Mars Science and Human Exploration

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Compelling Reasons To Explore Mars

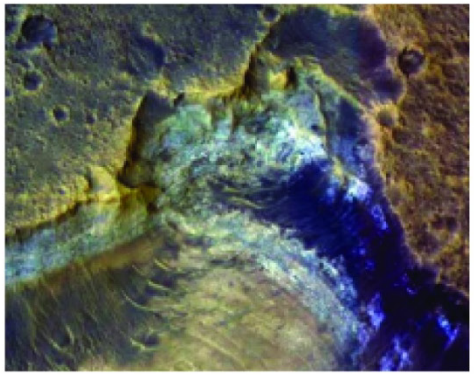
- Many of the key questions in ***solar system science*** can be addressed effectively at Mars:
  - Solar system history
  - Planetary evolution
  - Potential for life
- Mars provides the opportunity to approach, and possibly answer, ***origin and evolution of life questions***
  - Clear potential for past and possibly present biological activity
- Mars has a ***well-preserved record*** of its climate and geologic evolution exposed at the surface
  - A comparable record of ancient planetary processes, including those possibly leading to the origin of life, exists on no other terrestrial planet, including Earth
- Mars is the ***most accessible place in the solar system*** where these highest-priority science questions can be addressed

SOURCE: NRC Planetary Decadal Survey (2011)

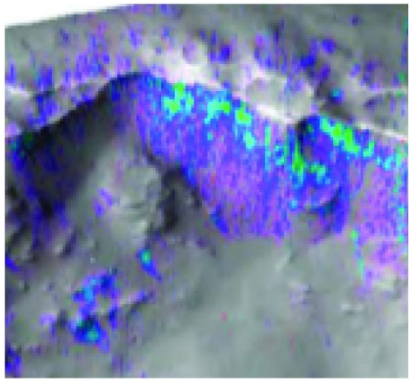
WHAT HAVE WE LEARNED?

1. Martian science
2. How to operate on Mars

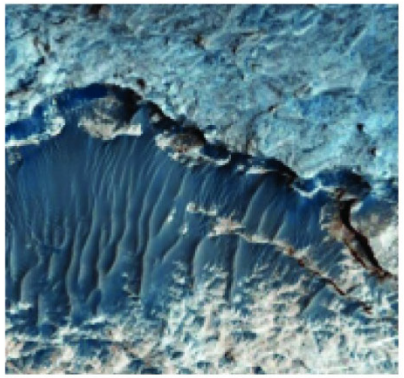
1. Mars has incredible diversity



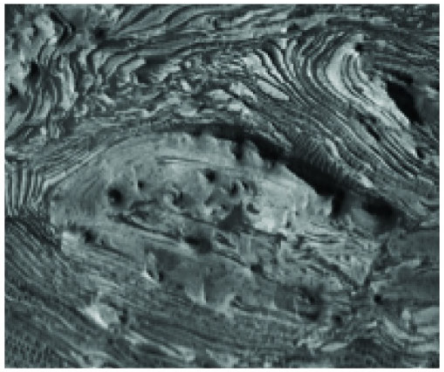
Noachian layered phyllosilicates



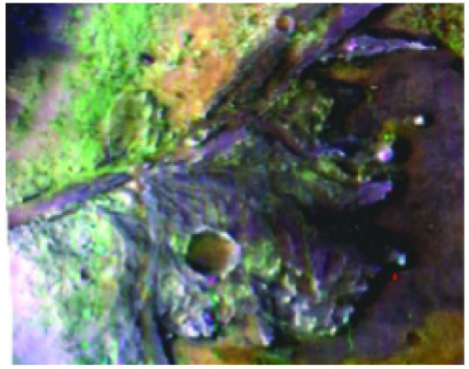
Noachian massive phyllosilicates



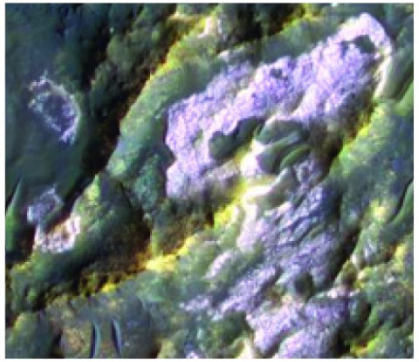
Noachian layered sulfates and hematite



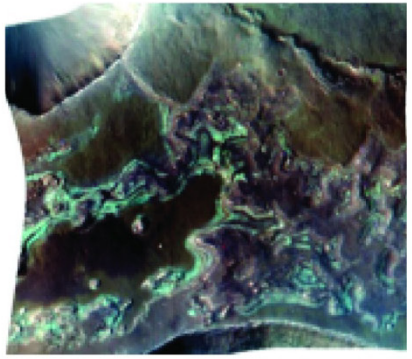
Hesperian layered deposits



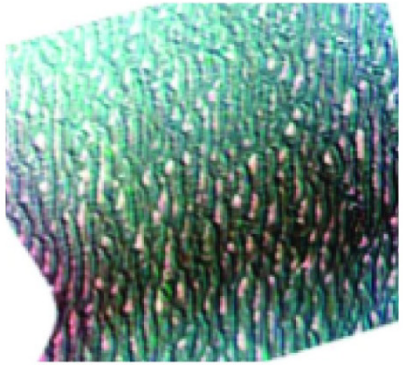
Noachian intra-crater deltas with aqueous minerals



