National Aeronautics and Space Administration

Mars Exploration Program Analysis Group
March 3, 2009

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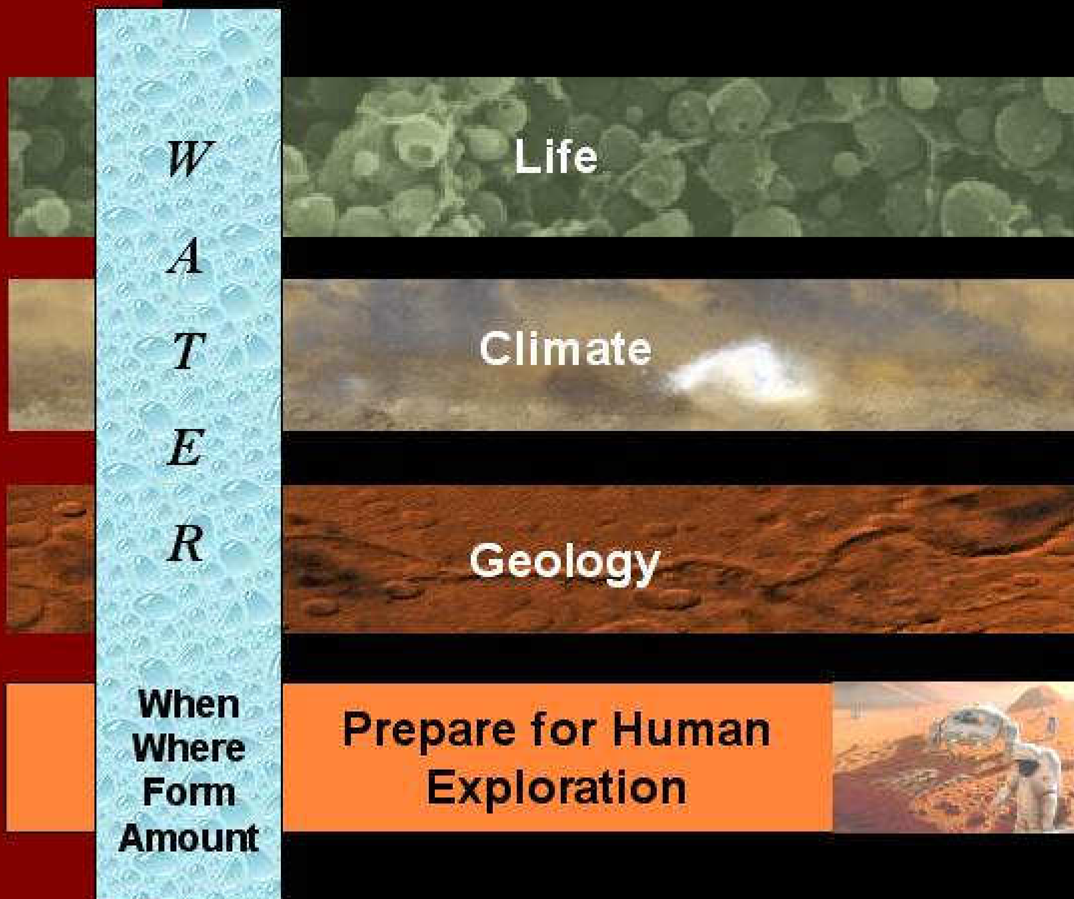
Outline

- Folow the Water
- Missions in Development
- Science Overview
- Next Decade

The Mars Science Strategy: "Follow the Water"

- When was it present on the surface?
- How much and where?
- Where did it go, leaving behind the features evident on the surface Mars?
- Did it persist long enough for life to have developed?



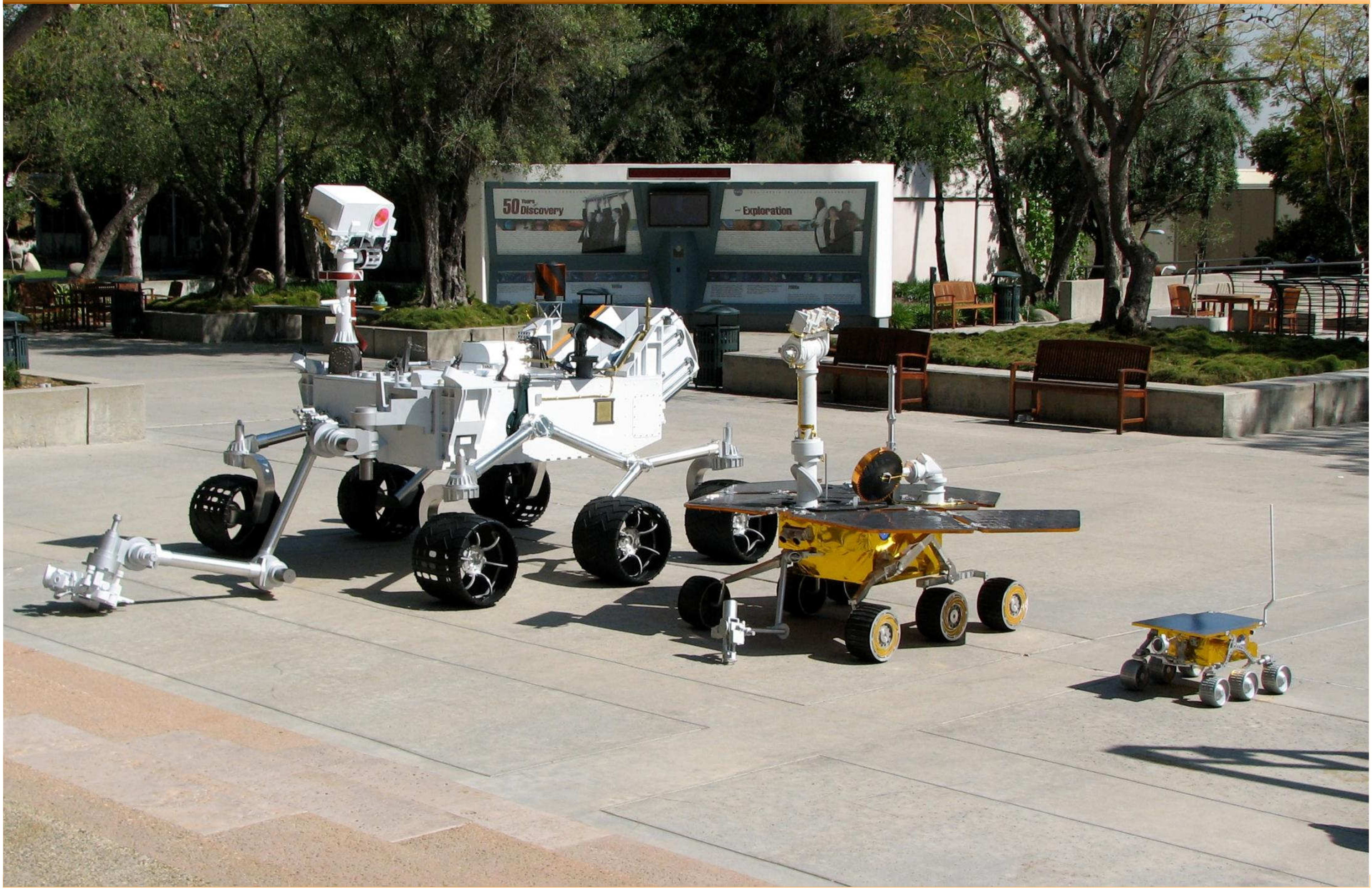
Understand the potential for life elsewhere in the Universe

