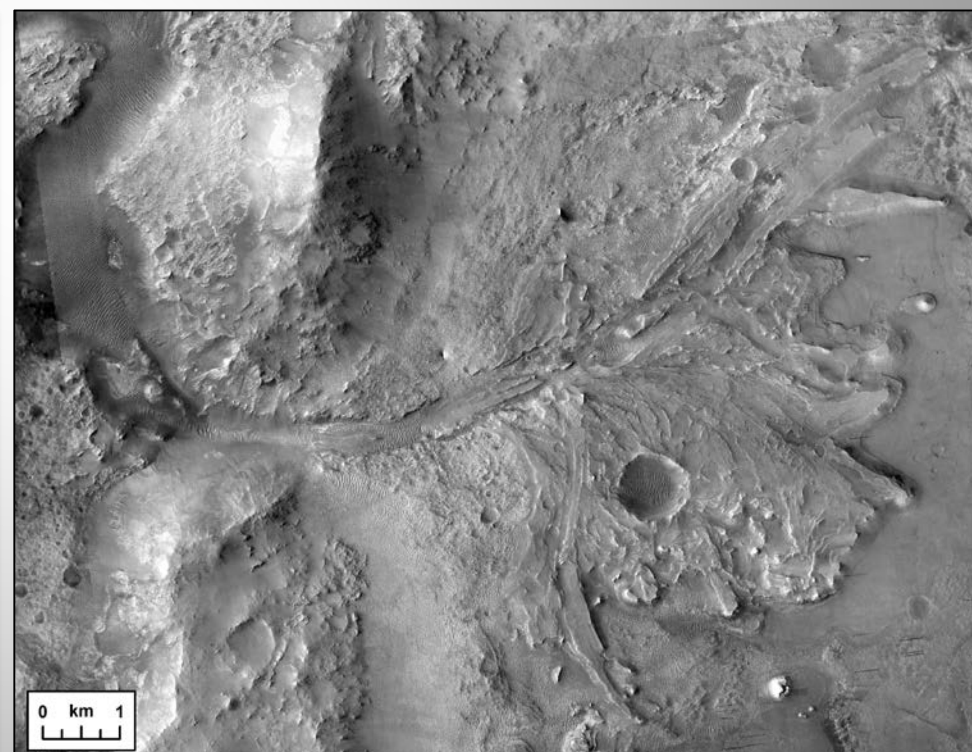
Jakosky and Phillips [2001]

Ancient Mars = Not Dry

Significant geologic evidence that ancient Mars had liquid water that carved large river valleys, filled lakes, and moved sediment across the planet.

[e.g., *Pieri,* 1980; *Carr,* 1987; *Cabrol and Grin,* 1999, 2001, 2010; *Fassett and Head,* 2008a,b; *Goudge et al.,* 2016]





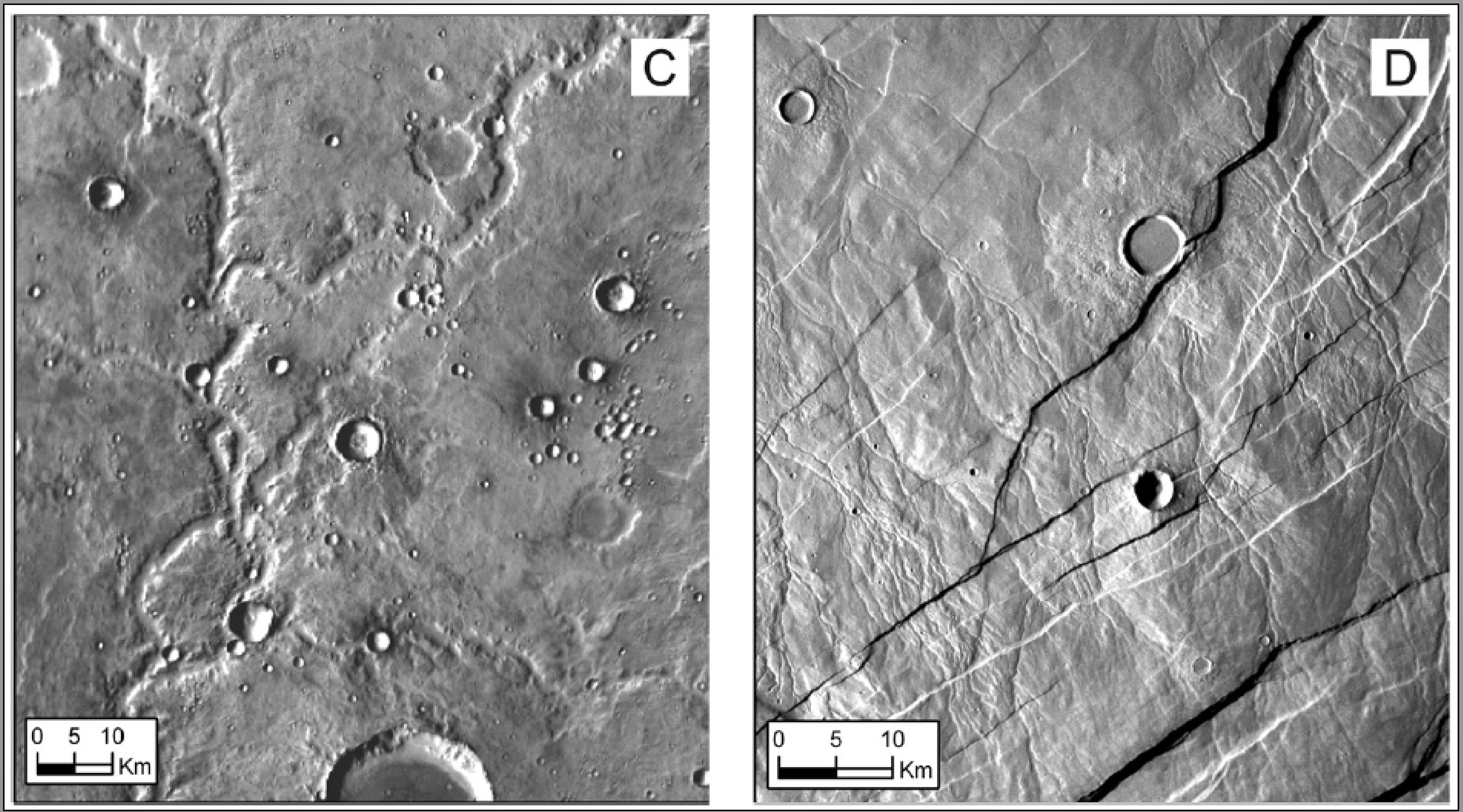
Harrison and Grimm [2005]

How do we get ages on Mars?

Use meteorite impacts, which occur over time and leave behind craters.

How do we get ages on Mars?

Old | **Young**



Fassett and Head [2008]

Timeline of Water on Mars

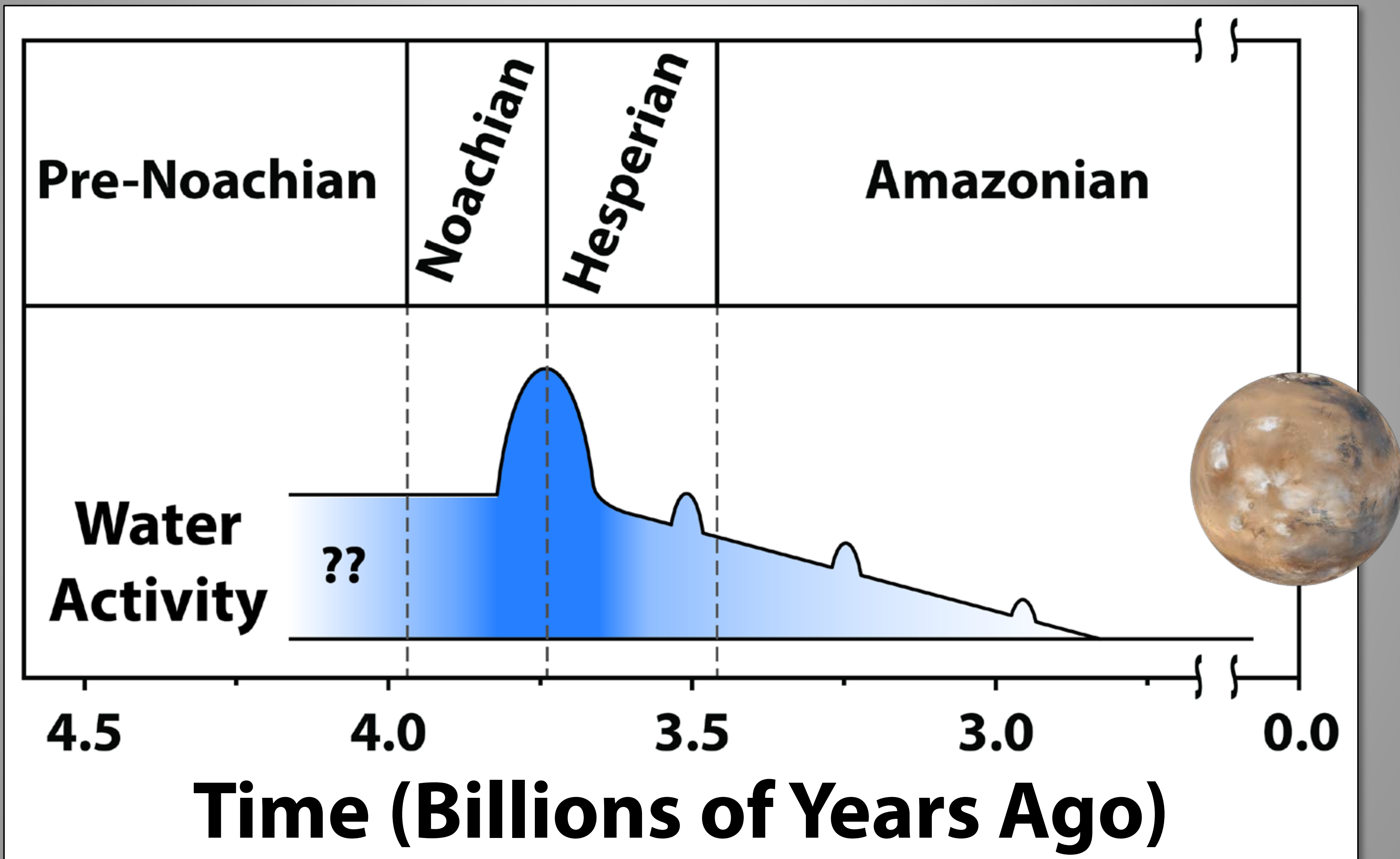


Figure modified from *Ehlmann et al.* [2011]

Timeline of Water on Mars

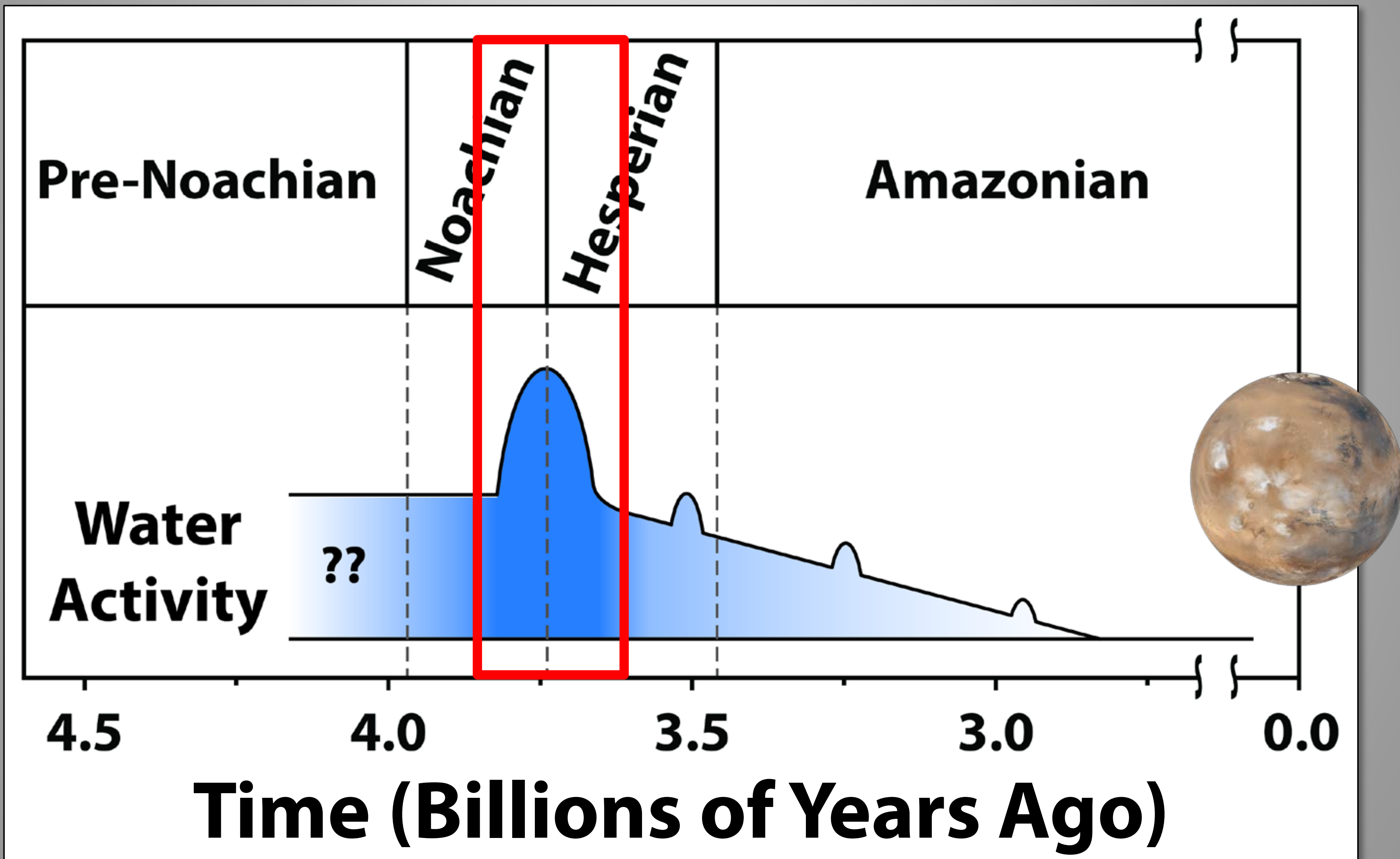
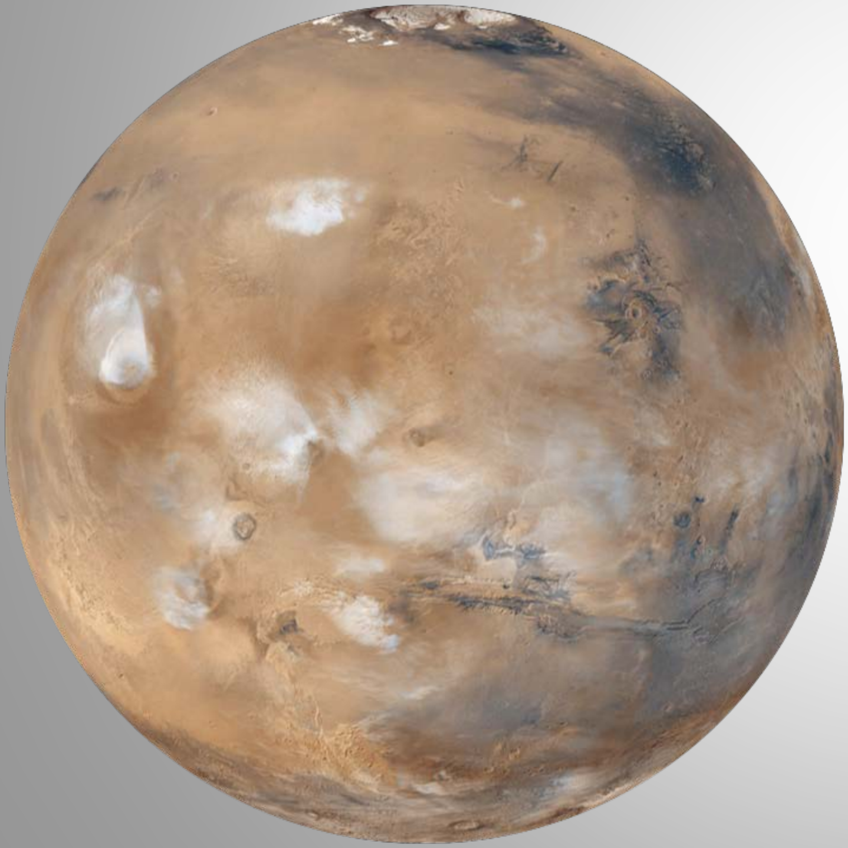
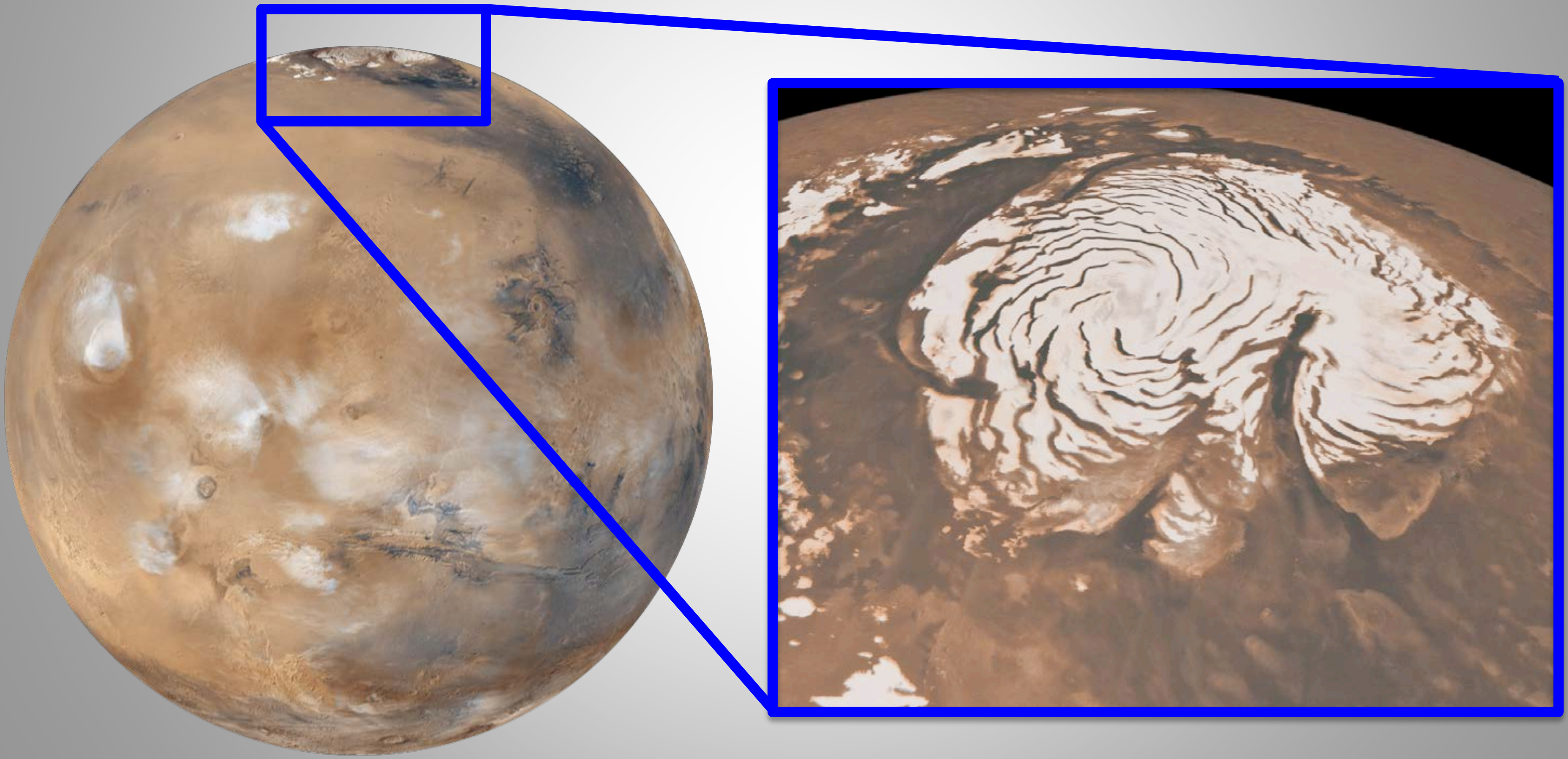