Noachian putative chloride deposits

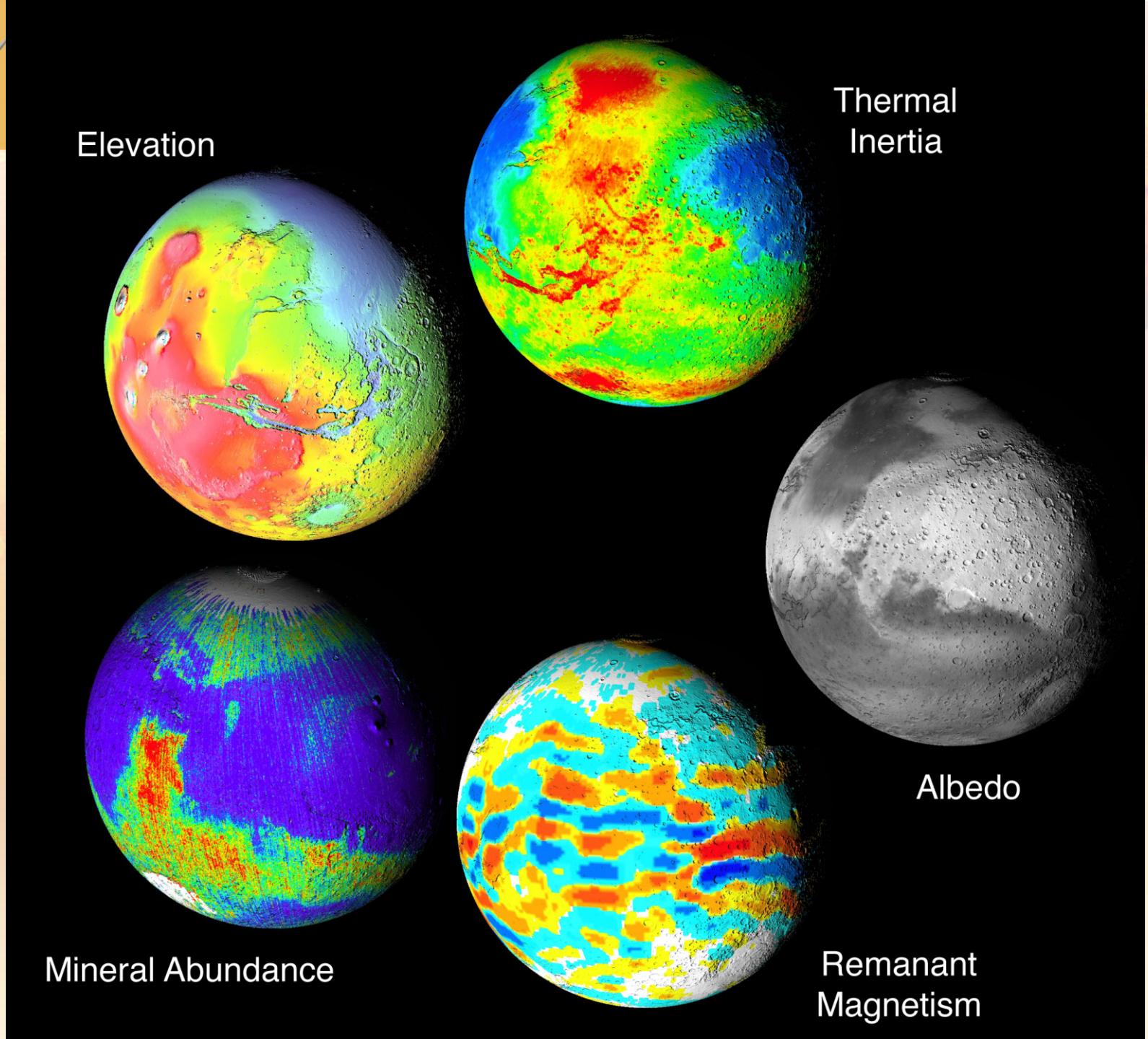


Hesperian silica deposits



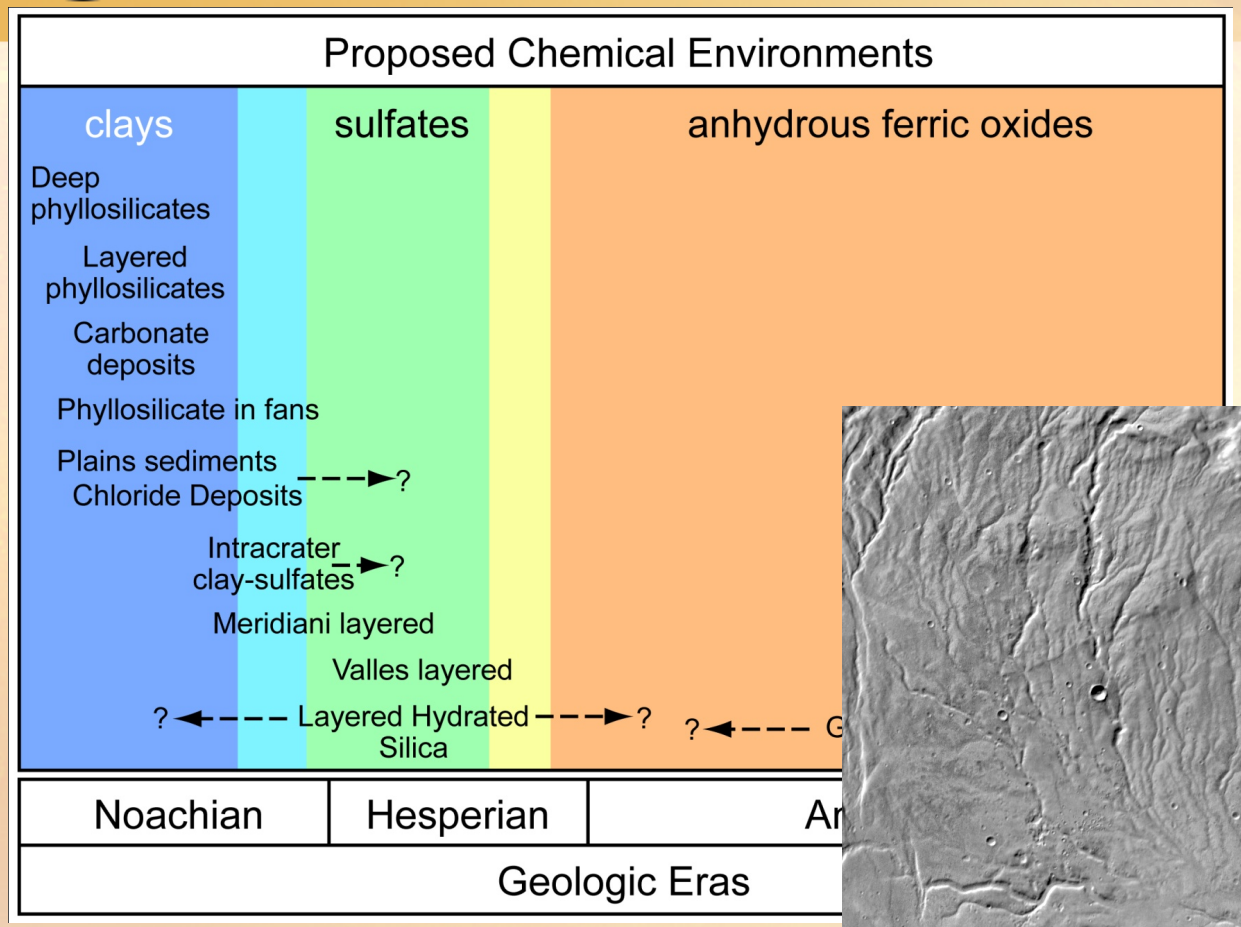