Characterize the present and past climate and climate processes

Understand the geological processes affecting Mars' interior, crust, and surface

Develop Knowledge & Technology Necessary for Eventual Human Exploration

Rover Family Tree

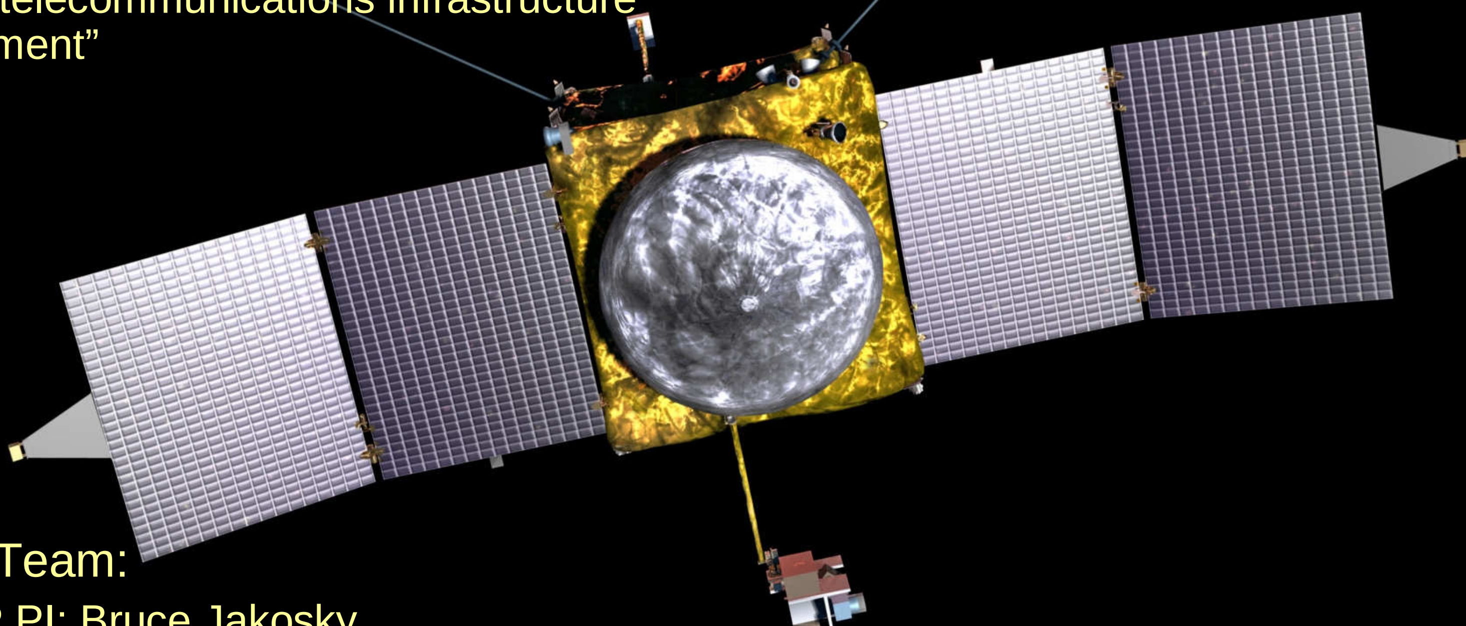


Mars Science Laboratory

- MSL is the first astrobiology mission since Viking. Ten instrument packages with the objective to explore and quantitatively assess a region of Mars as a potential habitat for life, past or present. Analytic and in-situ measurements will provide essential ground truth to anchor regional and global remote sensing mineralogy data
  - These in-situ data will:
    - Test hypotheses of early Martian environmental evolution, including climate history
    - Determine which environments might have best preserved environmental signals, and possibly biosignatures
    - Test interpretations of global mineralogy inferred from orbit
- Feed Forward Engineering:
  - New EDL system will enable future high-mass landings
  - Develop experience with sample collection, manipulation, and sample preparation
  - Targeted landing—critical capability for accessing high-priority science targets
  - Next generation of complex lab instruments to another planetary surface

NASA Selects Scout-13—MAVEN

- Fulfillment of a high-priority National Academy of Science Objective — Aeronomy
- Importance to Mars Exploration Program:
  - Addresses key science objectives for upper atmosphere, solar wind interaction, and escape to space, as defined by MEPAG (2006) and the NRC (2003)
  - Provide telecommunications infrastructure "refreshment"



- The Mission Team:
  - CU/LASP PI: Bruce Jakosky
    - GSFC Project Management
    - Lockheed Martin spacecraft and Ops
    - Instruments from UCB, LASP, GSFC, and CESR/France

What have we discovered?

[The 2003 projection of where our discoveries might take us]

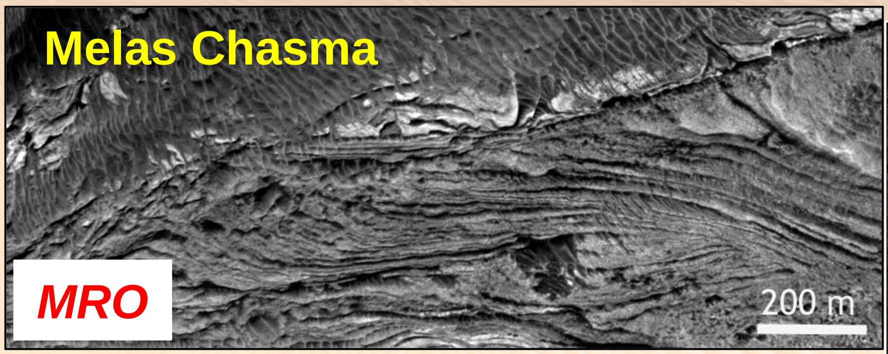
- **Search for Evidence of Past Life**
  - **Keys: Understand stratigraphy, biologic preservation potential**
  - **Low scientific risk: sedimentary targets are very large**
- **Explore Hydrothermal Habitats**
  - **H-t environments considered highly prospective for life**
  - **Can be pursued using in-situ missions**
- **Search for Present Life**
  - **Explore active aqueous areas**
  - **Need to access specific targets (small?, subsurface?); major PP issues; MSR required.**
- **Explore Evolution of Mars**
  - **Science in first decade significantly changes the questions to be asked**
  - **Need for planet-wide recon through second decade**