Figure modified from *Ehlmann et al.* [2011]

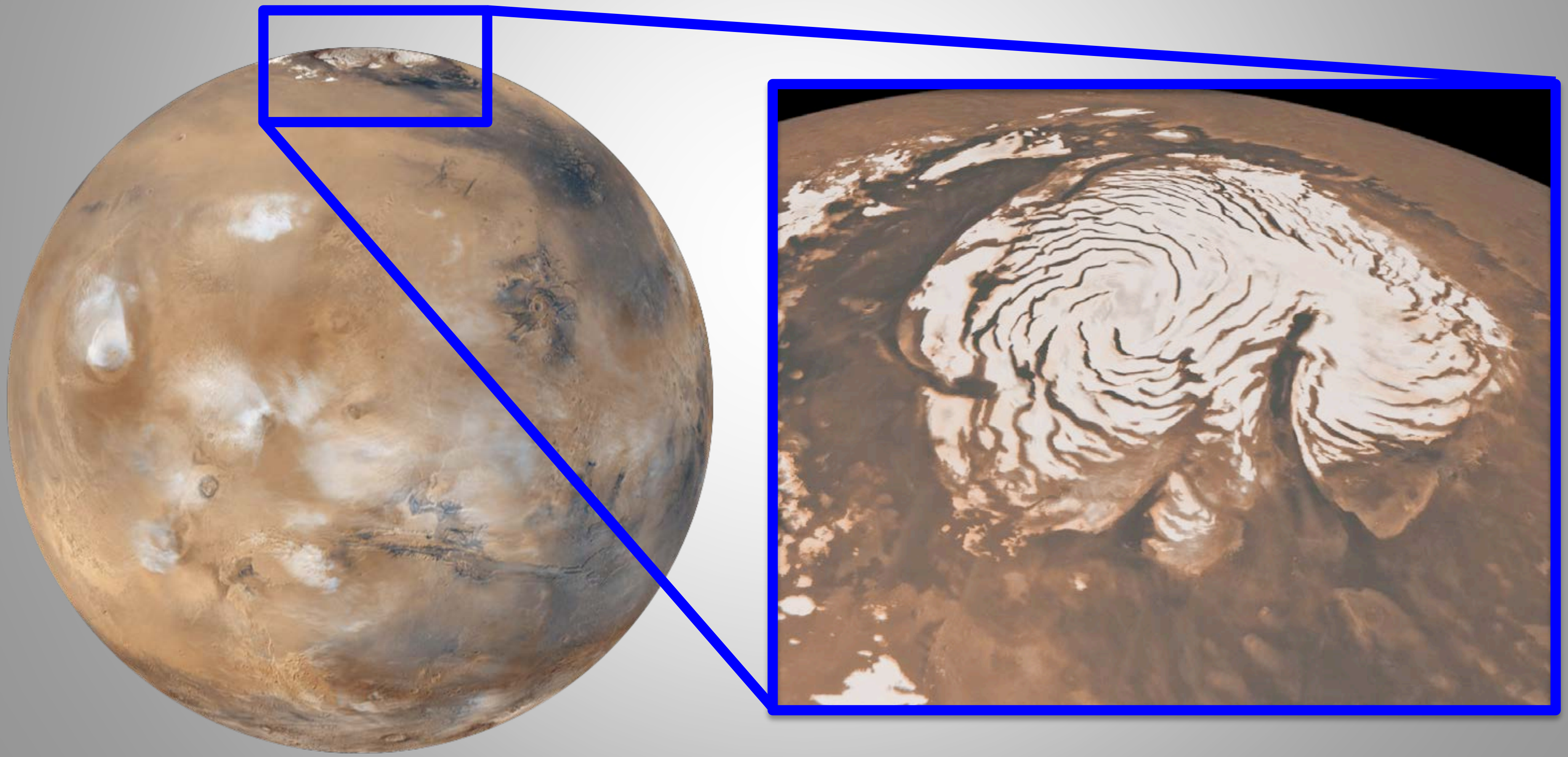
OK, but where did all the water come from/go??



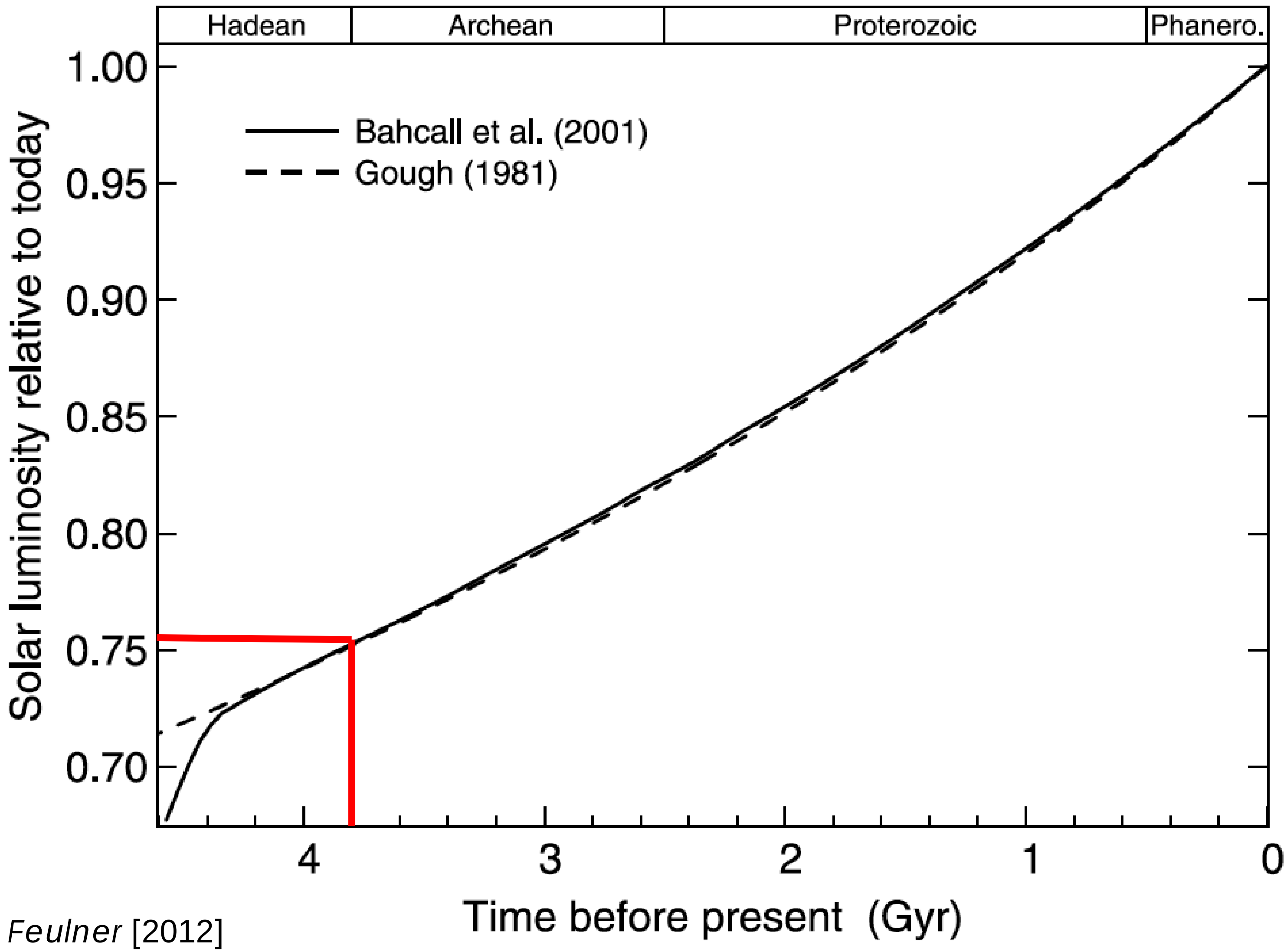
OK, but where did all the water come from/go??



OK, but where did all the **liquid** water come from/go??

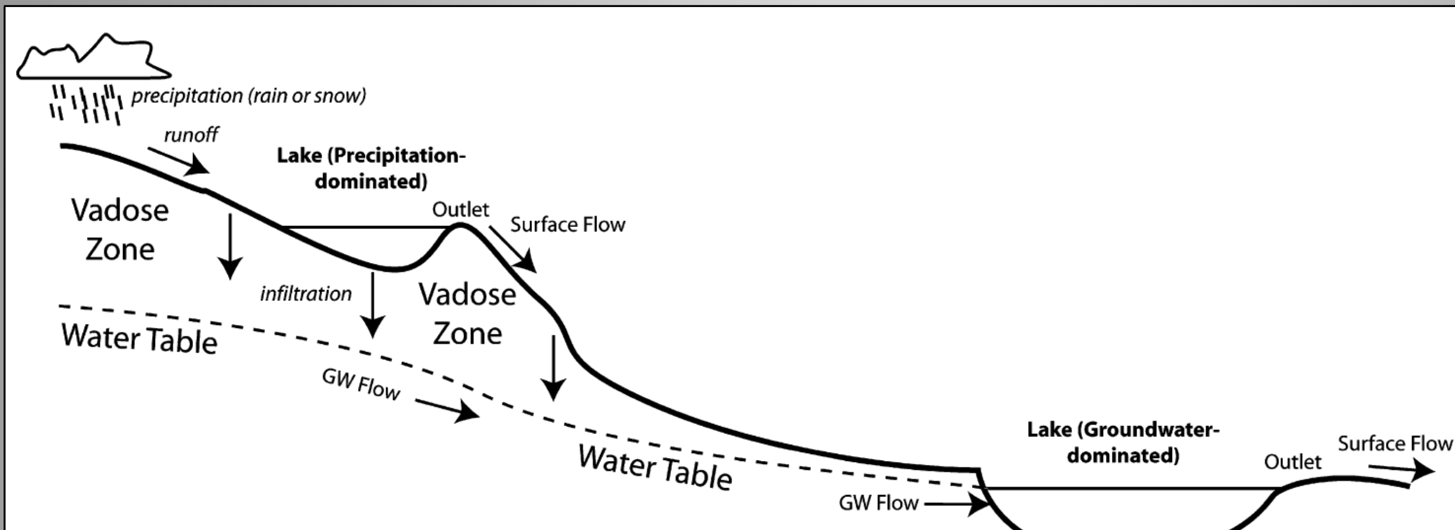


Faint Young Sun Paradox

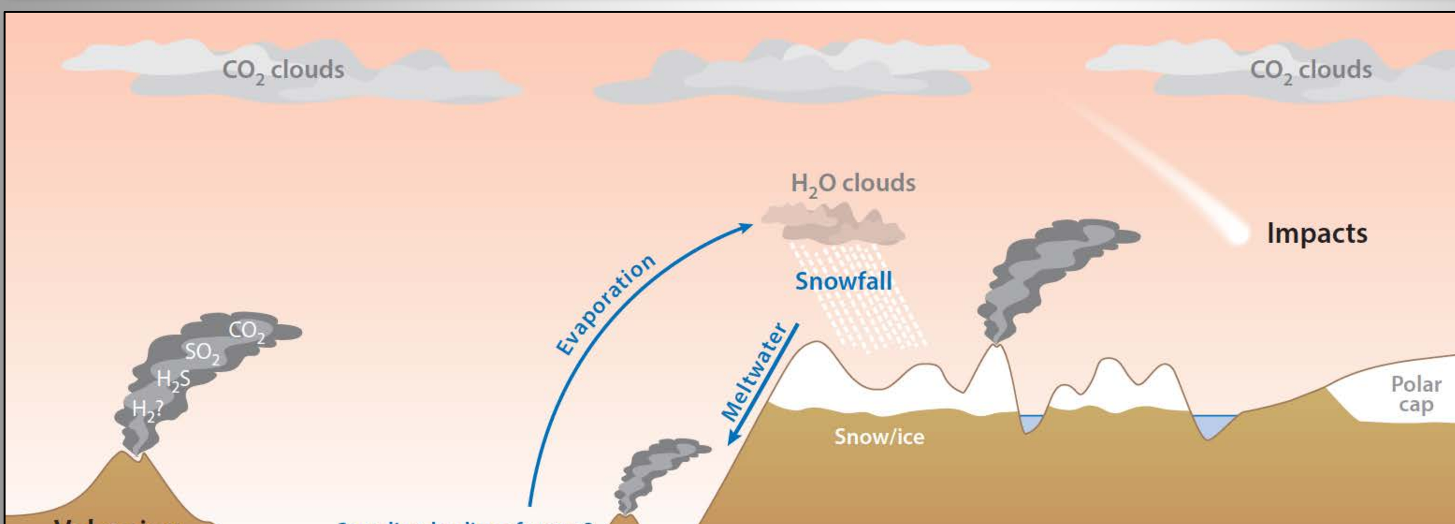


Feulner [2012]

Paradigms for Early Mars Climate



Fassett and Head [2008]



Wordsworth [2016]

Persistently Warm

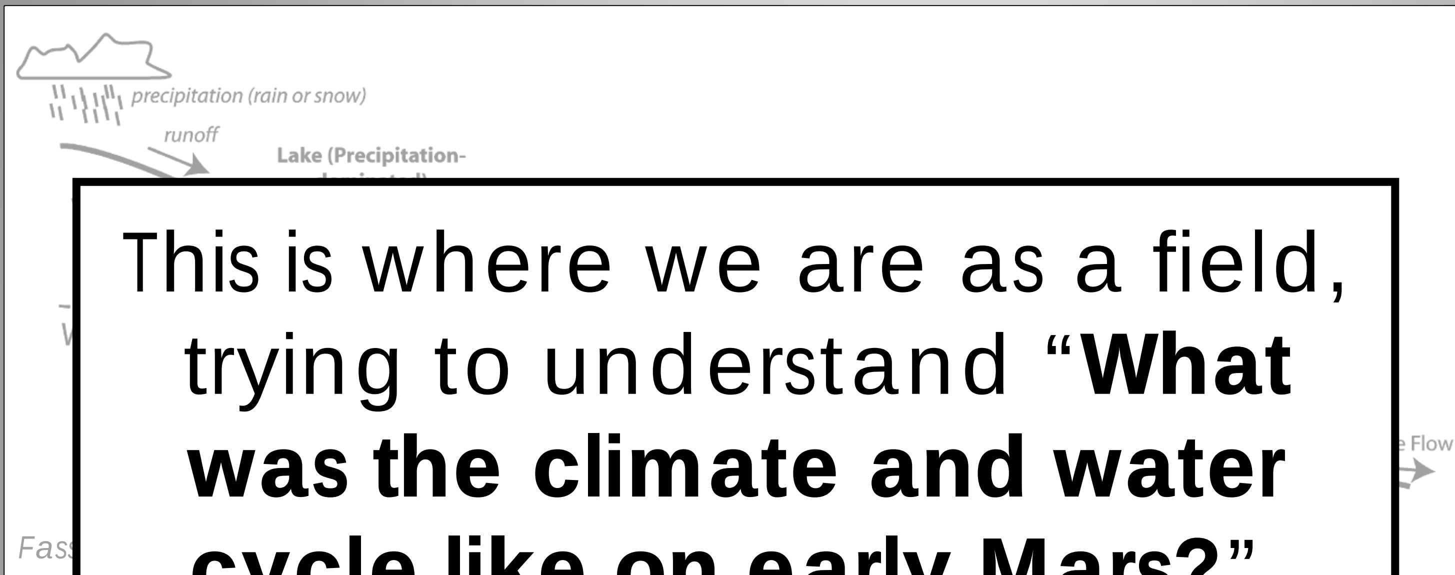
Rainfall and surface runoff.