Amazonian gypsum polar dune materials

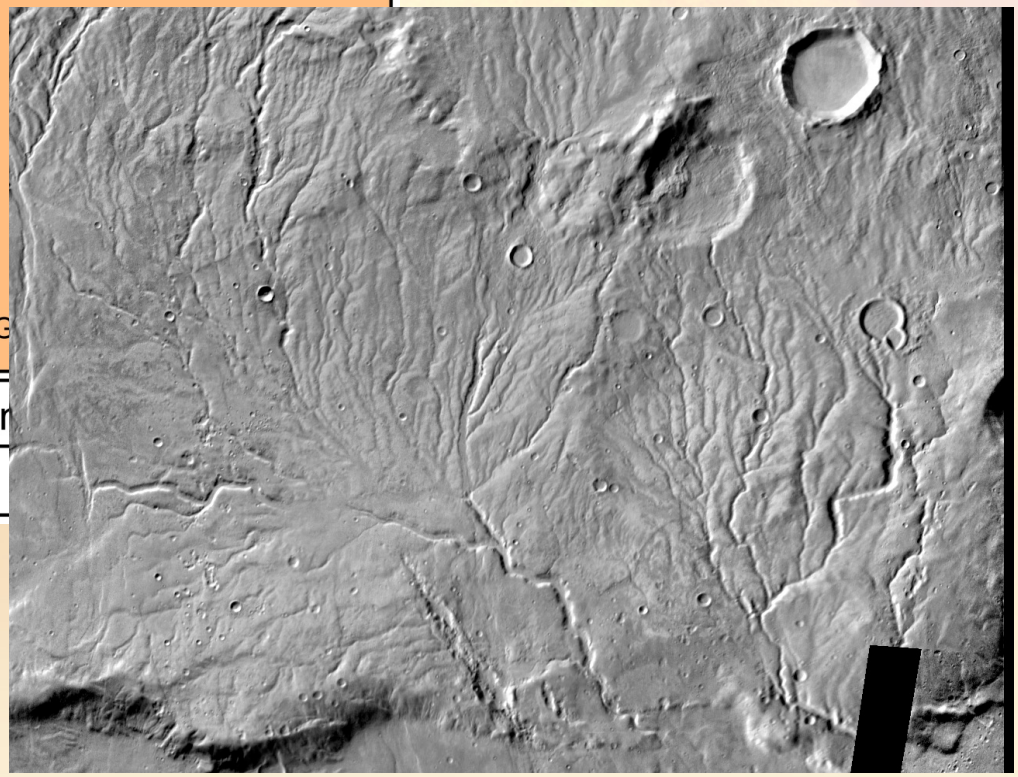
Source: NRC Planetary Decadal Survey (2011)



Source: NRC Planetary Decadal Survey (2011)