RESULTS

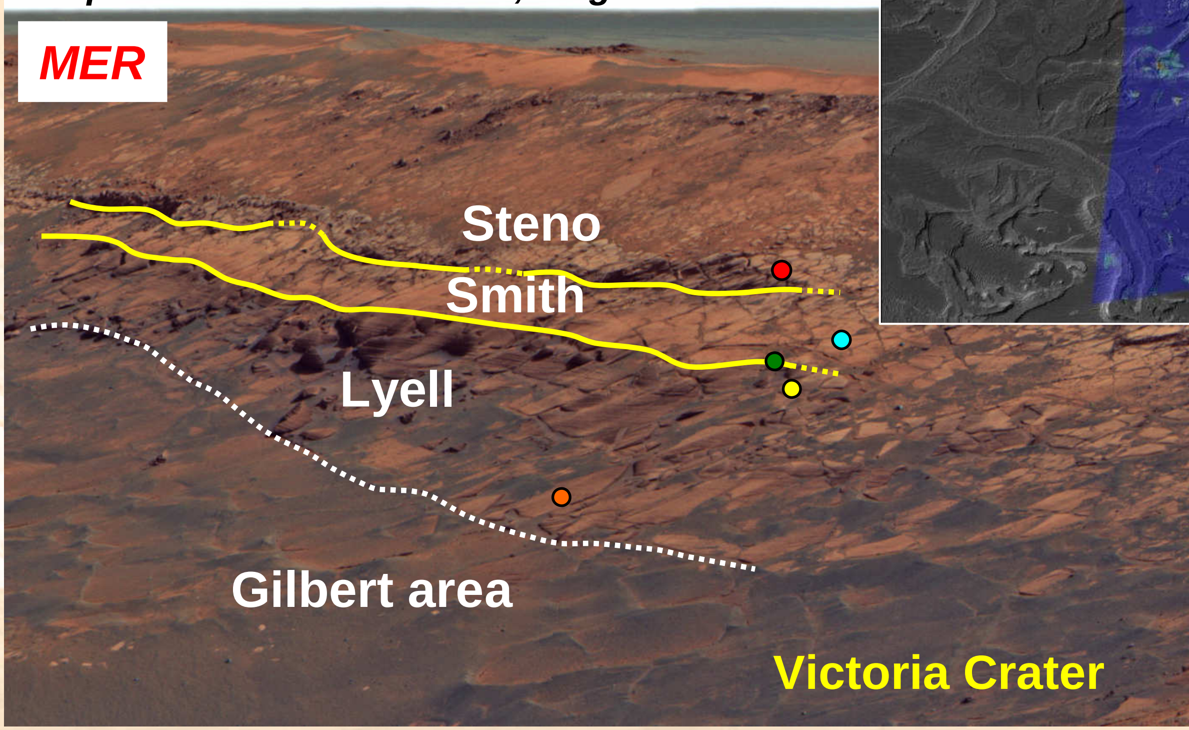
WHAT HAVE WE FOUND?