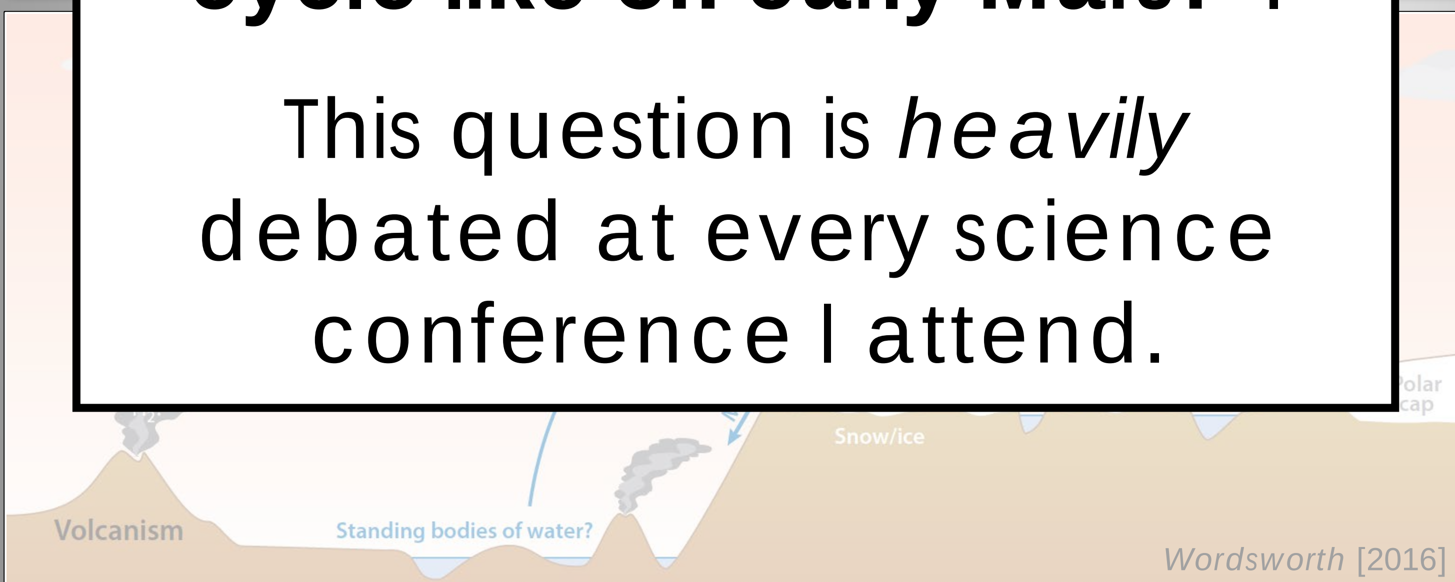
vs.

Episodically Warm

Snowfall and infrequent melting.

Paradigms for Early Mars Climate





This is where we are as a field, trying to understand "**What was the climate and water cycle like on early Mars?**".

This question is *heavily* debated at every science conference I attend.

Persistently Warm

Rainfall and surface runoff.

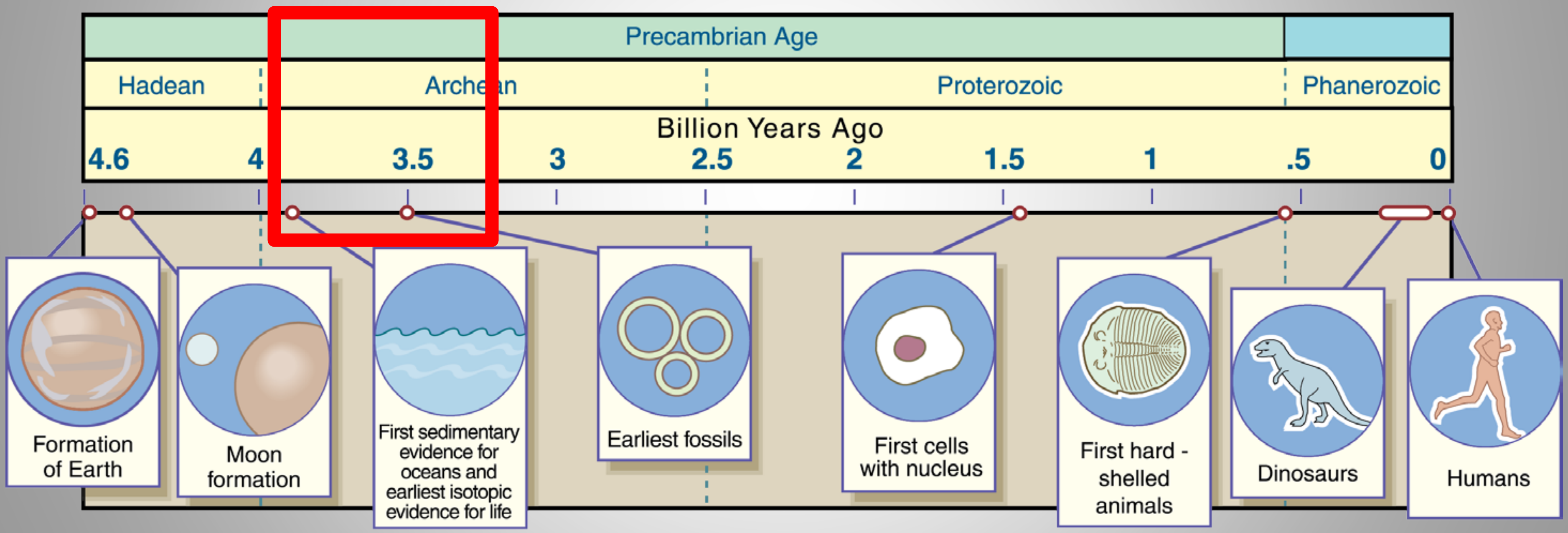
vs.

Episodically Warm

Snowfall and transient melting.

Critical Time for Life on Earth

Time when Mars had liquid water is the same time when we find the first signs of life on Earth!



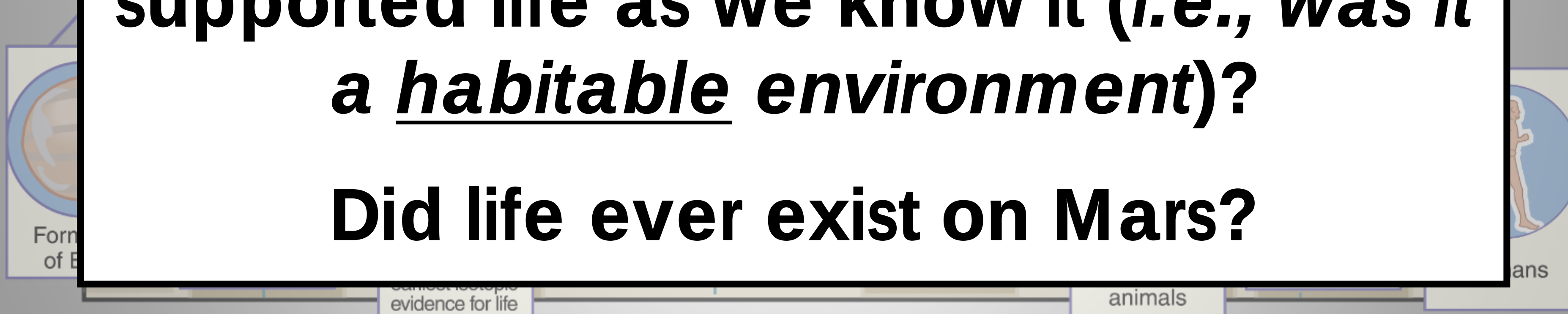
Dan Brennan/UW-Madison News Graphic

Critical Time for Life on Earth

Key questions:

Could the early Mars environment have supported life as we know it (*i.e., was it a habitable environment*)?

Did life ever exist on Mars?



Dan Brennan/UW-Madison News Graphic

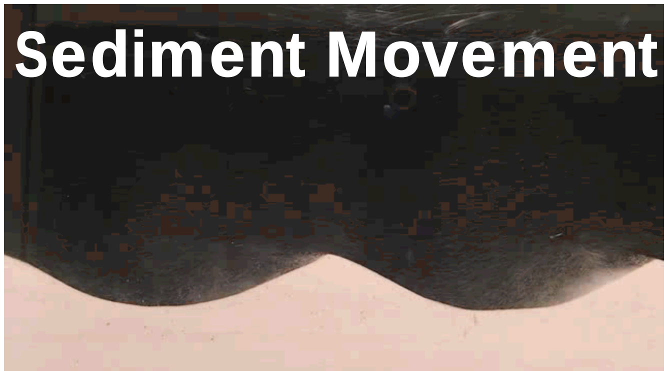
Active Research Questions

- What was the climate and water cycle like on early Mars?
- Could the early Mars environment have supported life as we know it (i.e., was it a habitable environment)?
- Did life ever exist on Mars?
- **Planetary geologists look for answers to these questions recorded in the rocks!**

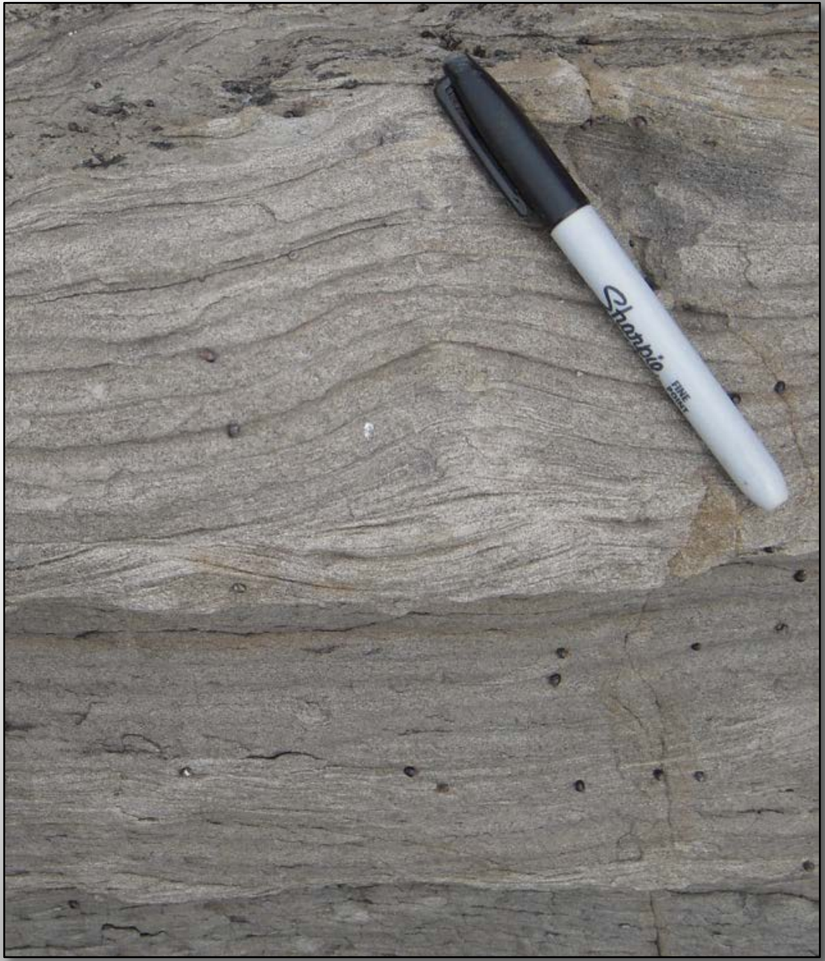
Rocks Record Past Environments

Sedimentary rocks record the environmental conditions during building of the deposit.