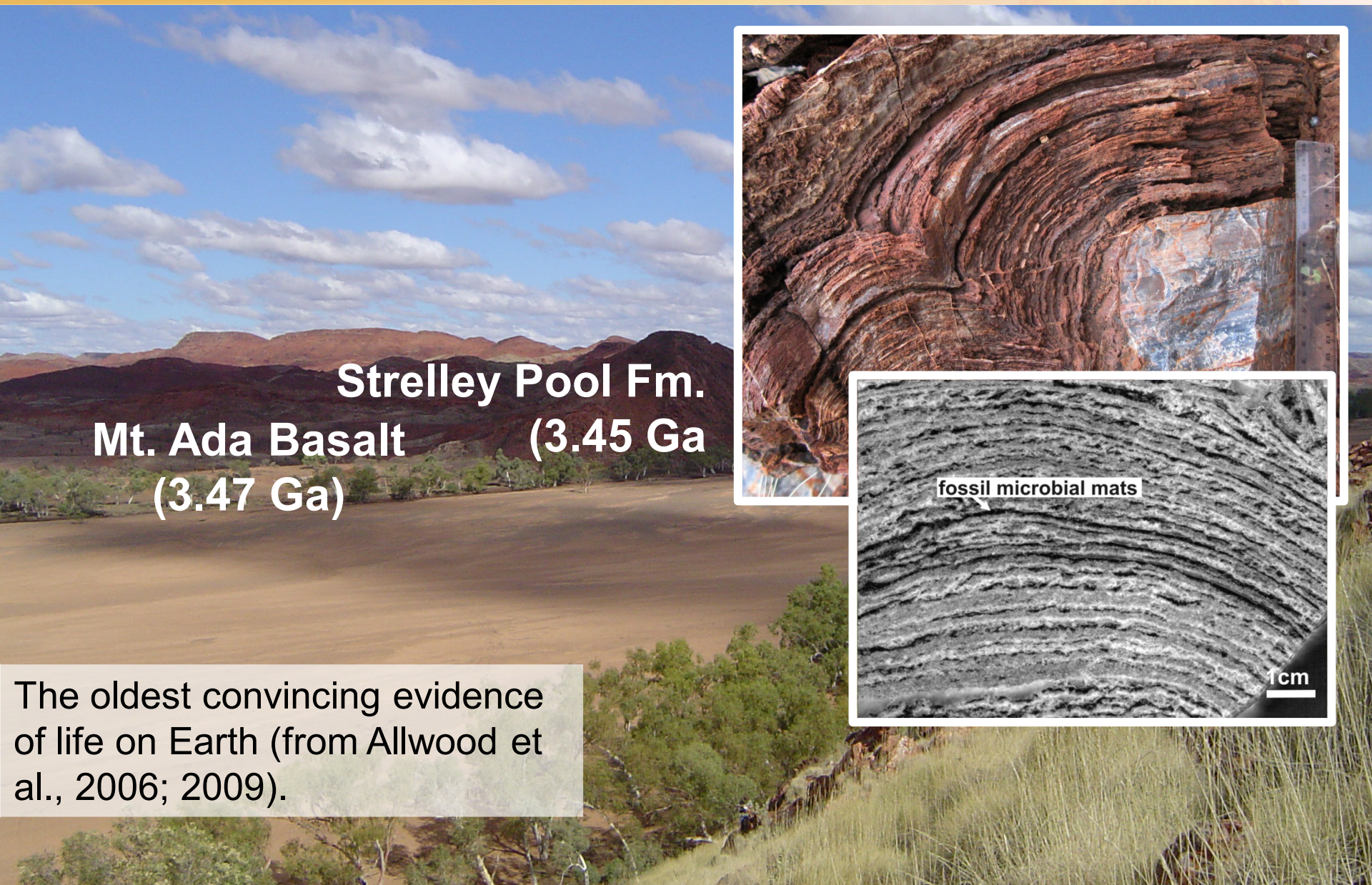
2. Mars was once wet and warm



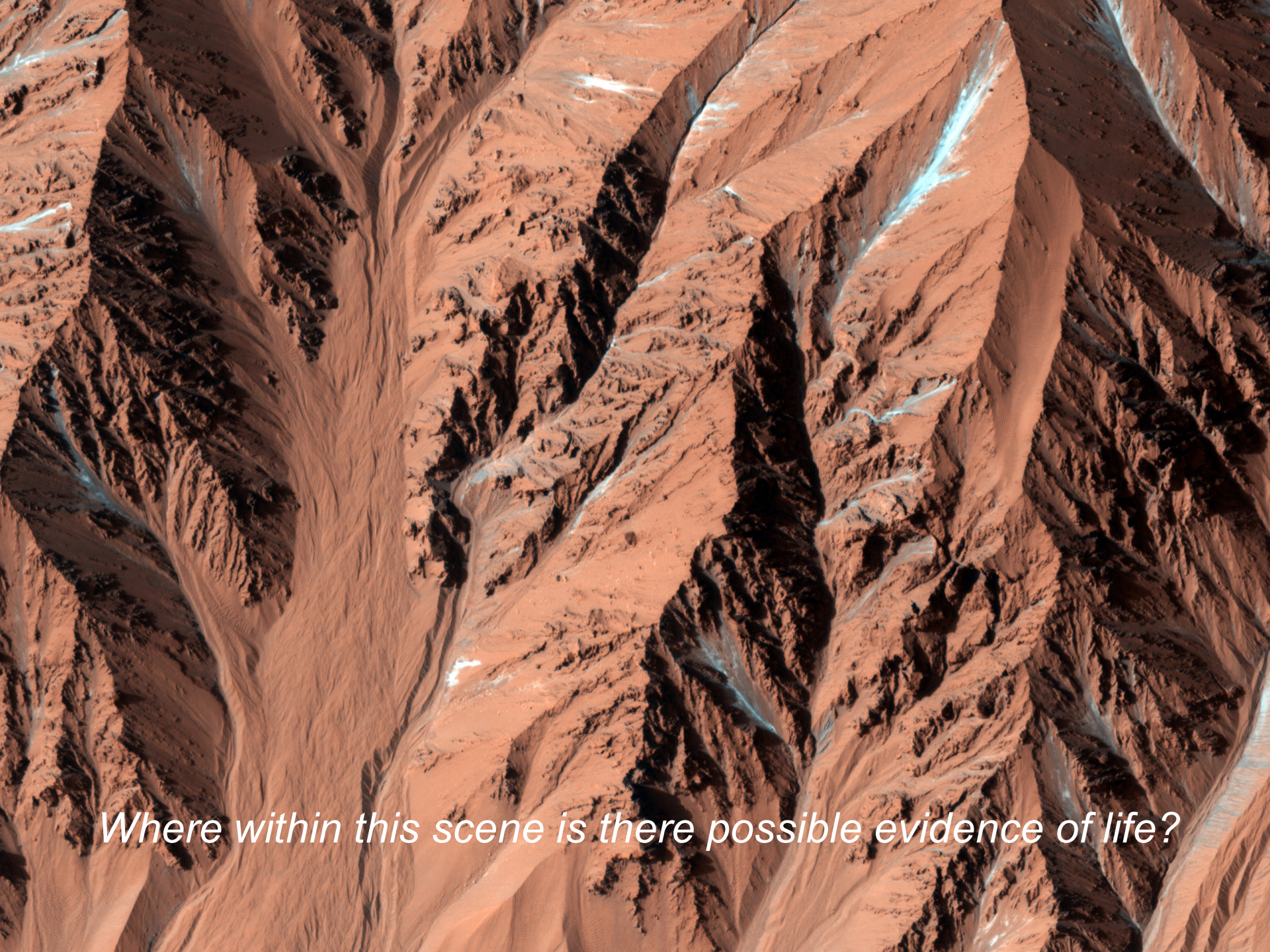


Source: NRC Planetary Decadal Survey (2011)