Discoveries: Possibility of Past Life

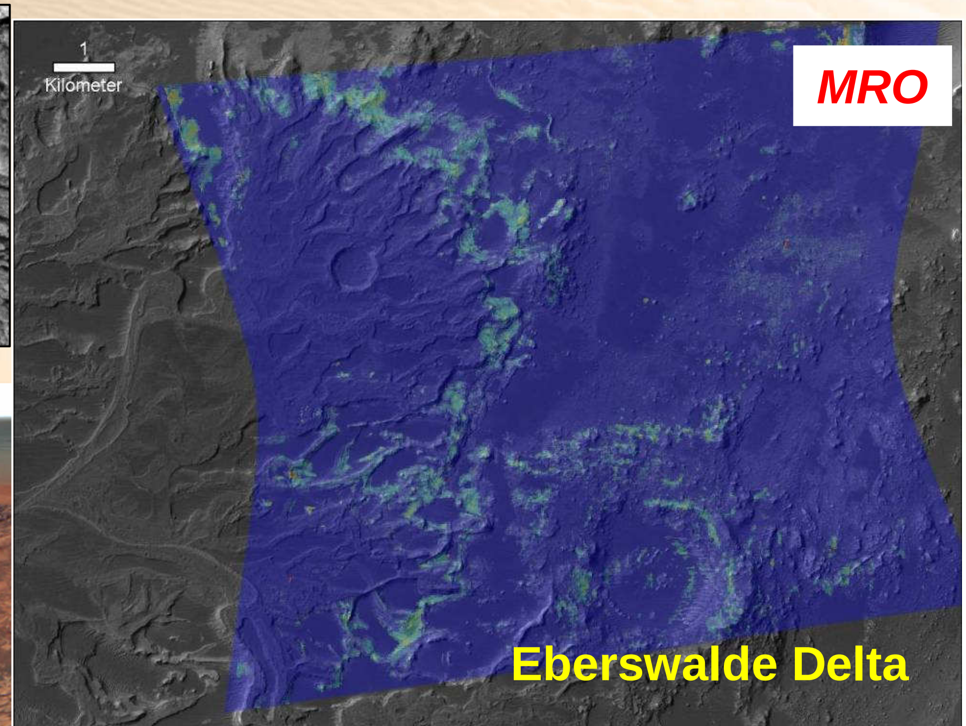
Large-scale sedimentary structures



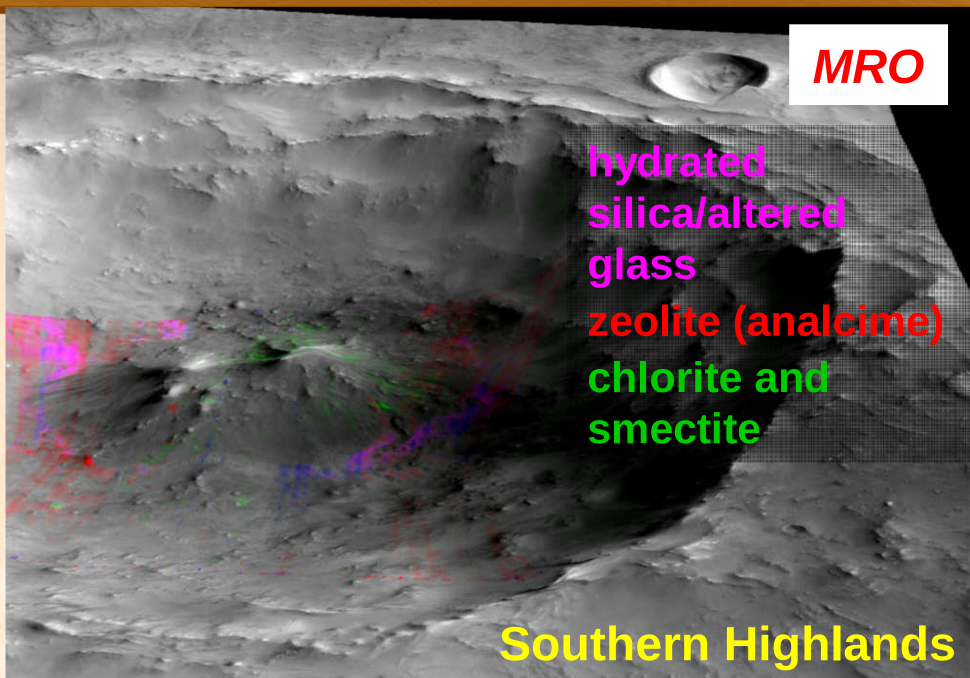
Hesperian subsurface water, diagenesis



Delta, showing phyllosilicate layers



Discoveries: Possibility of Past Life

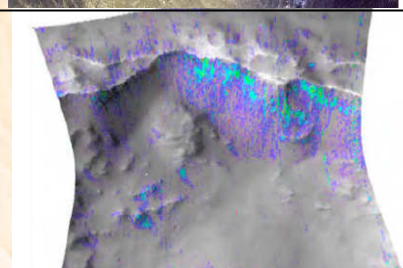
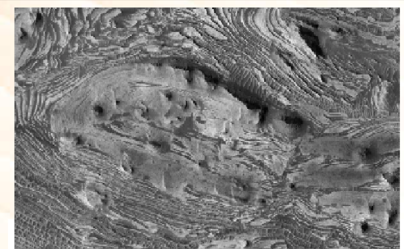
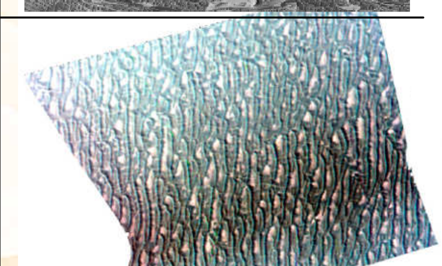
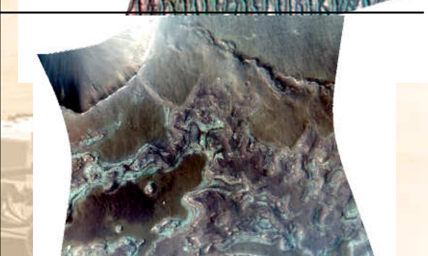


Widespread alteration, Southern Highlands

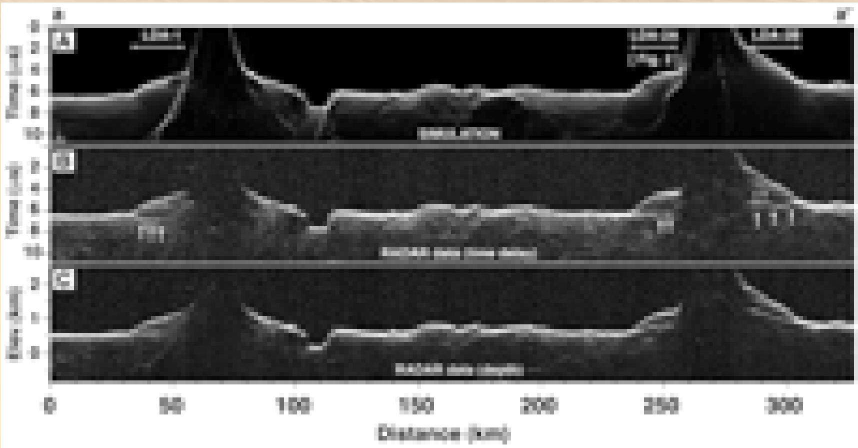
Ancient hydrothermal deposits

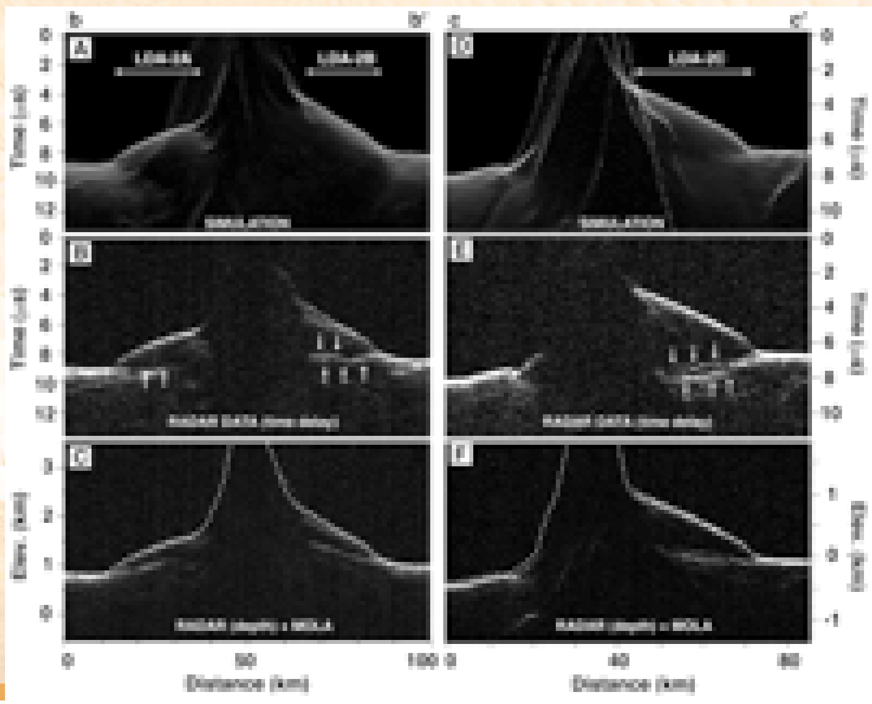
Discoveries: Evolution of Mars

Mars' surface geology can be classified into a diverse number of different geologic terranes that formed in response to evolving planetary conditions.

Noachian layered clays (type: Mawrth Vallis)		Noachian Meridiani-type layered deposits (type: Terra Meridiani)	
Deep Noachian phyllosilicates exposed in highland craters, chasma walls (type: Tyrrhena Terra)		Hesperian Valles-type layered deposits (type: Candor Chasma)	
Noachian intra-crater fans with phyllosilicate-rich layers (type: Jezero Crater)		Amazonian gypsum deposits (type: Olympia Undae)	
Noachian "glowing terrain" (type: Terra Sirenum)		Thin Hesperian layered deposits with hydrated silica (type: Ophir Planum)	

Radar Sounding Evidence for Buried Glaciers in the Southern Mid-Latitudes of Mars.