Fluid Movement

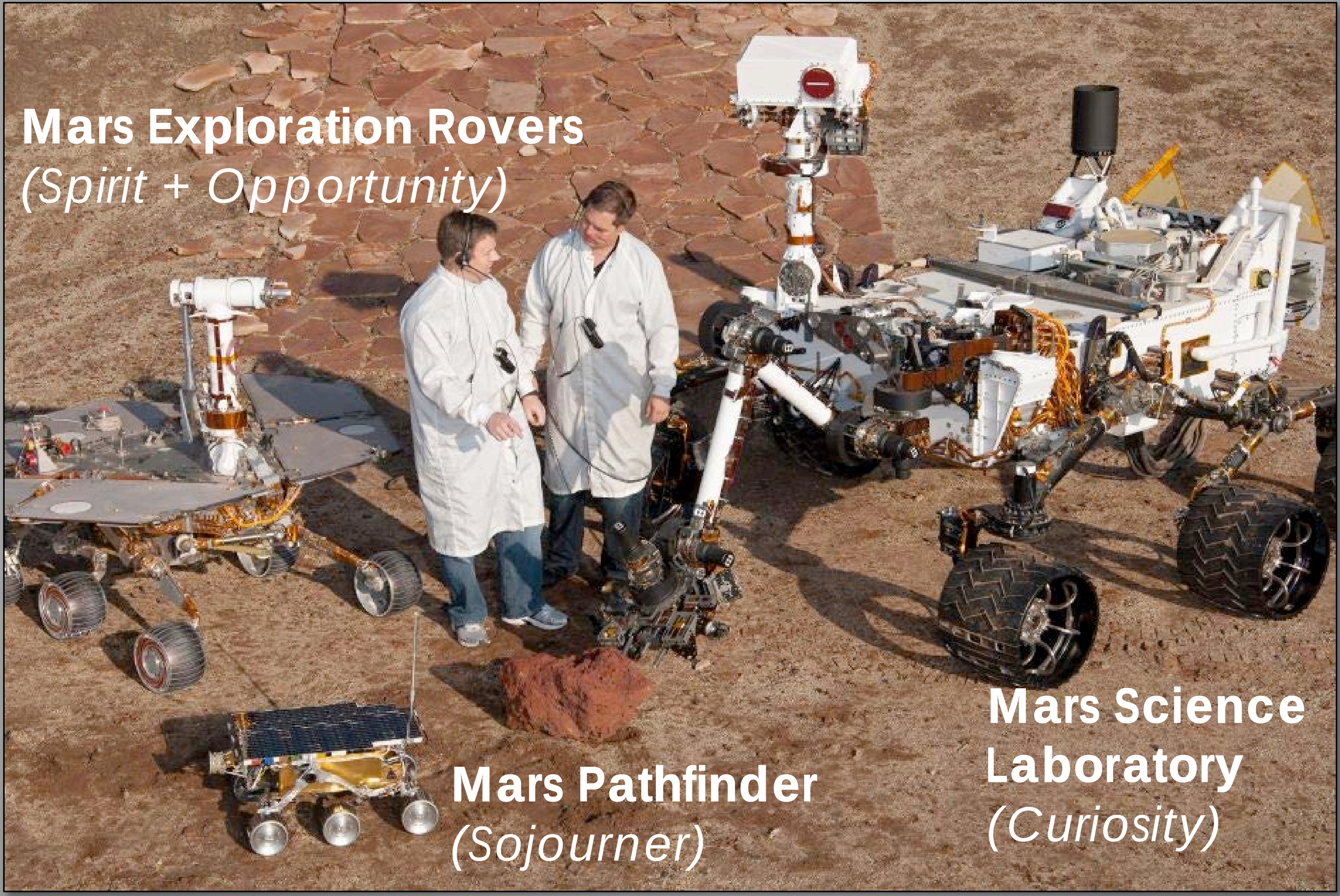


Recorded in Rocks

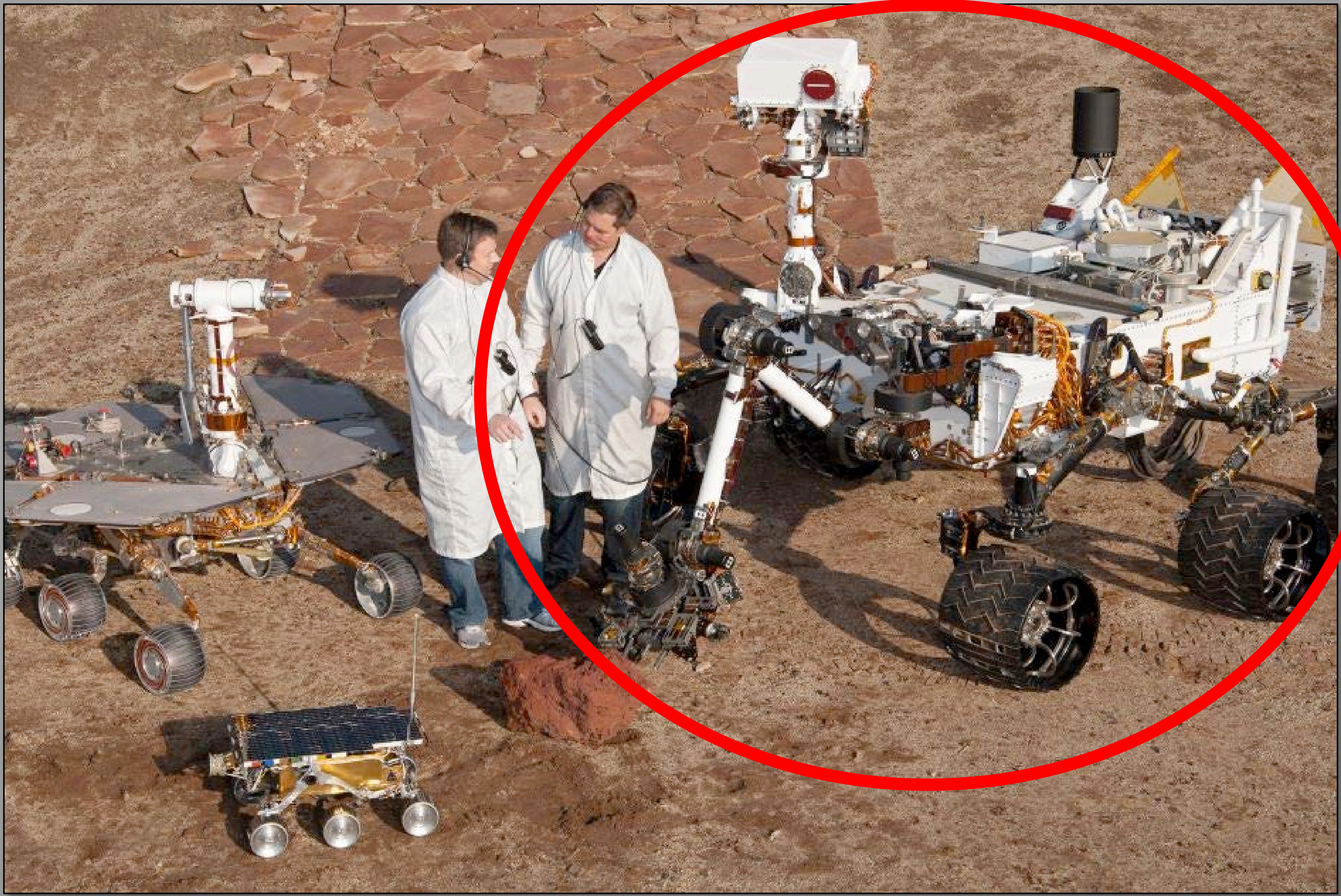


Animations courtesy of E. Prokocki and M. Perillo

Rovers = Mars Field Geologists

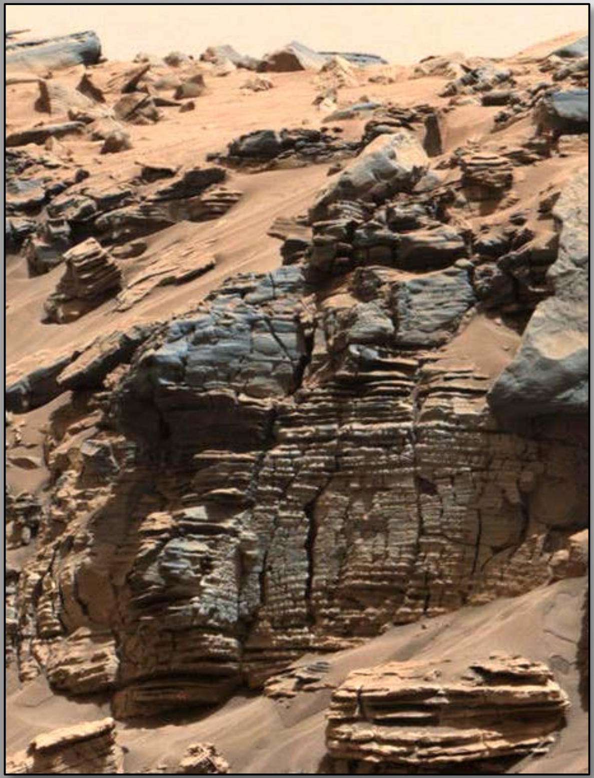


Mars Science Laboratory (MSL)



MSL – Ancient Habitable Lake

MSL has explored rocks that record an ancient, <u>habitable</u> environment. [e.g., *Grotzinger et al.,* 2014, 2015]



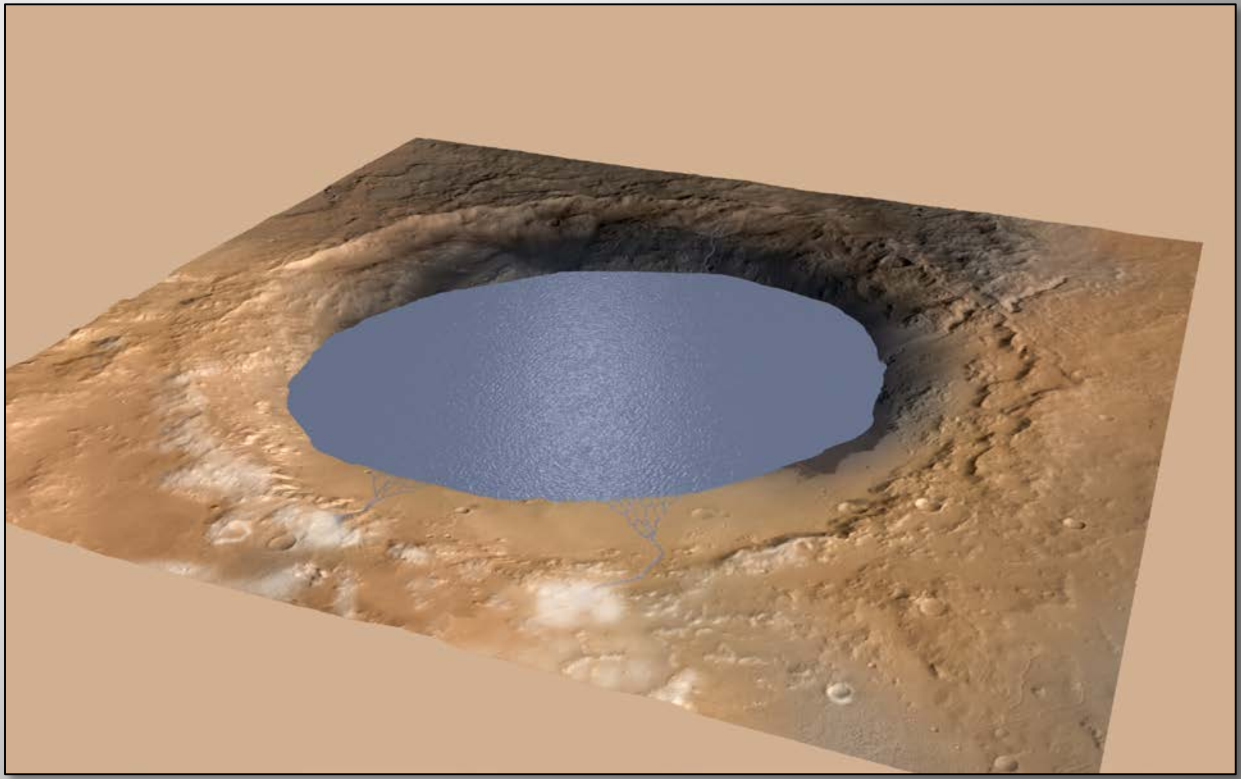
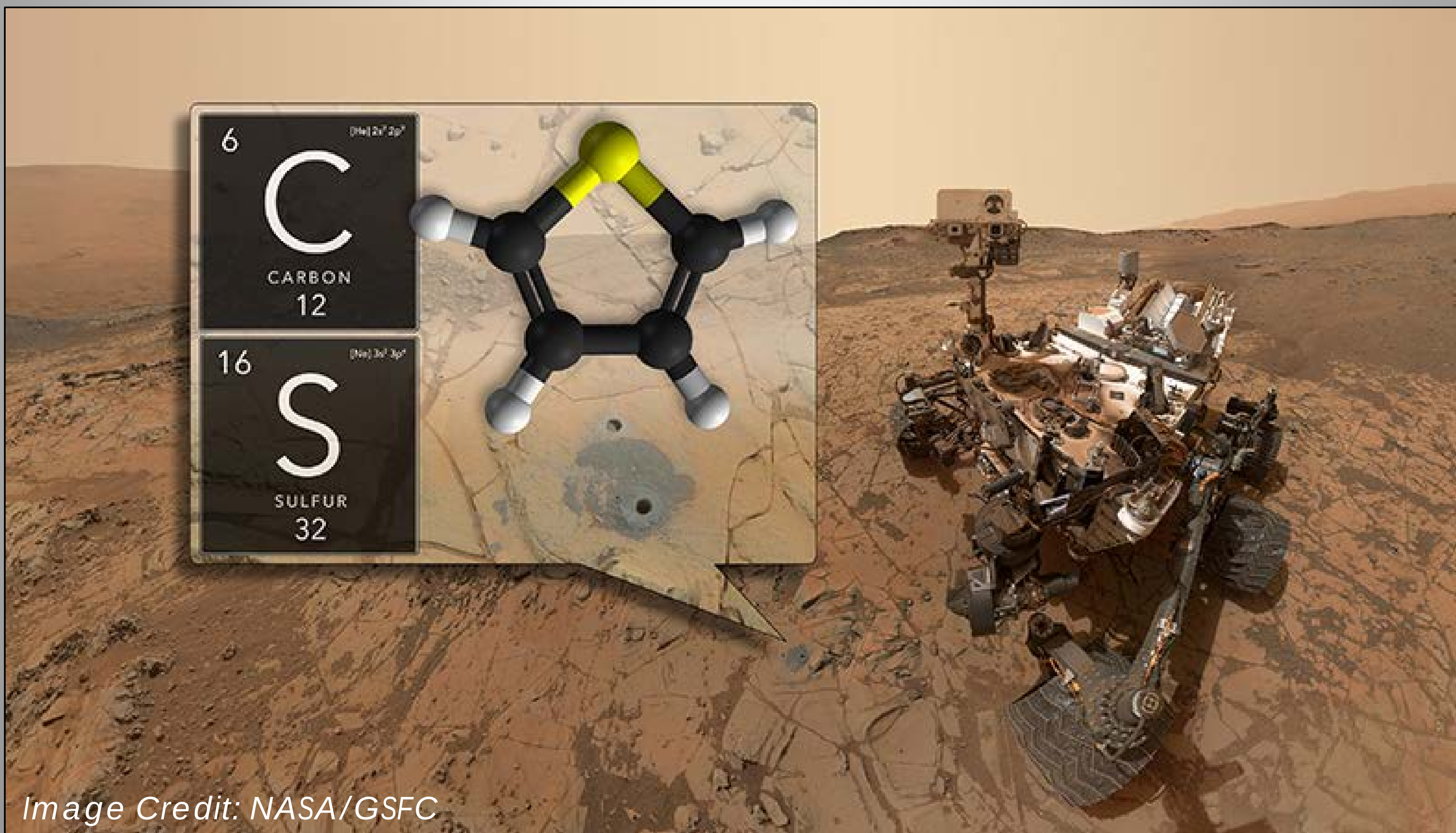


Image Credits: NASA/JPL

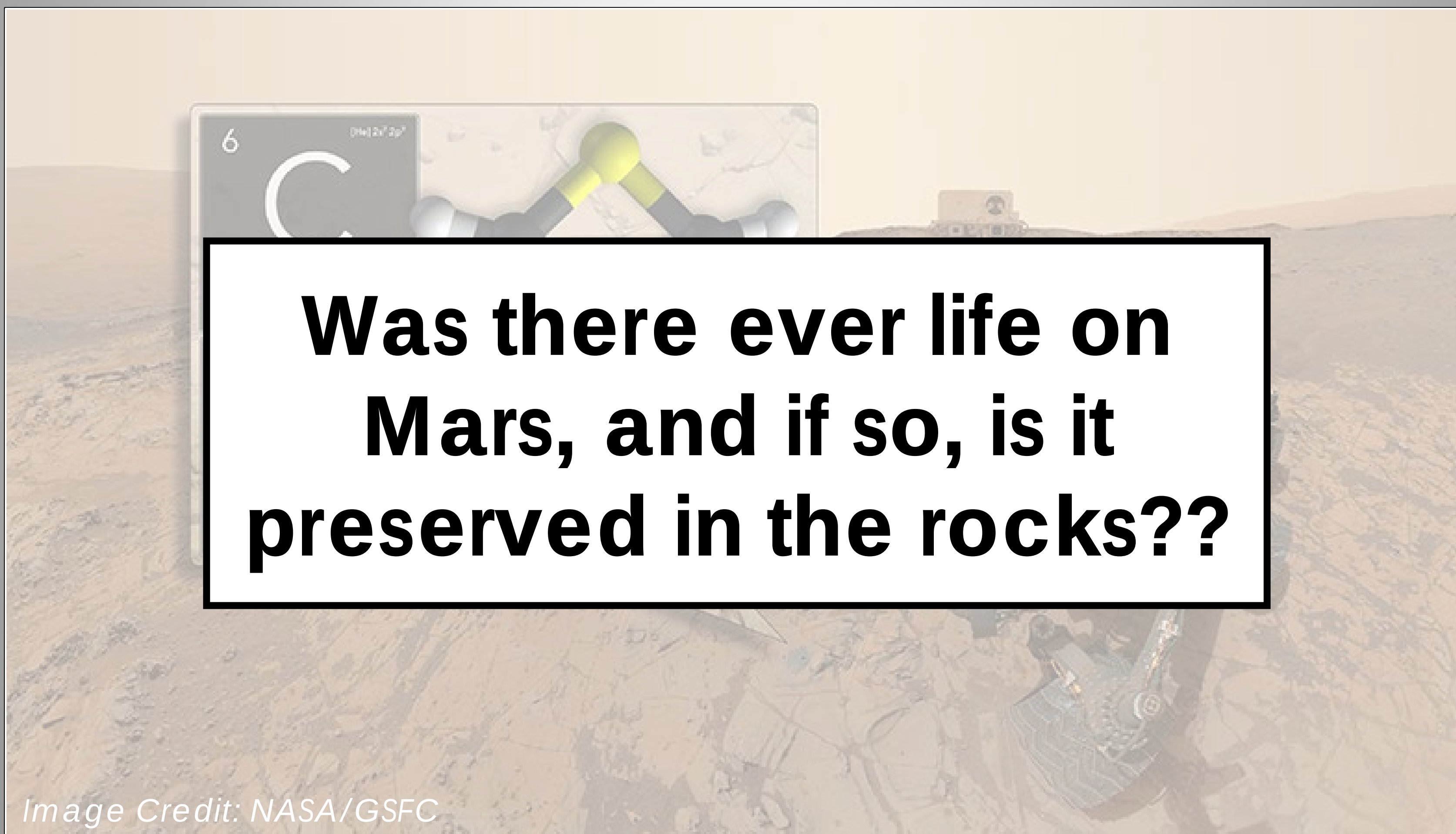
MSL – Ancient Organics

MSL identified complex organic molecules *(biotic or abiotic)* in ancient lake deposits. [*Eigenbrode et al.*, 2018]