3. By analogy with Earth, <u>some</u> ancient martian environments were likely habitable

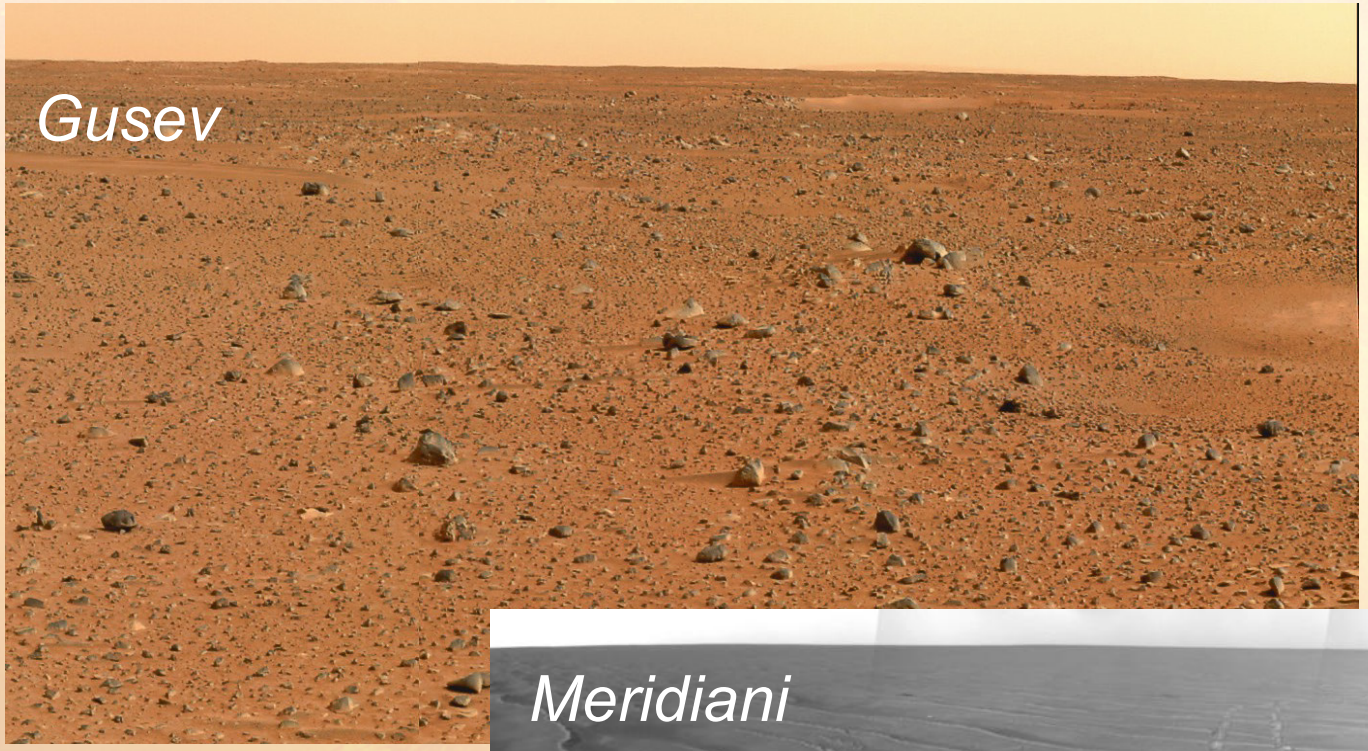


The oldest convincing evidence of life on Earth (from Allwood et al., 2006; 2009).


Where within this scene is there possible evidence of life?

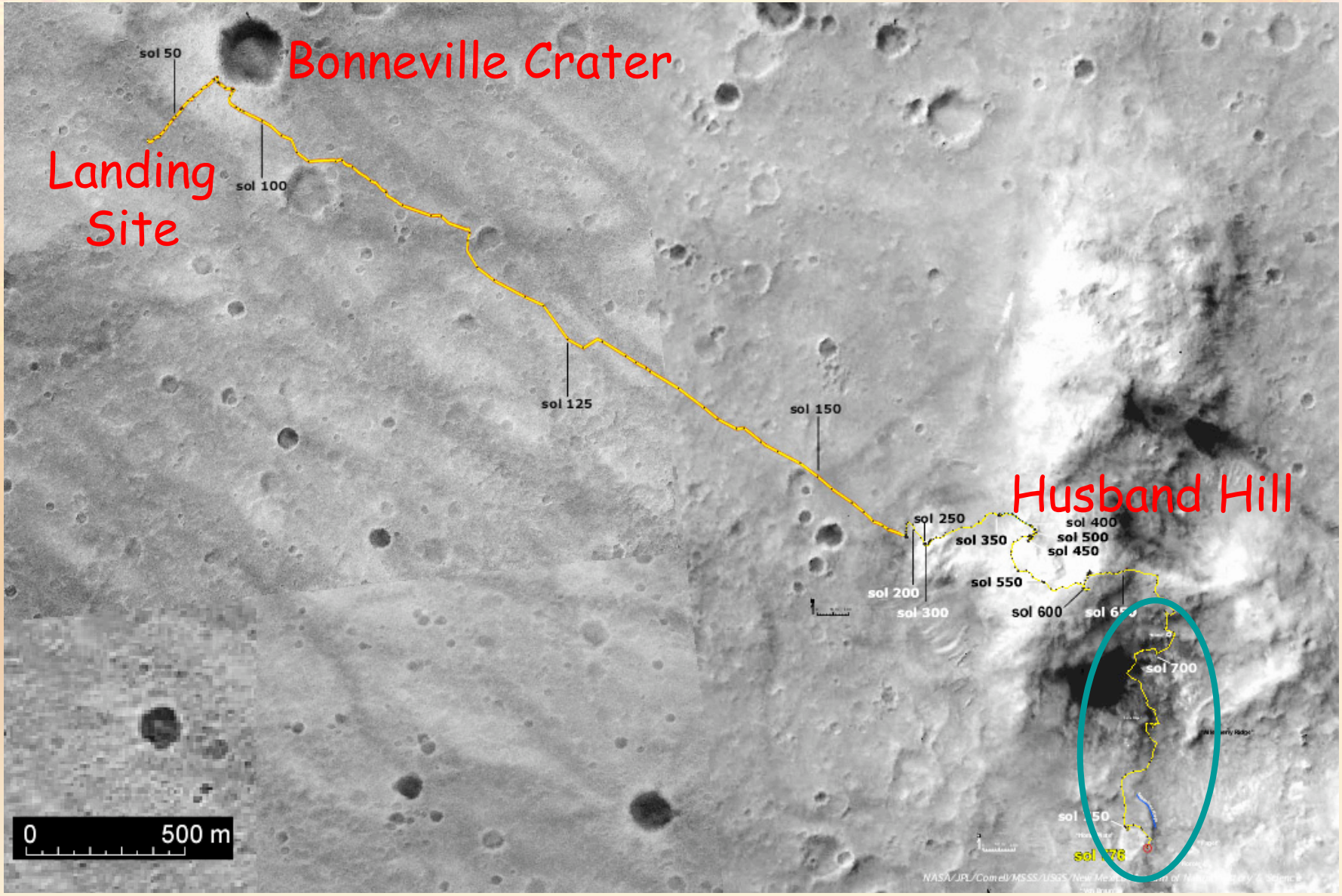
Some Lessons Learned:
1. Mobility is good