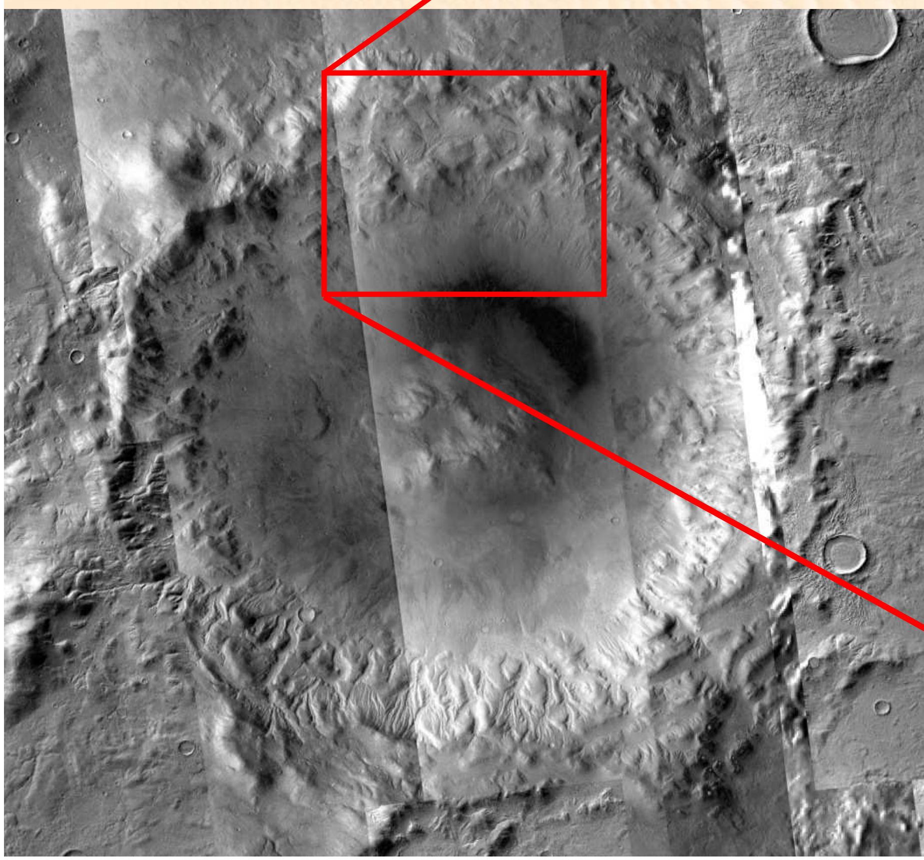


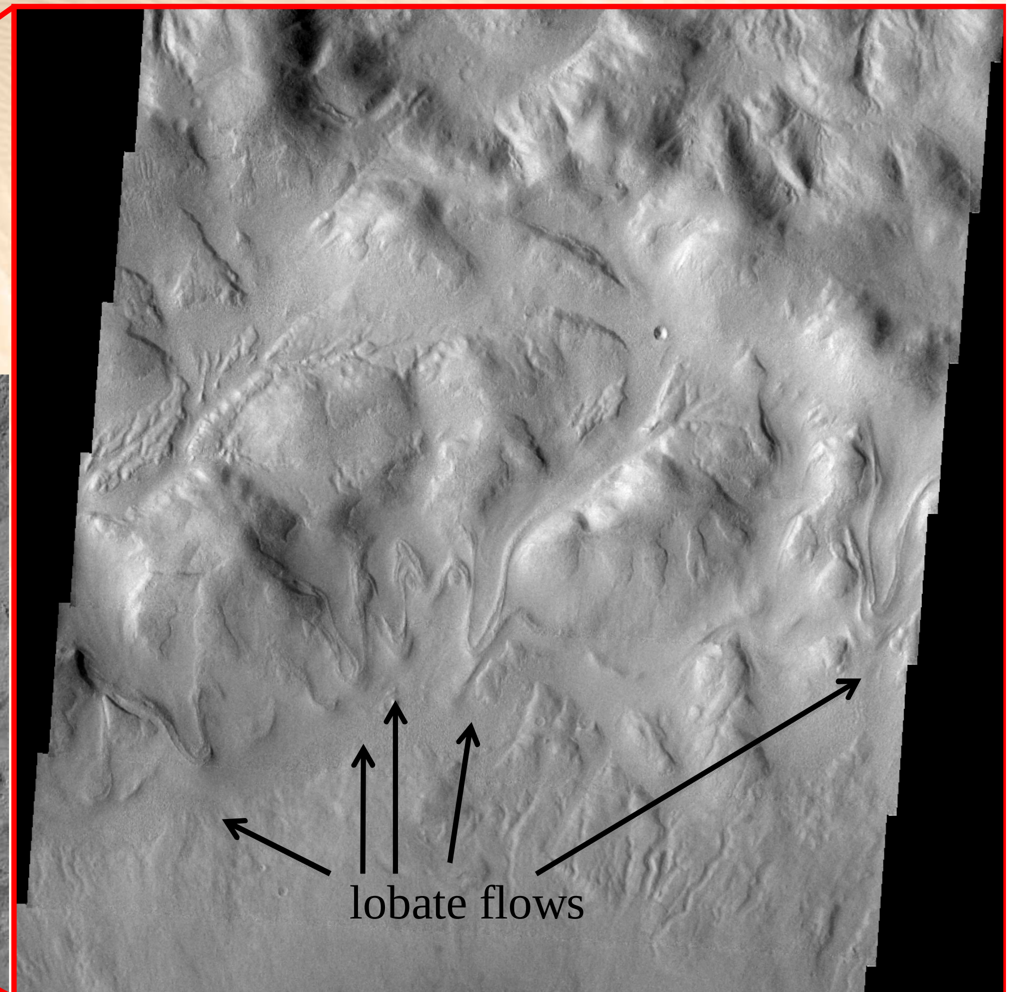
Science. 21 Nov. 2008,
John W. Holt, et al.

Soundings in eastern Hellas region by SHARAD reveal radar properties entirely consistent with massive water ice, supporting debris -covered glaciers. These results imply that these glaciers harbor large quantities of water ice derived from high-obliquity epochs, now concealed beneath a thin protective layer.

Mid-Latitude Craters Show Evidence for Flow of Water/Ice on Mars

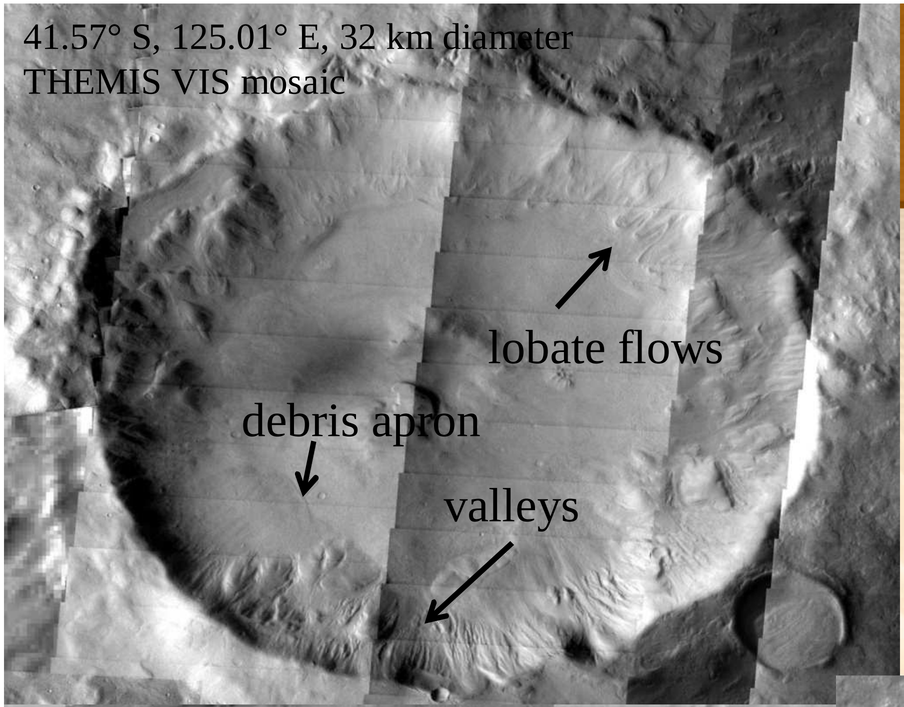
Icarus, 2009 Daniel C. Berman, David A. Crown, Leslie F. Bleamaster III