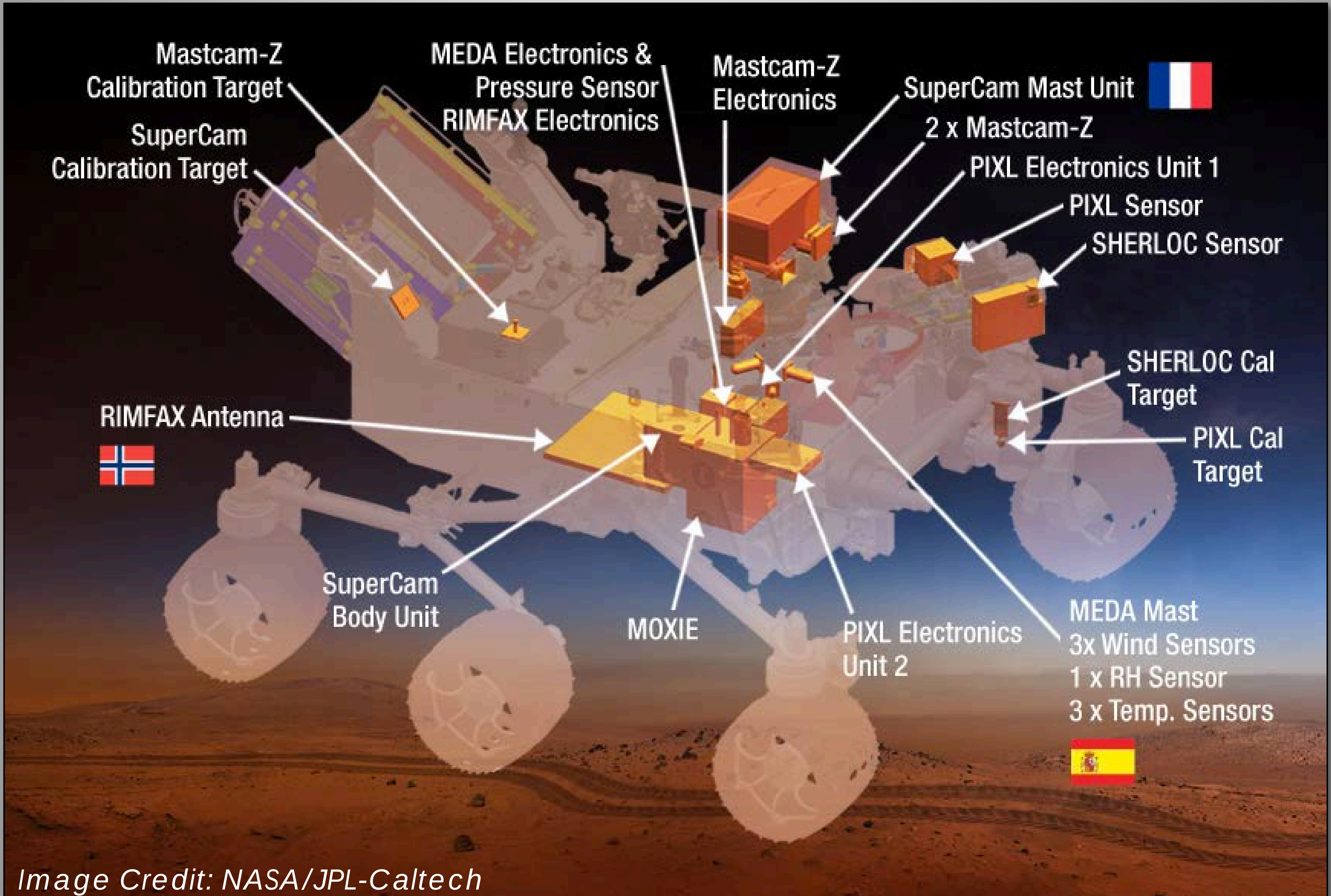
MSL – Ancient Organics

MSL identified complex organic molecules *(<u>biotic</u> or <u>abiotic</u>)* in ancient lake deposits. [*Eigenbrode et al.*, 2018]

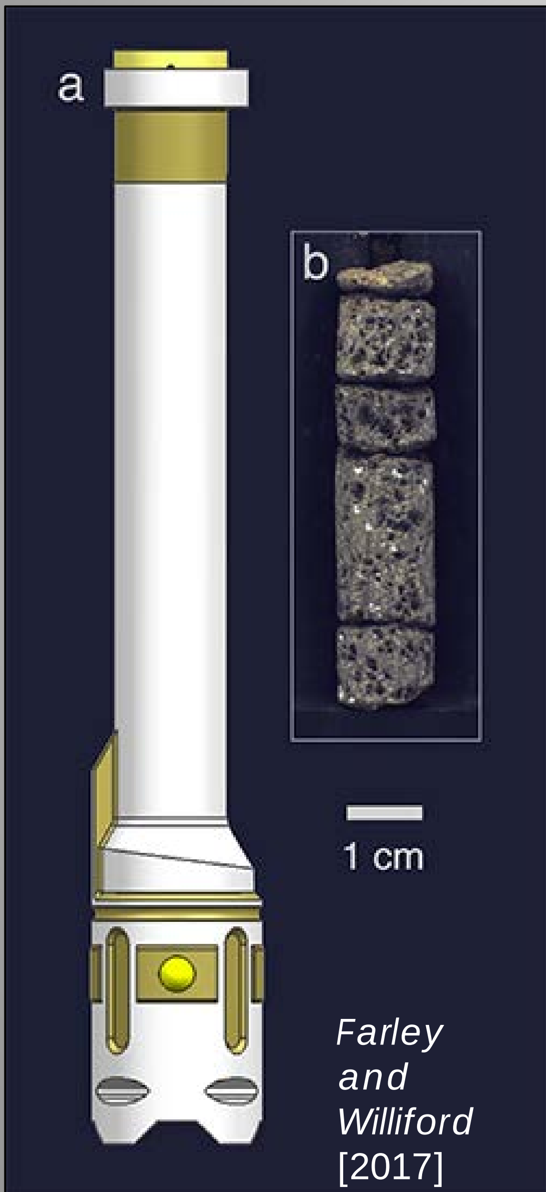


Was there ever life on Mars, and if so, is it preserved in the rocks??

NASA Mars 2020 Rover will explicitly search for evidence of <u>potential past life</u> on Mars.



Returning Mars Samples to Earth



Farley and Williford [2017]

One of most exciting aspects of the Mars 2020 mission is that it will collect samples to be brought back to Earth!

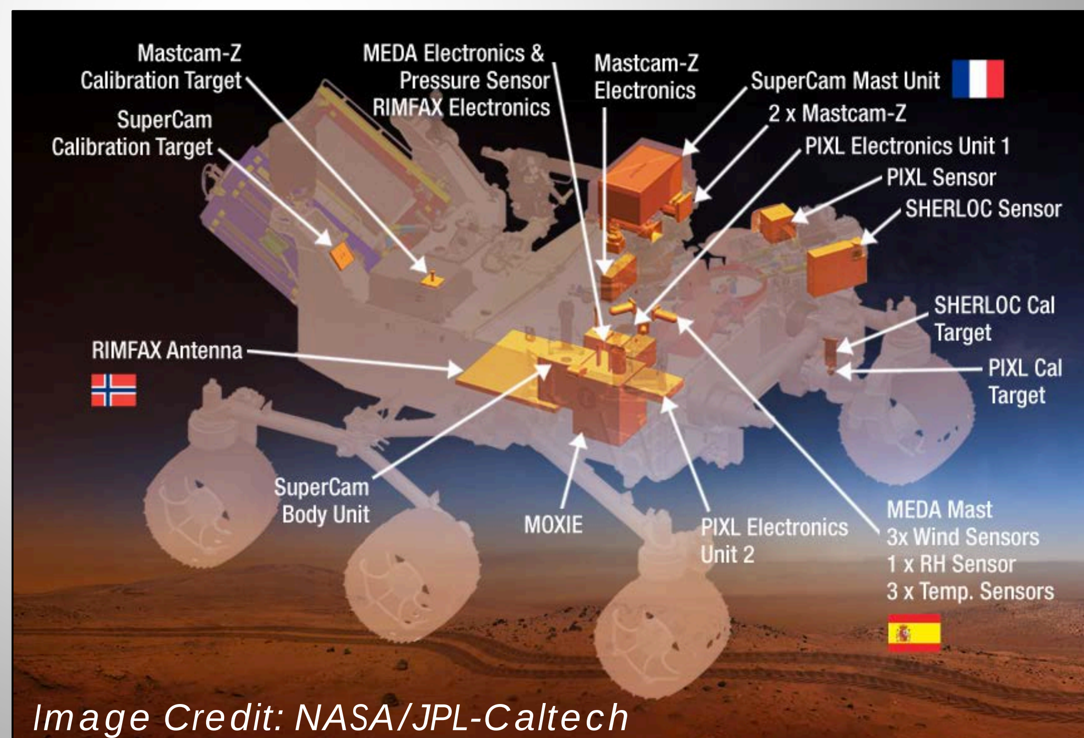
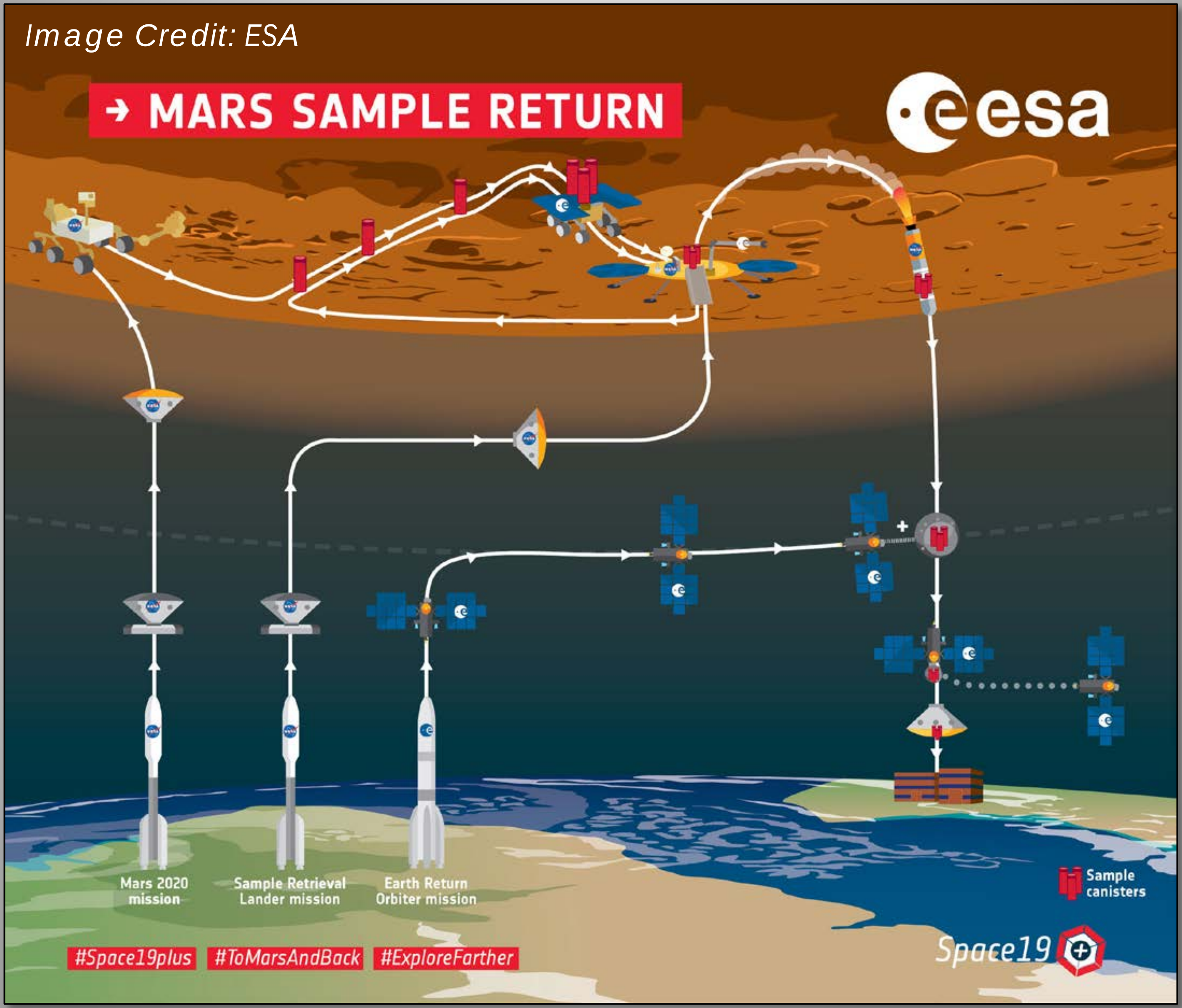


Image Credit: NASA/JPL-Caltech

Returning Mars Samples to Earth



How do we decide where to go?

Photo Credit: Max Fagin (via Twitter, @MaxFagin)

How do we decide where to go?

Scientists advocate for landing sites based on how sites could address Mars 2020 science goals:

1. Characterize geologic history of site with "astrobiologically-relevant ancient environment and geologic diversity".

2. Assess habitability/"potential evidence of past life" in units with "high biosignature preservation potential".

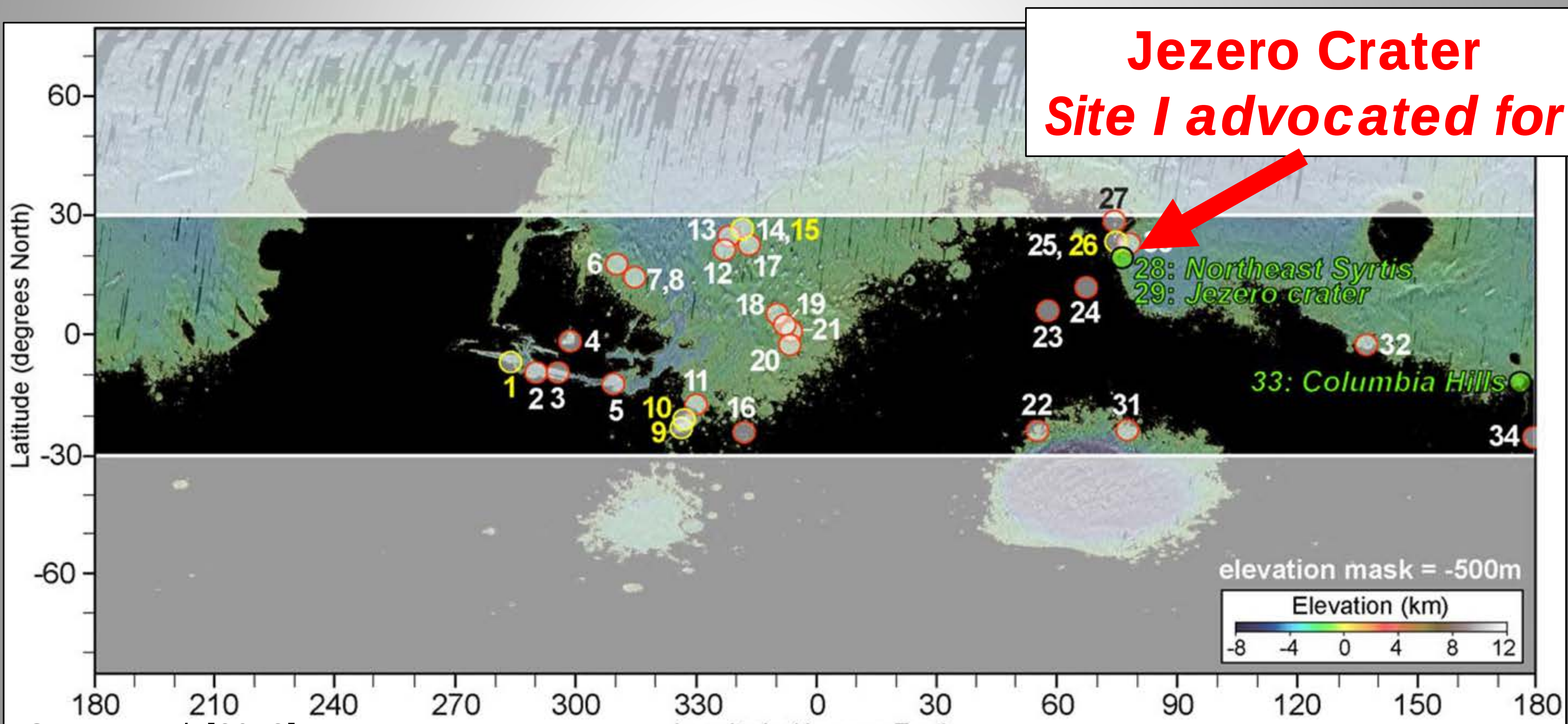
3. Cache scientifically compelling samples for potential return to Earth.

[*Farley and Williford*, 2015].

How do we decide where to go?

Sites narrowed down during four open workshops, where anyone could propose a site.

Started with >30 sites at 1st workshop in 2014.



Grant et al. [2018]

How do we decide where to go?

At workshops, scientists present on their site, and attendees vote on which they find most compelling.