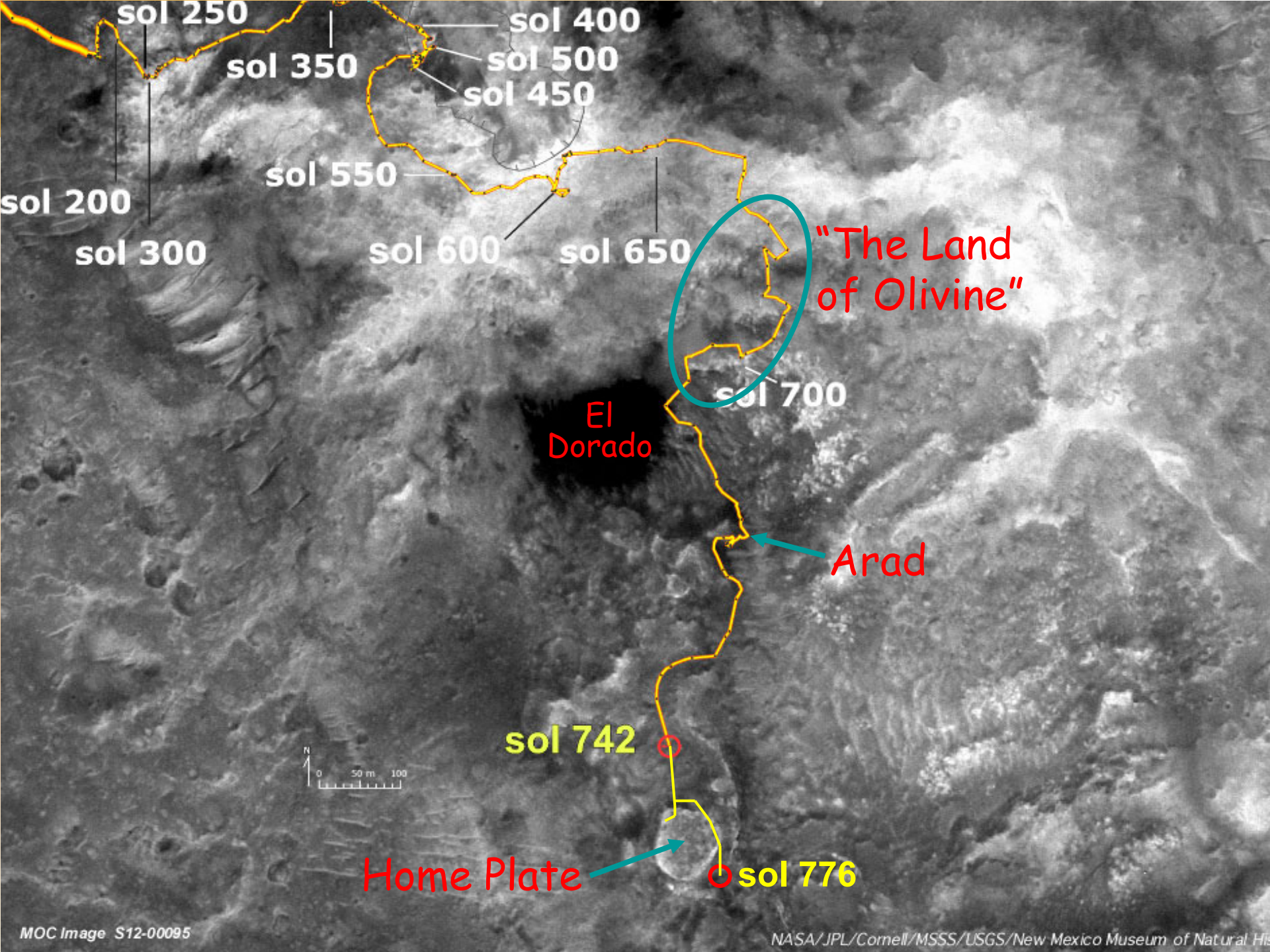
Most of our landing ellipses for MER look like this:



Some Lessons Learned:

A key to scientific exploration is mobility




sol 250
sol 350
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sol 500
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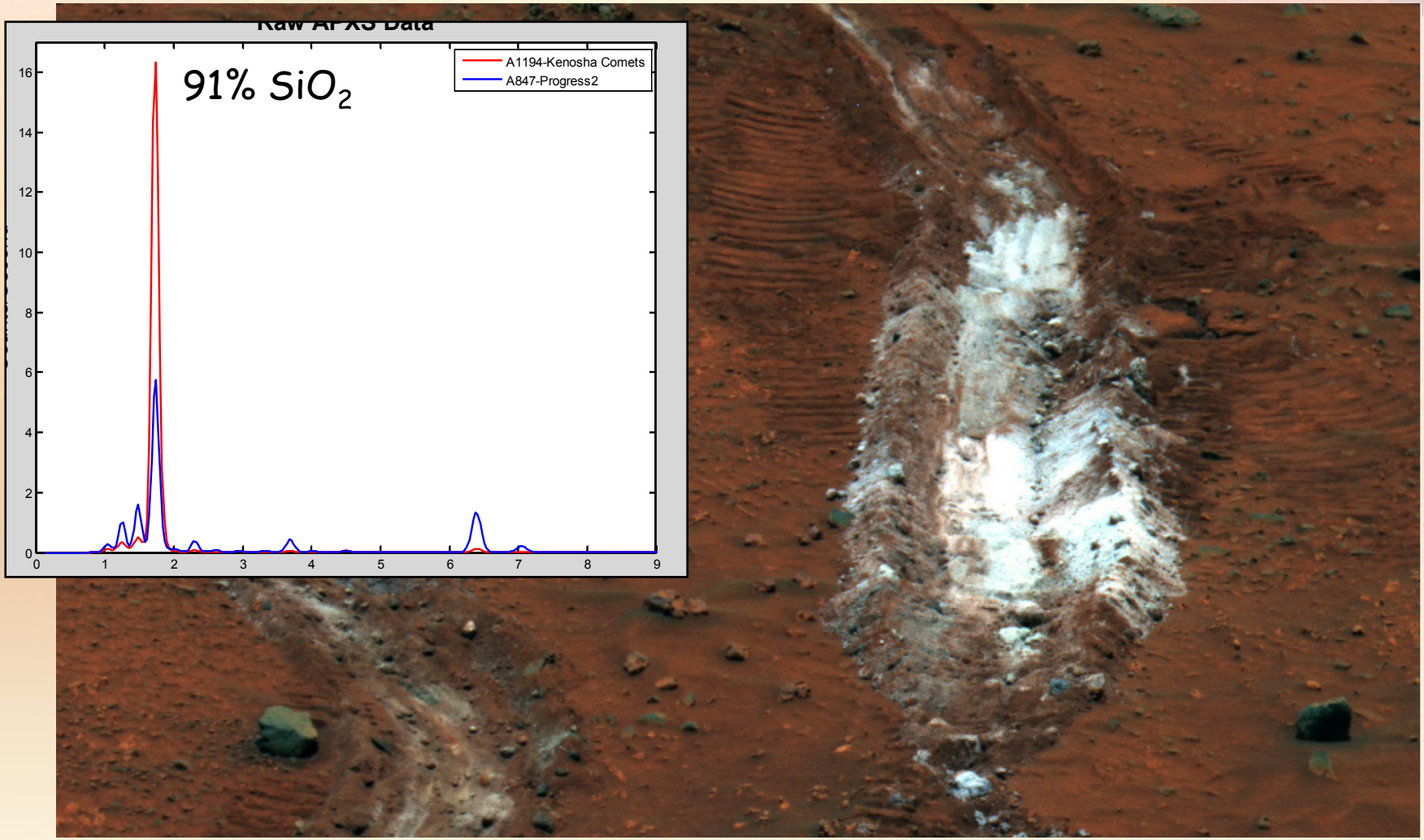
sol 550
sol 200
sol 300
sol 600
sol 650
"The Land of Olivine"
sol 700
El Dorado
Arad
sol 742
Home Plate
sol 776
MOC Image S12-00095
NASA/JPL/Cornell/MSSS/USGS/New Mexico Museum of Natural Hi