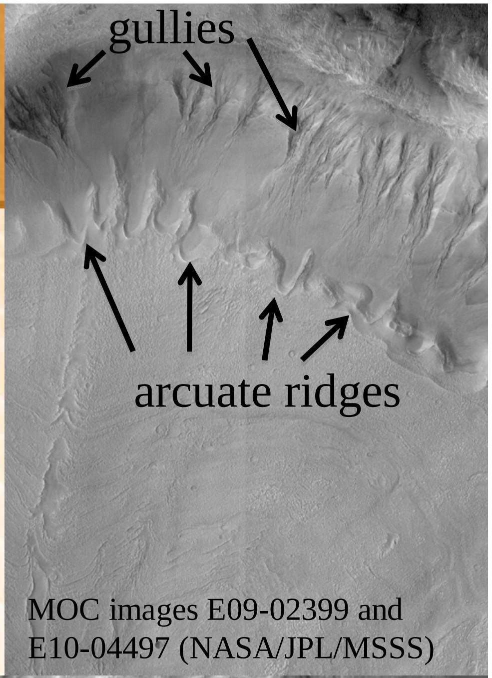
THEMIS VIS image V08298002
NASA/JPL/ASU

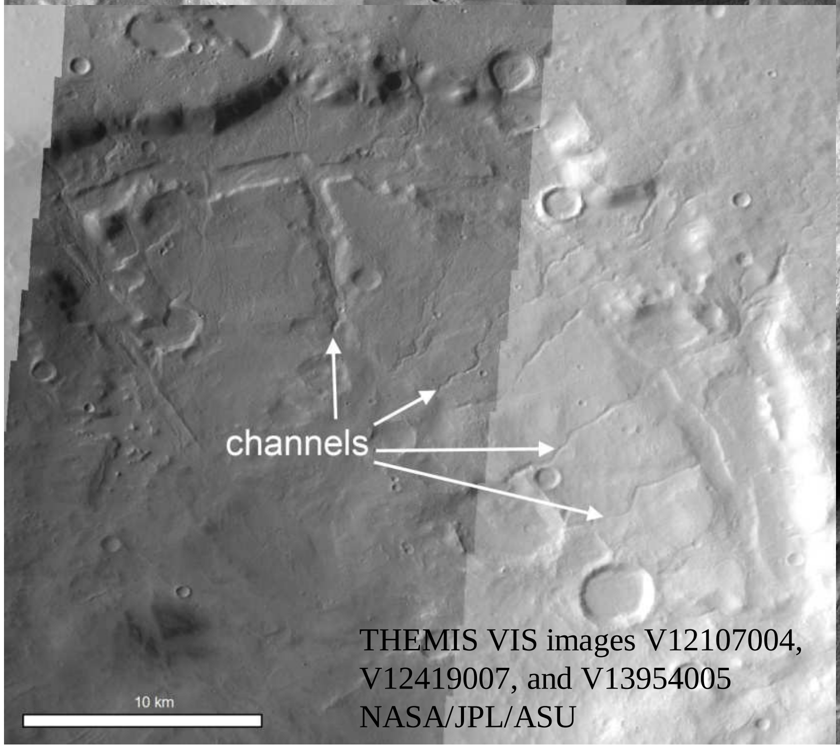
70 km diameter (39° S, 112.65° E)

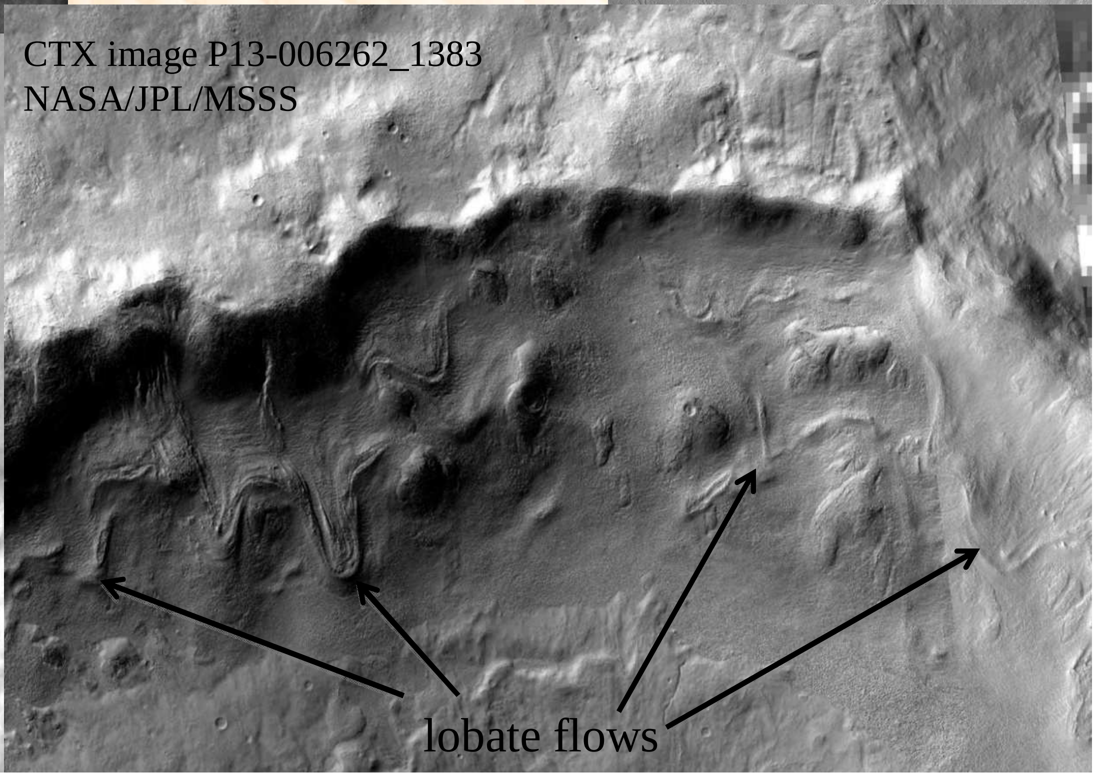


Flow features in Martian craters:

FEATURE	*Flow*
• Lobate flows	ice
• Channels	water
• Valleys	ice
• Debris aprons	ice
• Gullies	water
• Arcuate ridges	ice



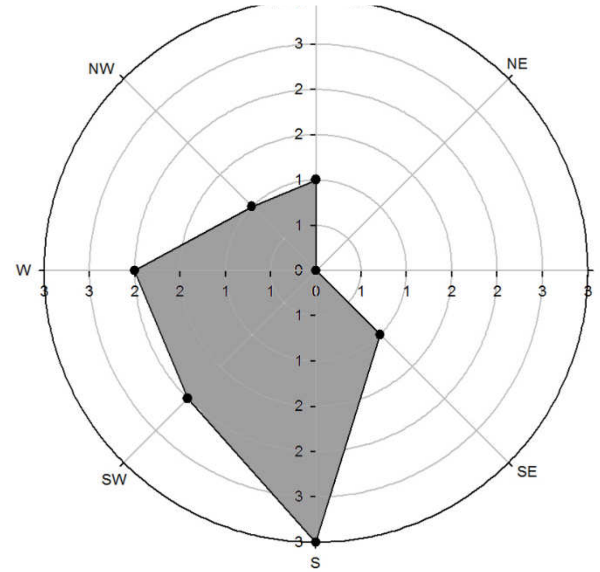


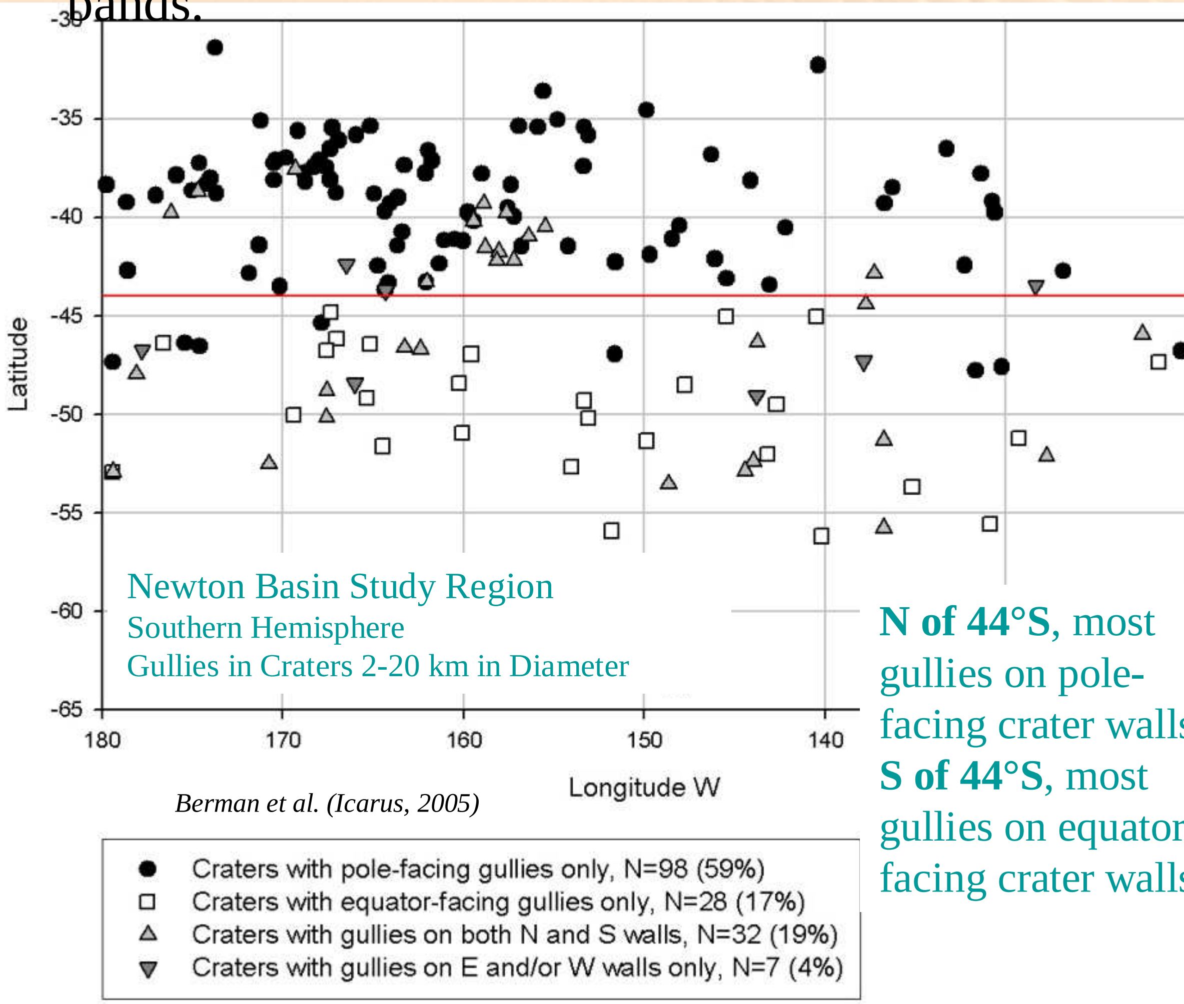


In northern and southern mid-latitude study regions, these features show different orientations in different latitude bands.

Most lobate flows on **pole-facing** crater walls in both hemispheres.

Arabia Terra Study Region
Northern Hemisphere
Lobate Flows in Craters 20-120 km in Diameter