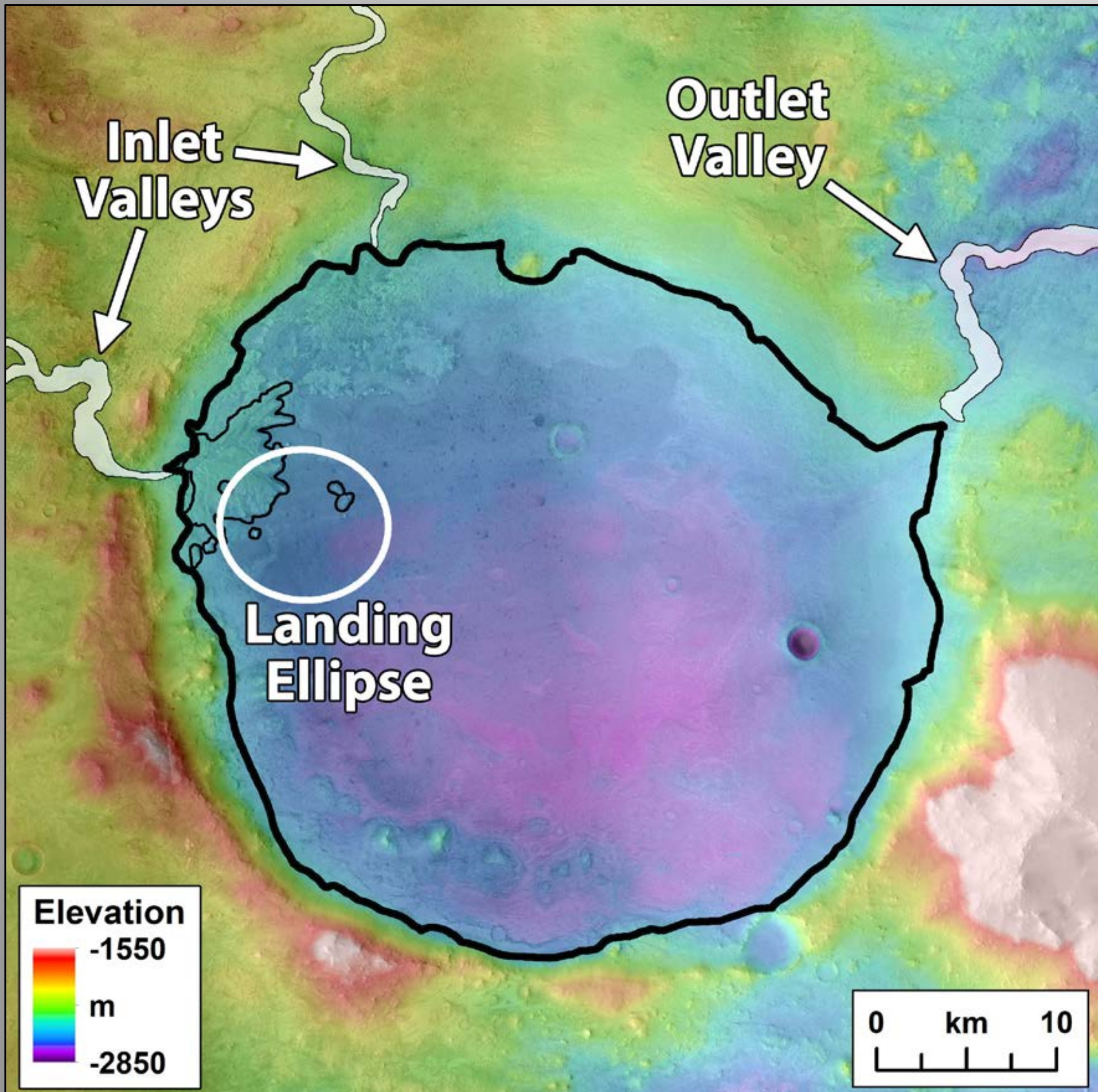
How do we decide where to go?

Sites are ranked, and that information is provided to NASA administrators, who make final decision.

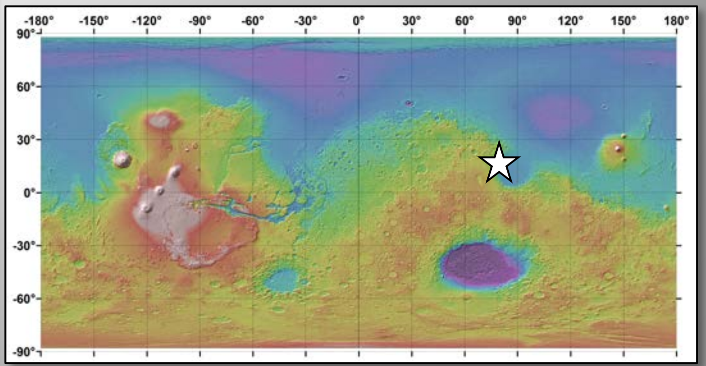
Rank	Site	Landing Site Scientific Selection Criteria										Overall Average	
		Characterizable Geologic Setting and History		Ancient Habitable Environment		High Biosignature Preservation Potential		Astrobiological quality of returned samples		Petrological quality of returned samples			
		Mode	Avg.	Mode	Avg.	Mode	Avg.	Mode	Avg.	Mode	Avg.	Mode	Avg.
1	Jezero crater	5	4.9	5	4.7	5	4.4	5	4.4	5	4.3	5	4.5
2	Columbia Hills	5	4.7	5	4.3	5	4.3	3	3.8	5	4.1	4.6	4.2
3	NE Syrtis	5	4.7	5	3.8	3	3.3	5	3.8	5	4.8	4.6	4.1
4	Eberswalde crater	5	5.0	5	4.5	5	4.3	3	3.4	3	3.0	4.2	4.0
5	SW Melas	5	4.5	5	4.1	5	3.9	3	3.6	3	3.1	4.2	3.9
6	Nili Fossae	5	4.4	3	3.4	3	3.2	3	3.4	5	4.7	3.8	3.8
7	Nili Fossae Carbonate	5	4.2	3	3.4	3	3.2	3	3.2	5	4.3	3.8	3.7
8	Mawrth Vallis	5	4.3	3	3.7	3	2.9	3	3.4	5	3.9	3.8	3.6
9	Holden crater	5	4.4	3	3.4	3	3.2	3	3.2	3	3.4	3.4	3.5
10	McLaughlin crater	3	3.6	3	3.9	3	3.0	3	3.5	3	3.5	3	3.5
11	Hypanis	3	3.8	3	3.6	3	3.1	3	3.0	3	2.8	3	3.2
12	Nili Fossae South	3	3.8	3	2.9	3	2.6	3	2.9	3	3.9	3	3.2
13	Ladon Valles	3	3.8	3	3.3	3	3.1	3	2.7	3	2.7	3	3.1
14	E. Margaritifer	3	3.7	3	3.1	3	3.5	3	2.7	3	2.7	3	3.1
15	Coprates Chasma	5	4.1	3	2.7	3	2.3	3	2.5	3	3.7	3.4	3.1
16	Oyama crater	3	3.3	3	3.2	3	2.8	3	2.7	3	3.1	3	3.0
17	Eridania	3	3.2	3	2.8	3	2.5	3	2.3	3	2.4	3	2.6
18	Nili Patera	5	4.6	3	2.4	3	2.5	1	1.4	3	2.2	3	2.6
19	Oxia Planum	3	3.0	3	2.4	1	2.1	1	2.1	3	2.7	2.2	2.5
20	Sabrina/Magong crater	3	3.1	3	3.0	3	2.2	1	1.8	1	2.0	2.2	2.4
21	Hadriacus Palus	3	3.2	3	2.5	1	1.5	1	1.6	3	2.8	2.2	2.3

Grant et al. [2018]

Final Winner: Jezero Crater

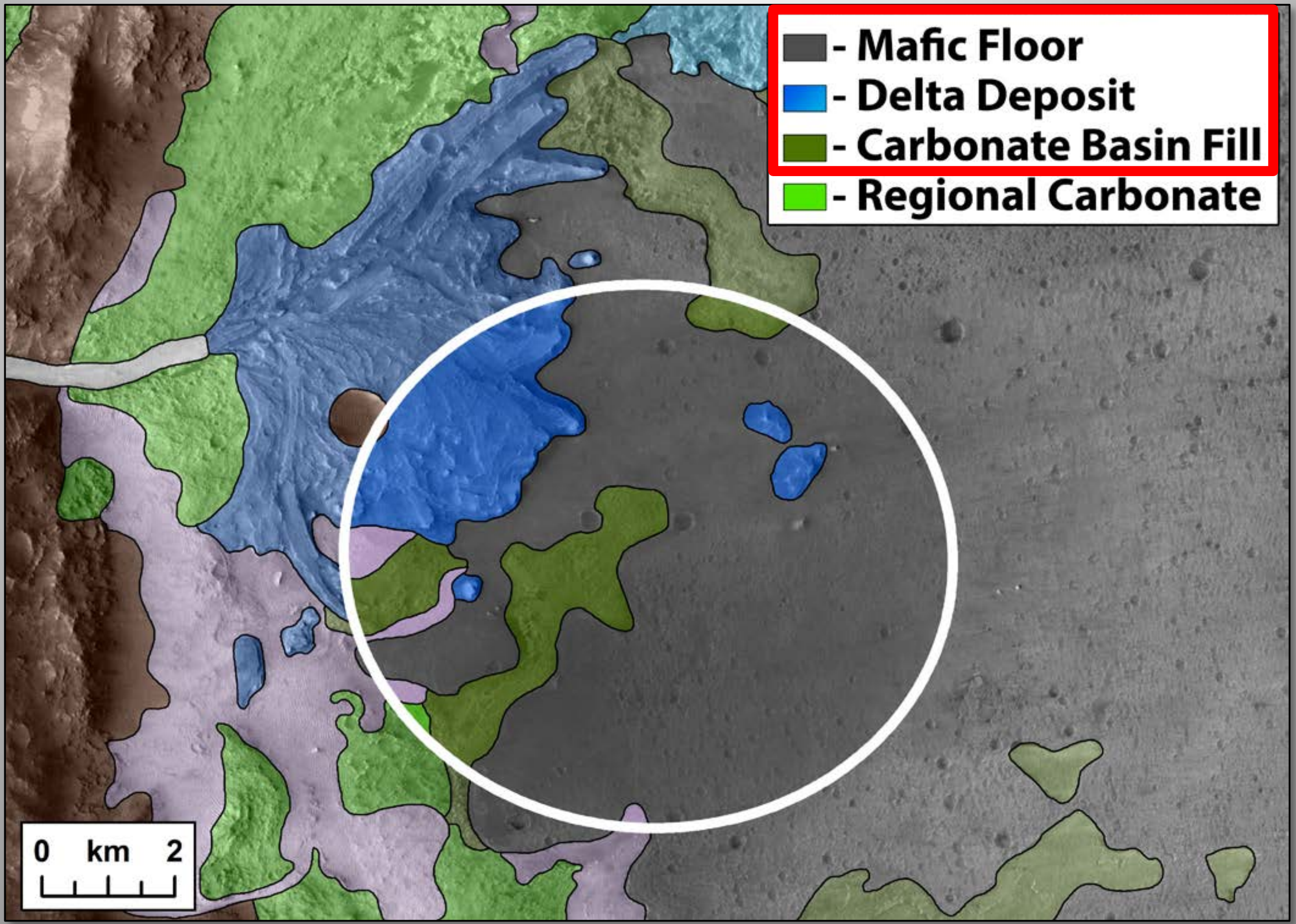


~45 km diameter Jezero crater that hosted a lake the size of Lake Tahoe or Lake Winnipeg during main period of Mars water activity. [*Fassett and Head,* 2005, 2008a,b; *Ehlmann et al.,* 2008a; *Schon et al.,* 2012; *Goudge et al.,* 2015, 2017, 2018]



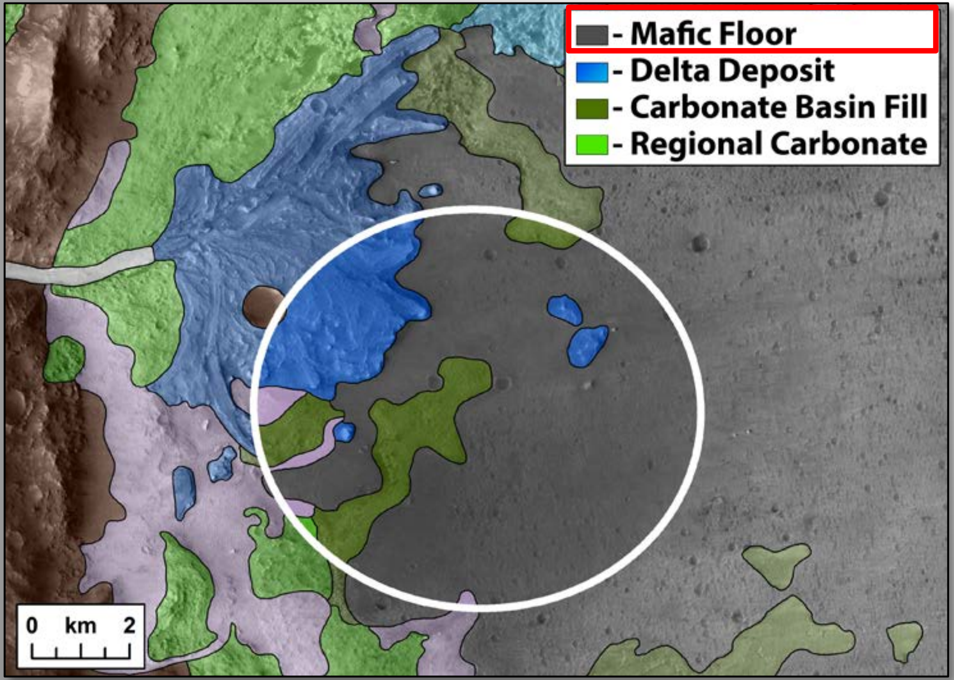
Mars 2020 at Jezero Crater

Jezero landing ellipse contains three primary geologic units for Mars 2020 Rover exploration. [e.g., *Goudge et al.*, 2015]



Jezero Mafic Floor Unit

- Most of ellipse is a unit that contains minerals associated with volcanism (*mafic* minerals). [*Goudge et al.*, 2012, 2015]
- Unit could be a lava flow deposit or a volcanic ash deposit from explosive volcanism. [*Goudge et al.*, 2012, 2015; *Schon et al.*, 2012; *Shahrzad et al.*, 2019]

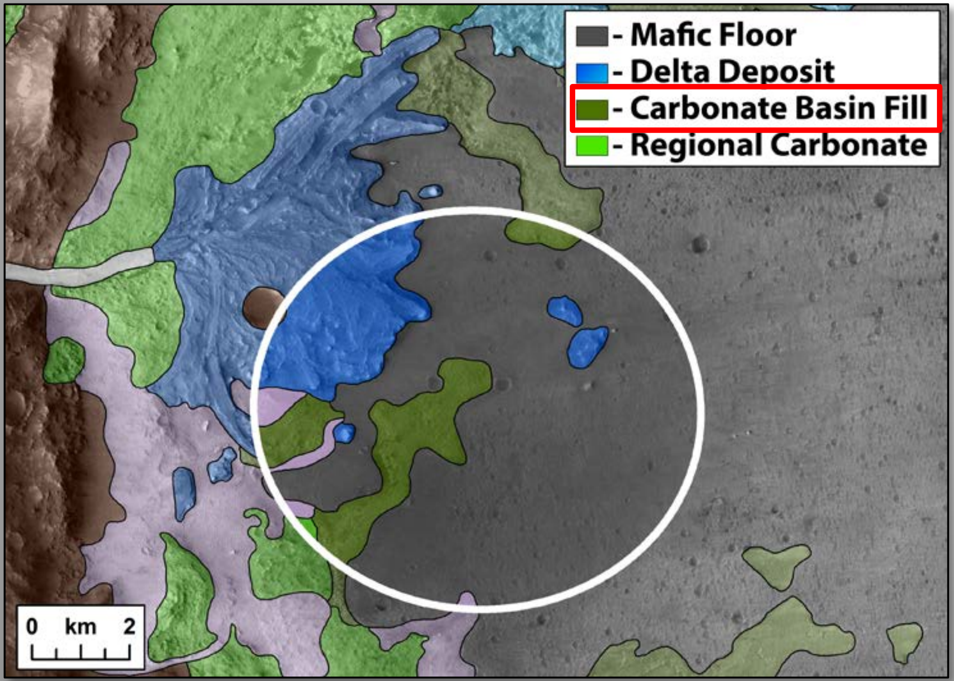


- **Units with mafic minerals can be easily age-dated in the lab. Would provide a key constraint for the entire martian geologic timescale.** *Presently this is tied to Apollo samples!*

Jezero Carbonate Unit

- Large exposures of a geologic unit that contains the mineral carbonate (*main component of limestone*). [*Ehlmann et al.*, 2009; *Goudge et al.*, 2015]

- Could potentially be a lake deposit. [*Ehlmann et al.*, 2009; *Schon et al.*, 2012; *Horgan et al.*, 2020]