Some Lessons Learned :
2. Longevity is good

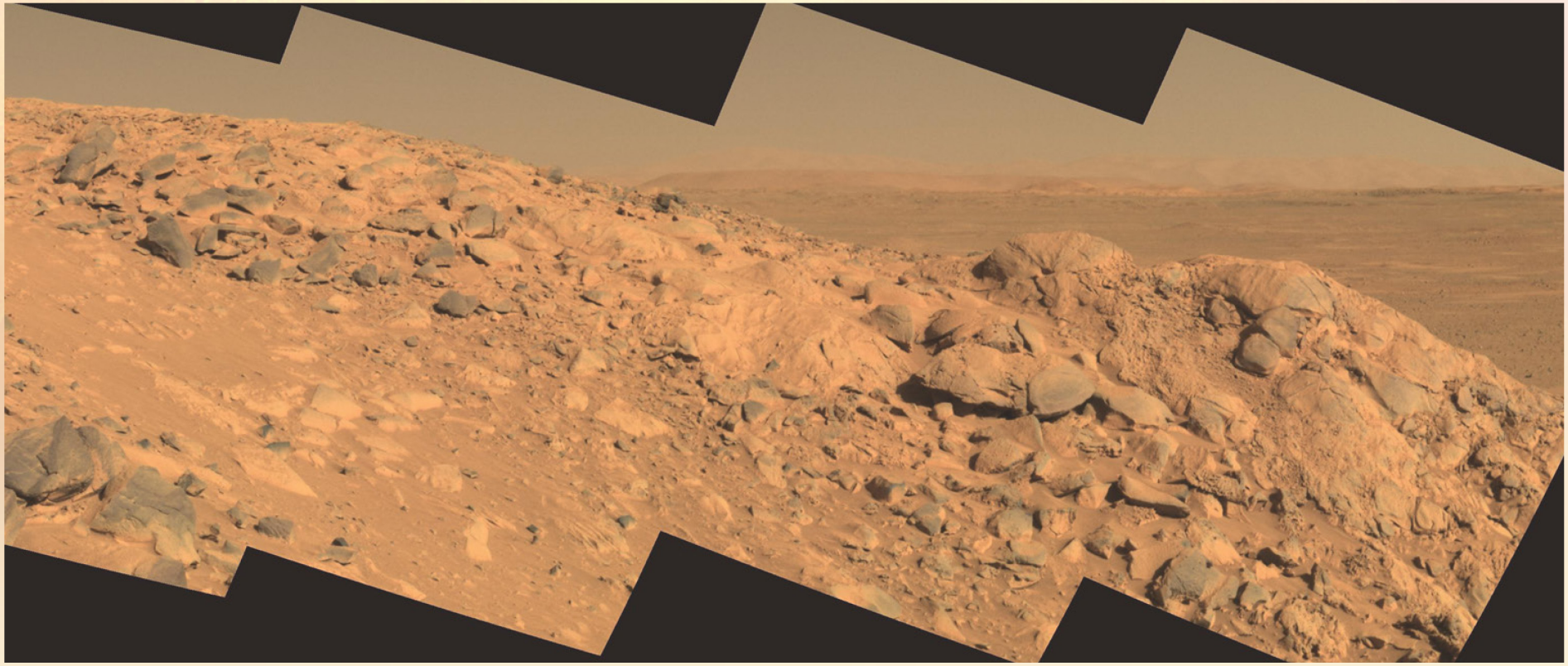
- Spirit's most significant discovery was made 1200 sols into its 90-sol mission:



Some Lessons Learned :
3. Steep terrain can be of critical importance

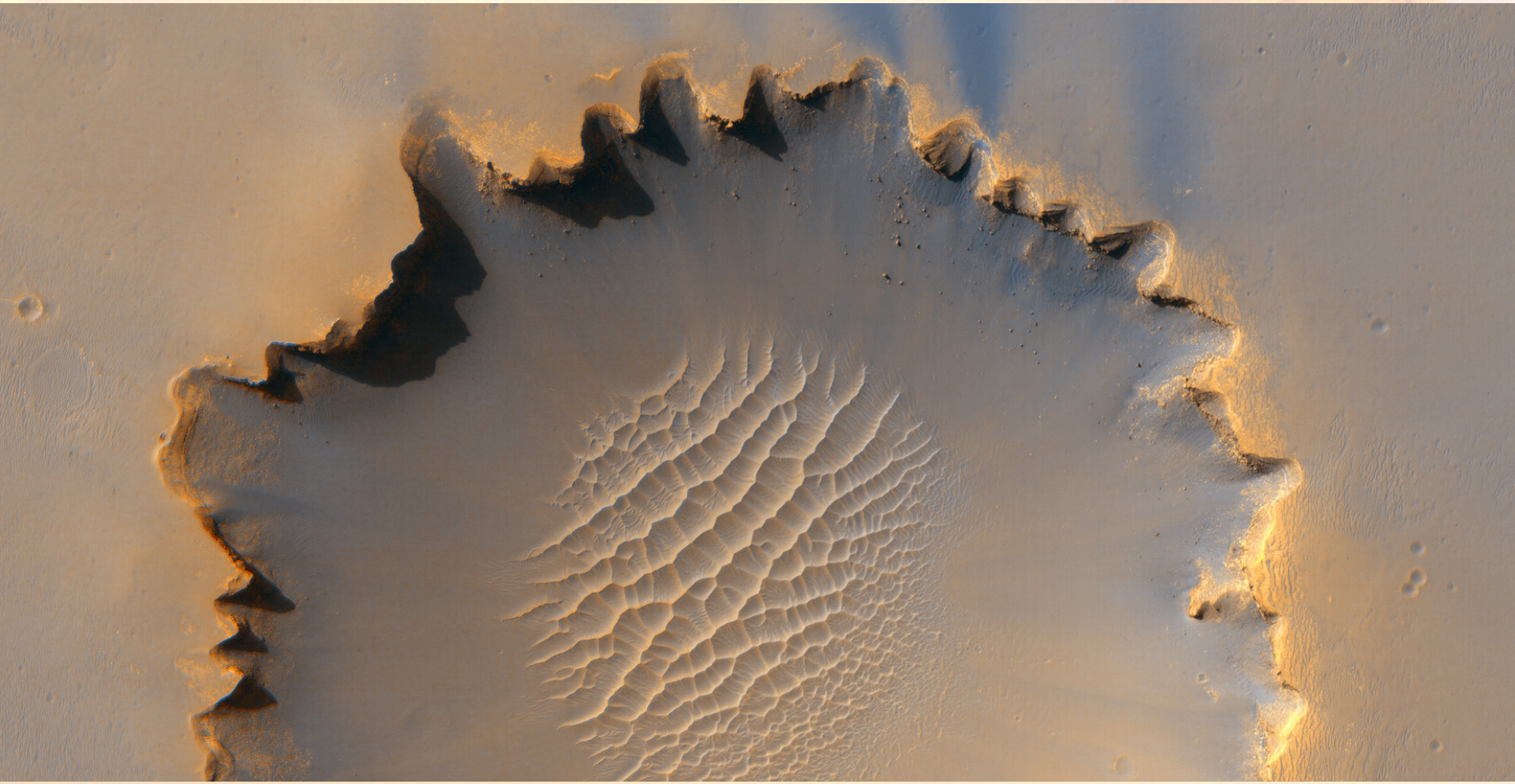
It pays to invest in the hardware, software, and testing necessary to handle steep terrain.

- don't just think about range and obstacle avoidance, also consider climbing and descending.



We need to be able to deliberately access places like this.

Some Lessons Learned :
4. High-Resolution orbital imagery is critical



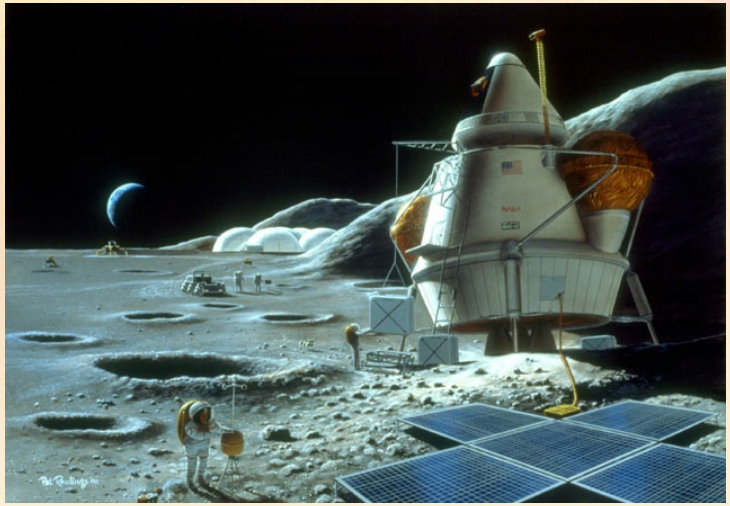
Imagine doing traverse planning around the edge of this crater without this information!

Three primary human-related science investigation strategies are recognized.

Field Science

On-Mars laboratory Investigations (and their connection to sample return)

Investigations requiring complex in situ instrumentation



A paradox

The **search for life** is our top scientific goal: We would like to use our most capable mission (a human Mars mission) to pursue it.

HOWEVER,

In order to safely land a human mission on Mars (and return the crew to Earth), we will have to **know in advance** that the risk due to biohazards is acceptable.

Solving the paradox

- The existence or absence of (extant) life at the landing site would have to be established by robotic means before a human landing.
  - This needs to constitute a **primary objective of the pre-human robotic program.**
  - **MSR would be critically important**
- The first human mission would naturally lend itself to investigations of **extinct life**, or characterization of life previously discovered by in-situ missions
  - Biologically safe
  - Sufficient scientific importance

Backup

Assuming a program of three crewed missions

	PLANETARY SCIENCE		SUSTAINED PRESENCE	
	Short Stay	Long-Stay	Short Stay	Long-Stay
One Site	BELOW SCIENCE FLOOR	BRONZE STANDARD	BRONZE STANDARD	GOLD STANDARD
Multiple Sites	SILVER STANDARD	GOLD STANDARD	BRONZE STANDARD	SILVER STANDARD

Why Humans?

Unique attributes human explorers could bring to bear in comparison to robotic explorers:

- Cognition
  - Rapidly recognize and respond to unexpected findings; sophisticated, rapid pattern recognition (e.g. structural/ morphological biosignatures).
- Dexterity
  - Humans are capable of fine-scale, non-repetitive manipulations. Valuable in sampling heterogeneous rocks/outcrops.
- Adaptability
  - Humans are able to react in real time to new and unexpected situations, problems, hazards and risks.
- Efficiency
  - Robotic manipulation requires several sols to accomplish what humans could do in a matter of minutes.