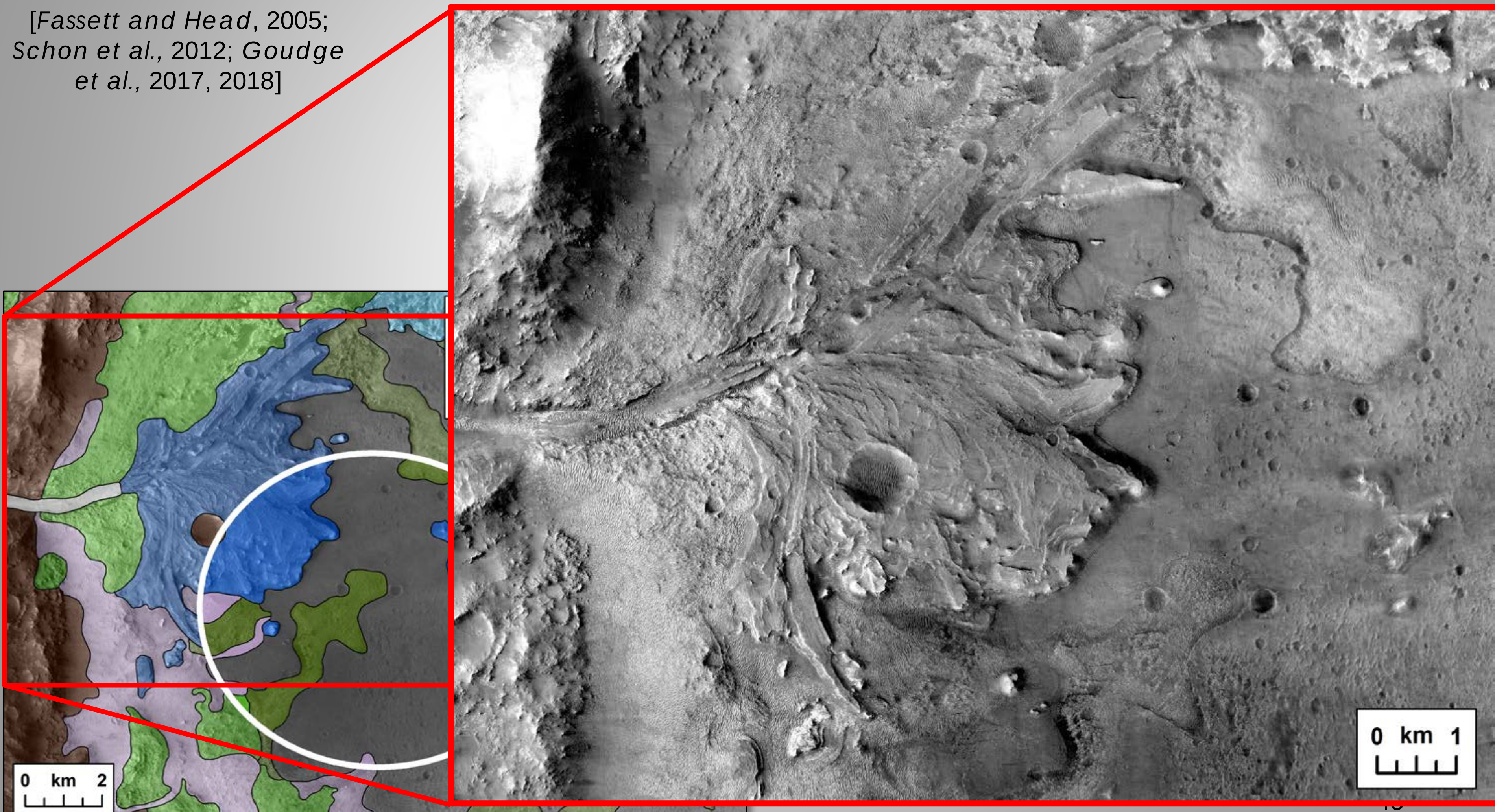


- **Carbonate is quite rare on Mars, but critically important. When it forms it can record: (A) the CO_2 composition of the atmosphere; and (B) the chemistry and temperature of water!** [*Halevy et al.*, 2011; *Niles et al.*, 2012]

Jezero Delta Deposit

Main feature of interest is a delta deposit.

[*Fassett and Head*, 2005; *Schon et al.*, 2012; *Goudge et al.*, 2017, 2018]



River Delta Deposits

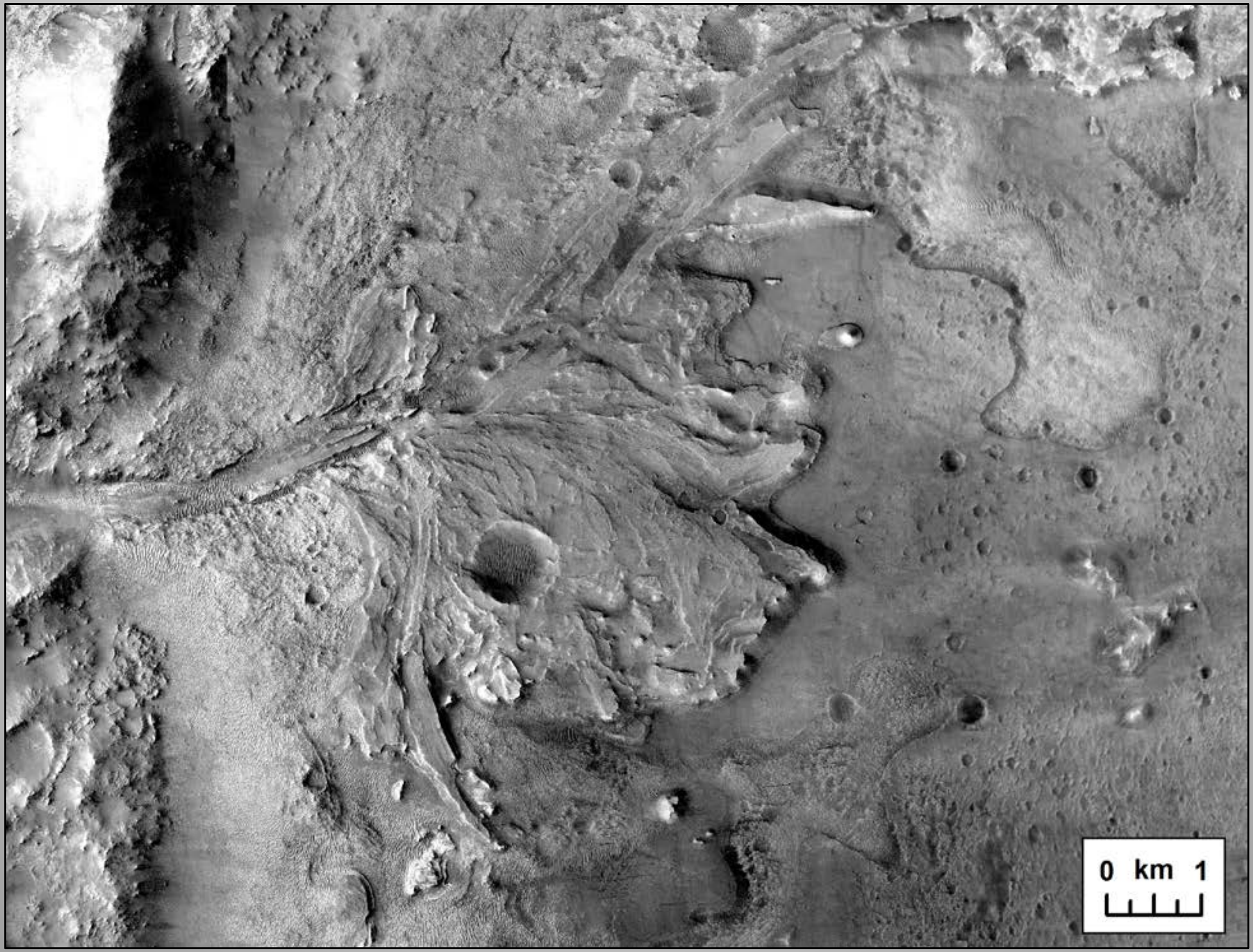
When a river enters a lake (or ocean), water stops and carried sediment is deposited, forming a delta.

Mississippi River & Delta

Image Credits: M. Manning, USGS

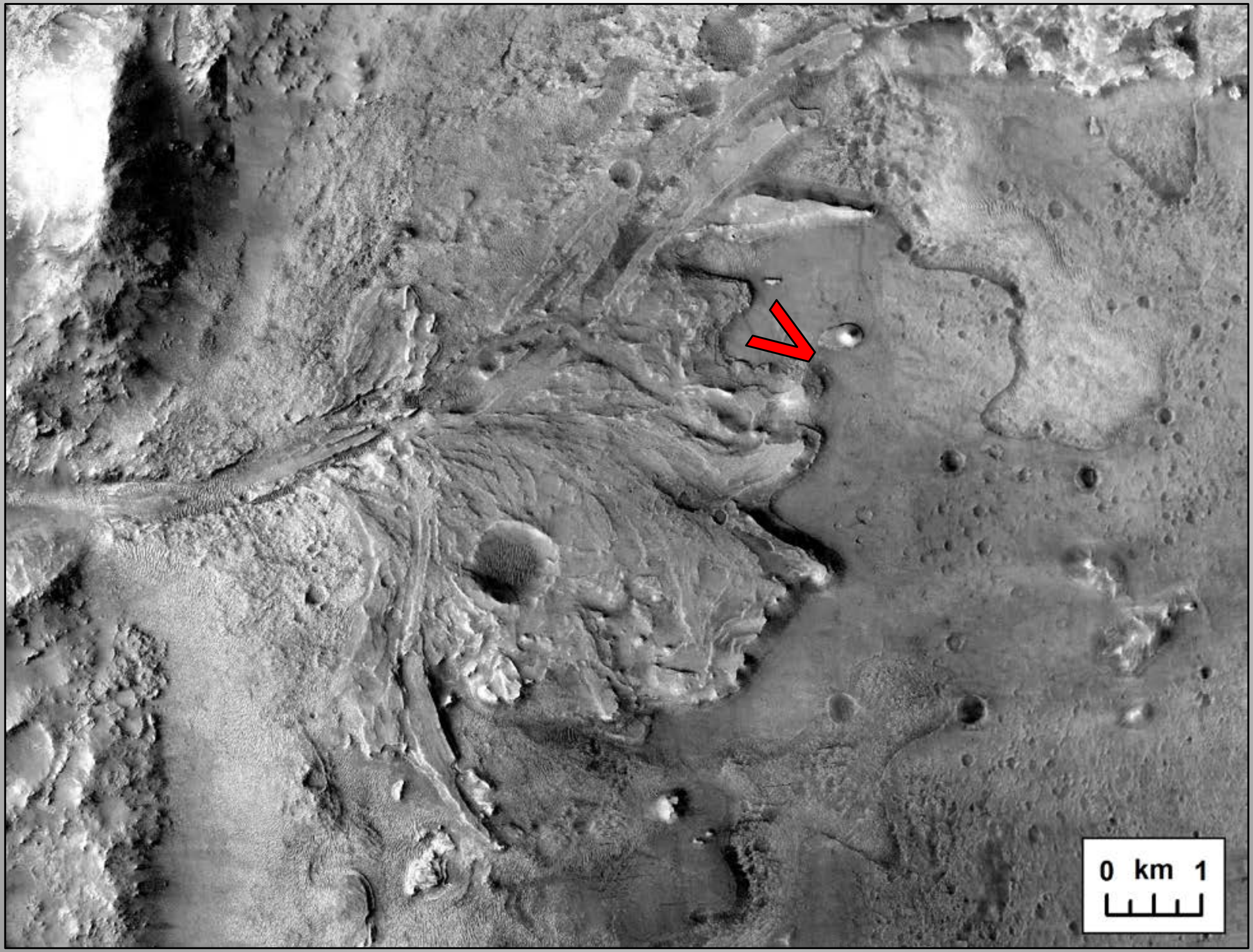
Jezero Delta Deposit

River entering Jezero crater built up sedimentary layers in a lake on Mars >3.5 billion years ago!!



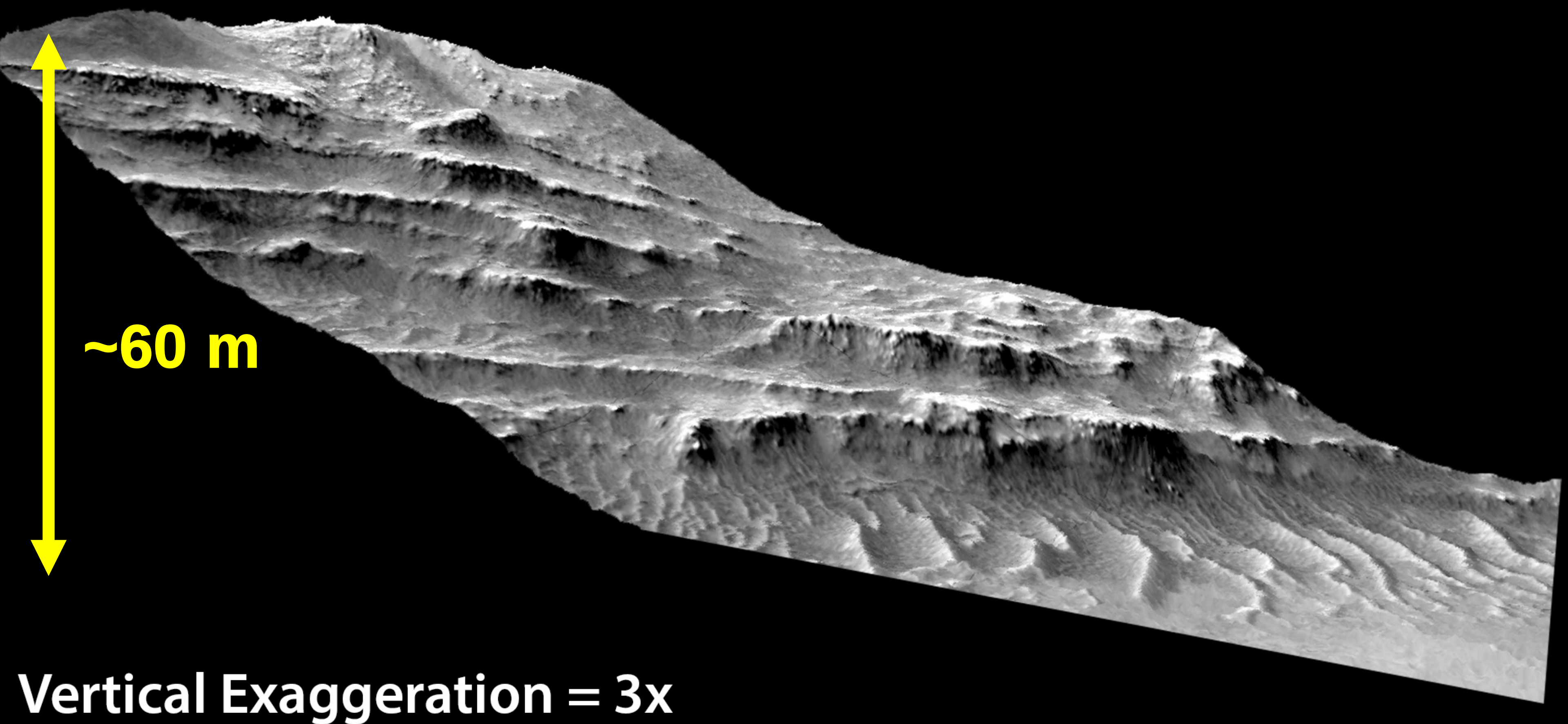
Jezero Delta Deposit

River entering Jezero crater built up sedimentary layers in a lake on Mars >3.5 billion years ago!!



Layers within Jezero delta record what the ancient martian surface was like when they formed.

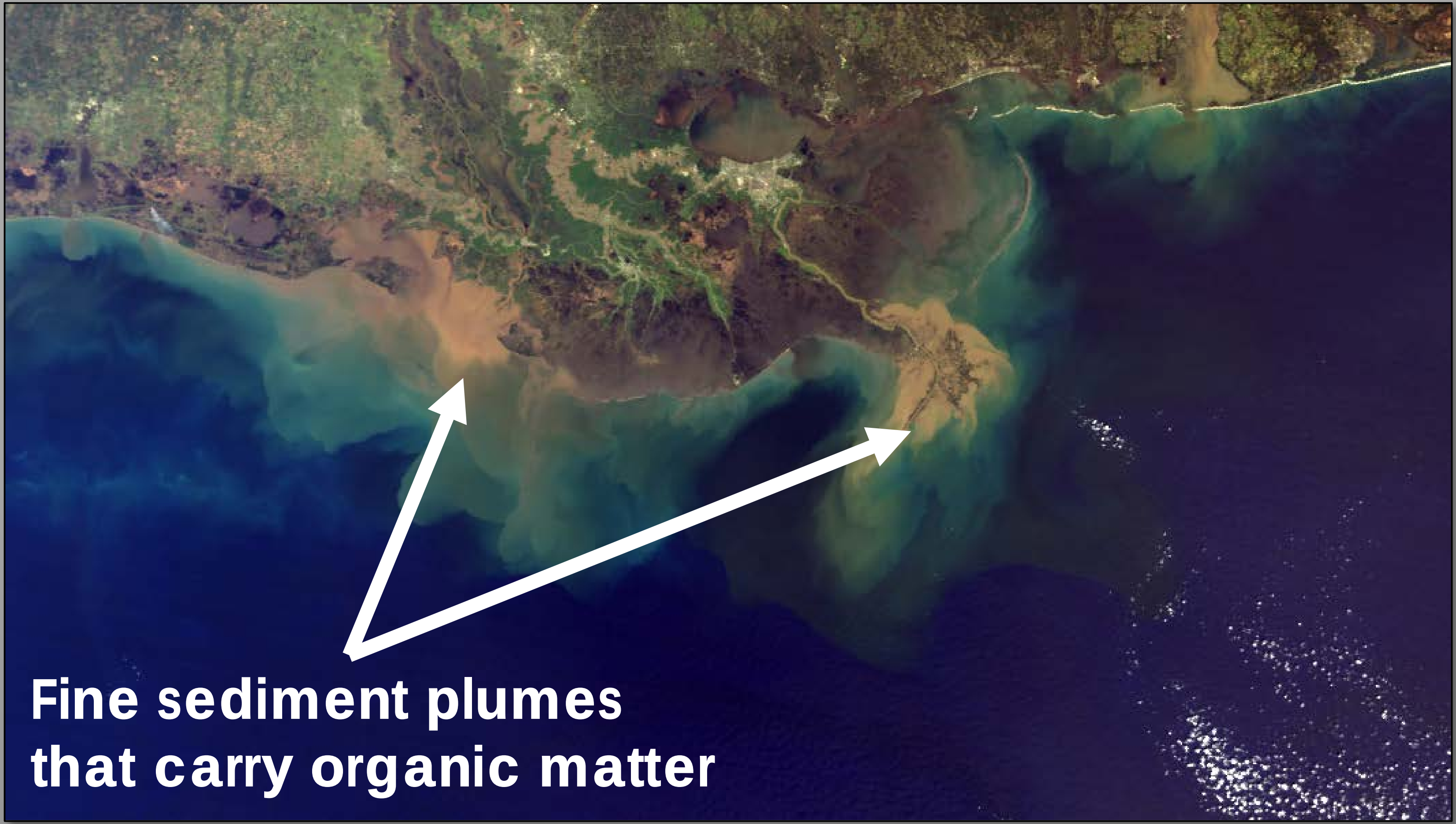
Mars 2020 will investigate these layers in detail!



Delta Deposits + Organic Matter

On Earth, river deltas collect and concentrate organic matter in specific layers.

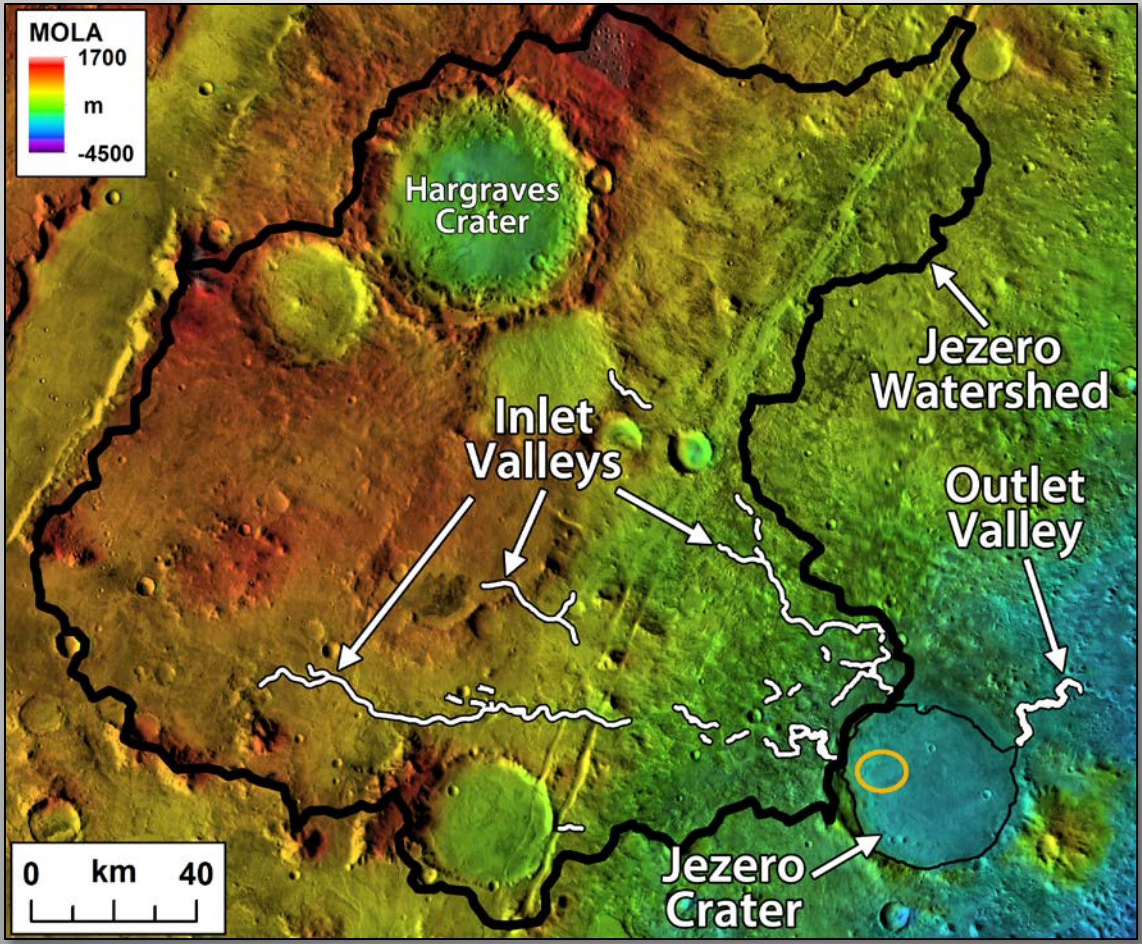
[*Rich,* 1951; *Huc,* 1988; *Summons et al.,* 2011; *Blair and Aller,* 2012]



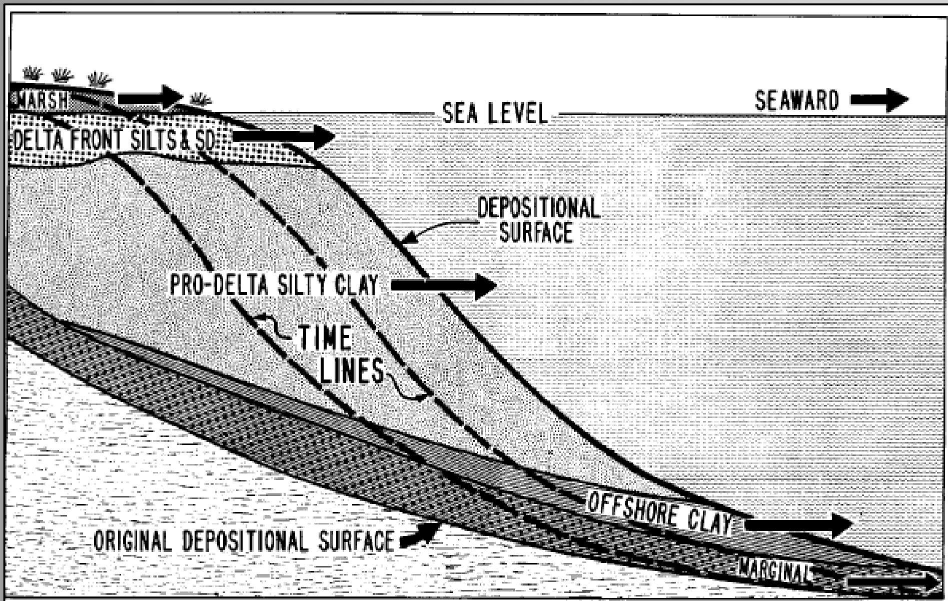
Jezero Lake Watershed

Jezero collected water and sediment (and organic matter?) from a very large (~30,700 km^2) watershed.

[e.g., *Ehlmann et al.,* 2009; *Goudge et al.,* 2015]



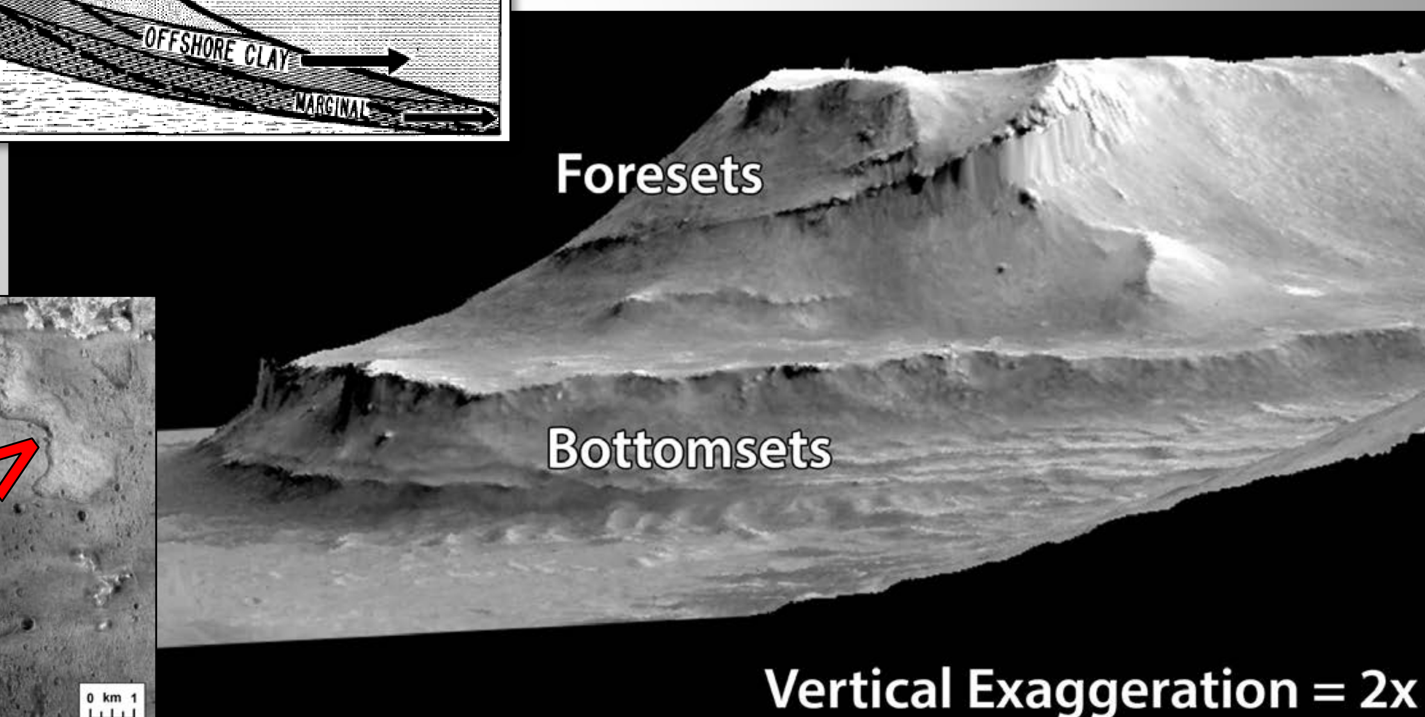
Jezero Delta + Organic Matter?

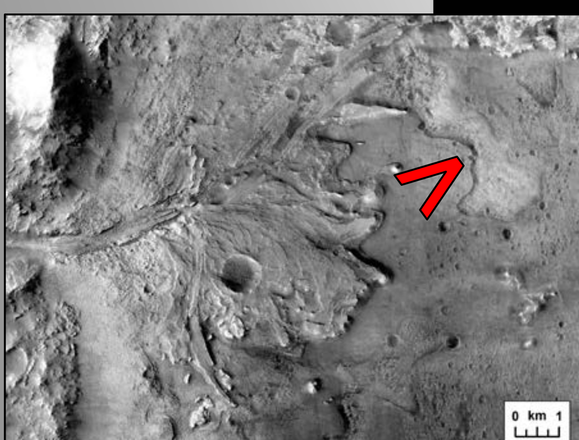


Scruton [1960]

Layers where we *expect* organic matter to be concentrated in a delta (*bottomsets*) will be accessible to Mars 2020!!

[*Goudge et al.*, 2017]

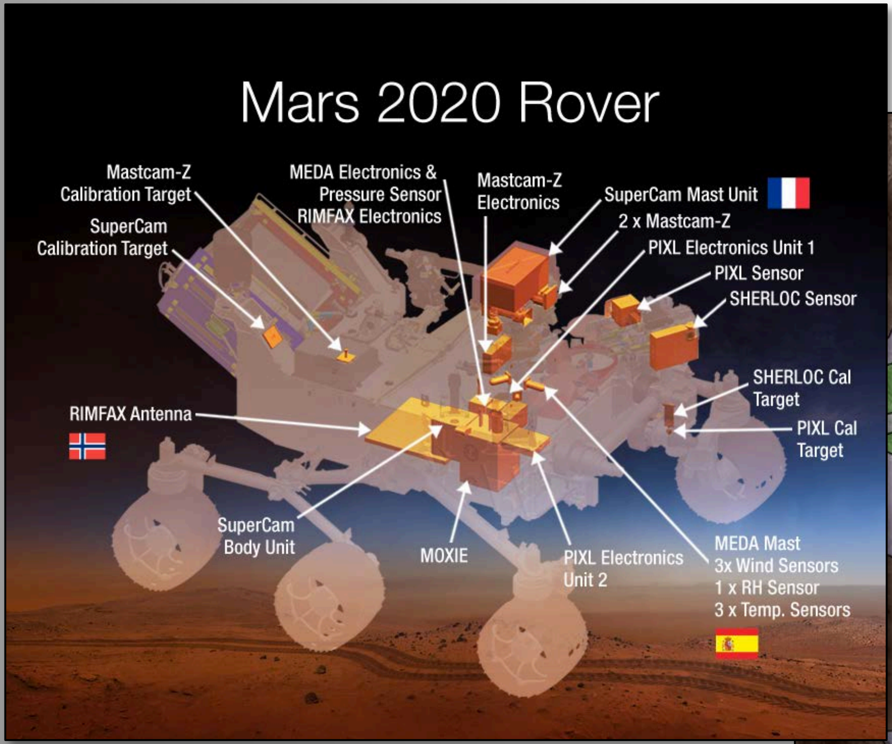


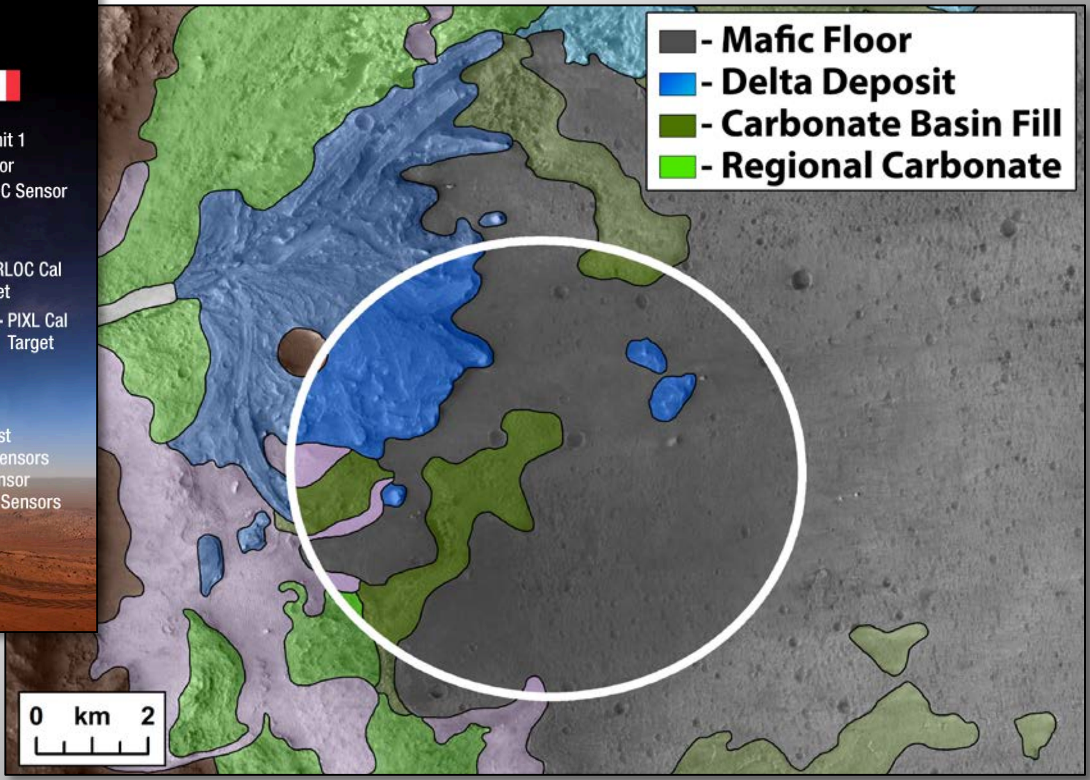


Mars 2020 at Jezero Crater

Mars 2020 launches this summer, and will begin exploring Jezero crater Feb. 2021.

Stay tuned for exciting results to come!!





Questions?