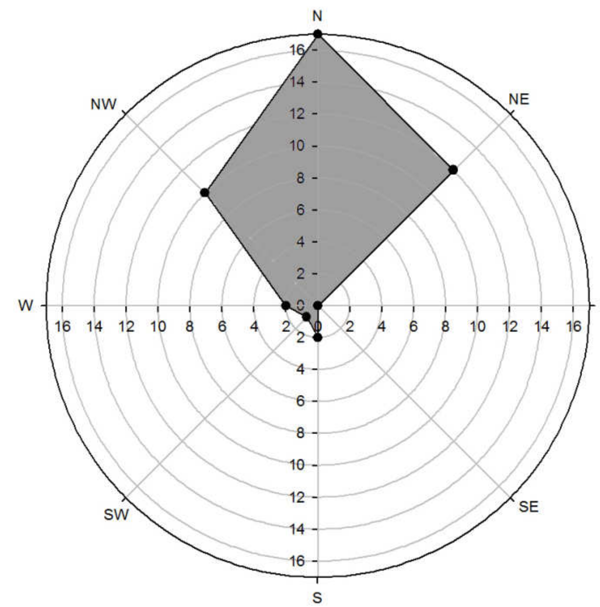


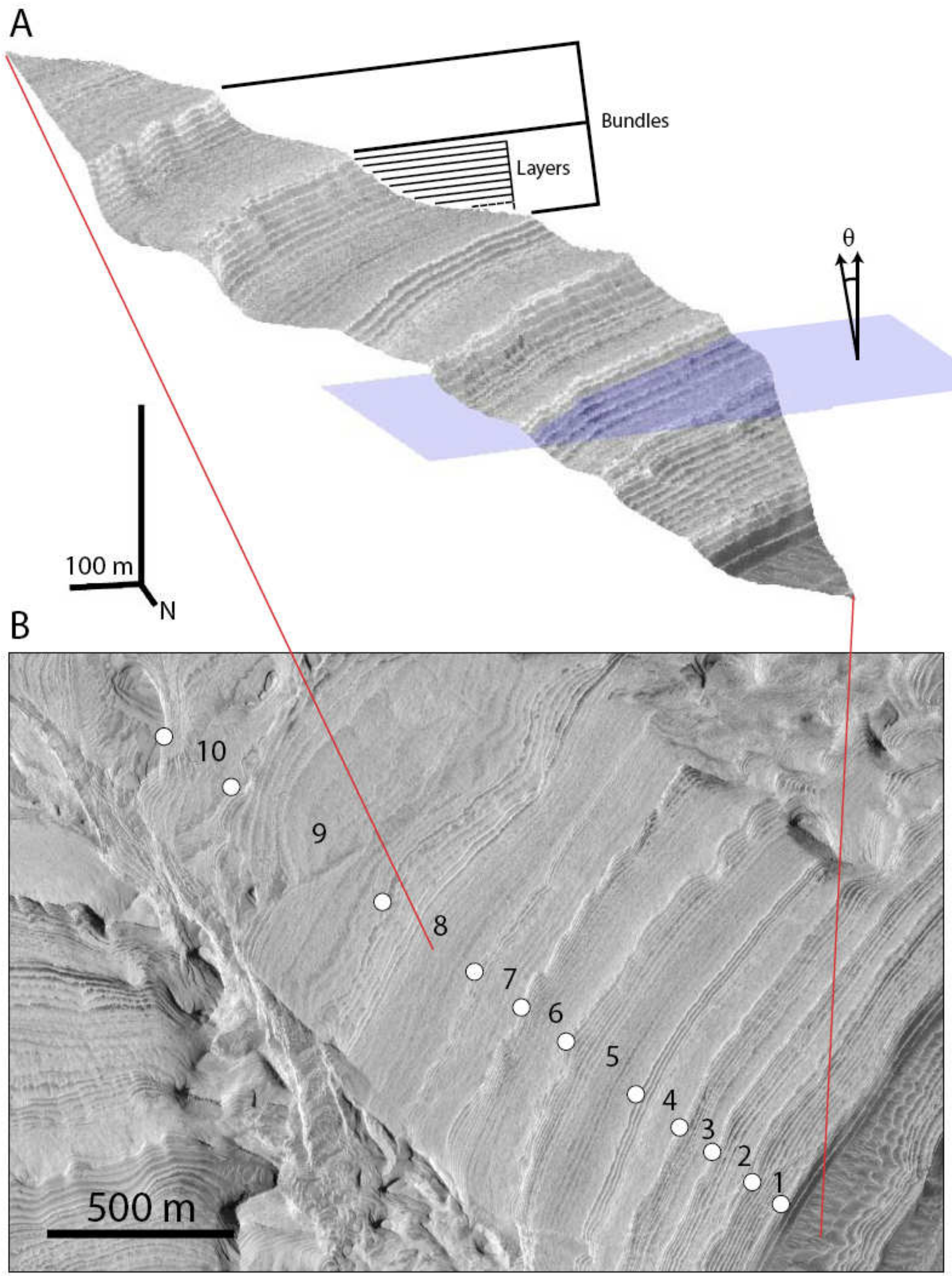


Berman et al. (Icarus, 2005)

N of 44°S, most gullies on pole-facing crater walls; **S of 44°S**, most gullies on equator-facing crater walls.

East Hellas Study Region
Southern Hemisphere
Lobate Flows in Craters 20-120 km in Diameter

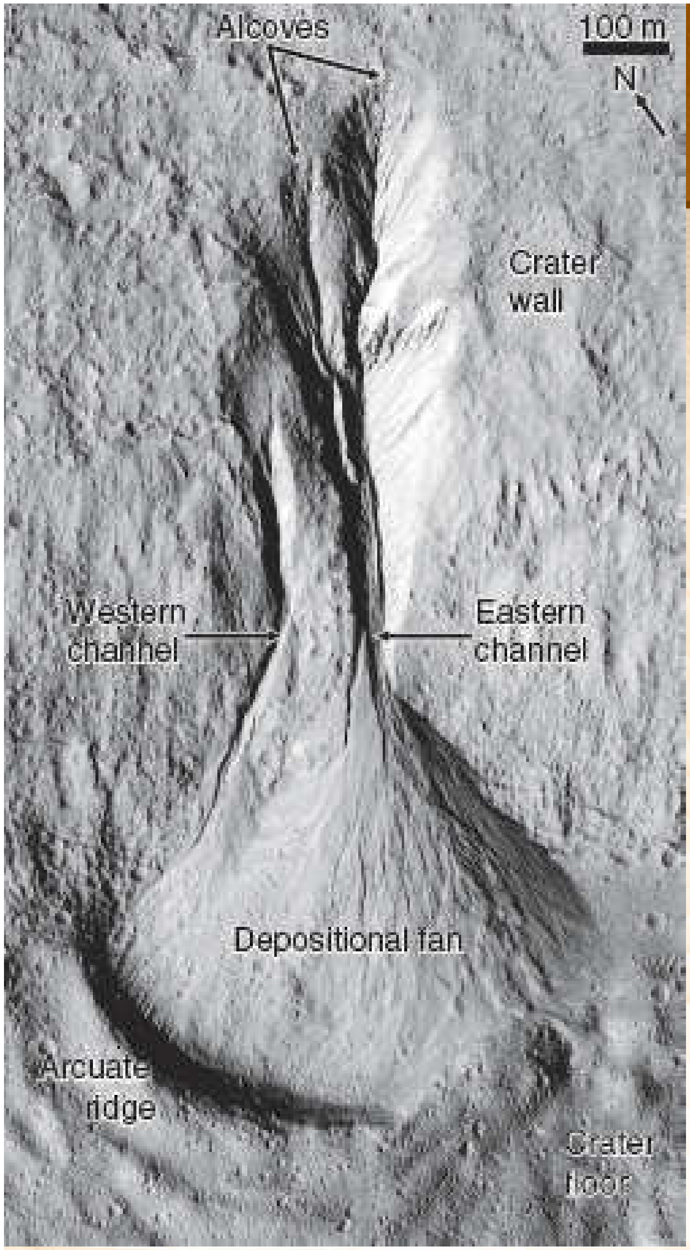




Quasi-Periodic Layering in the Sedimentary Rock Record of Mars. *Science* 5 Dec. 2008

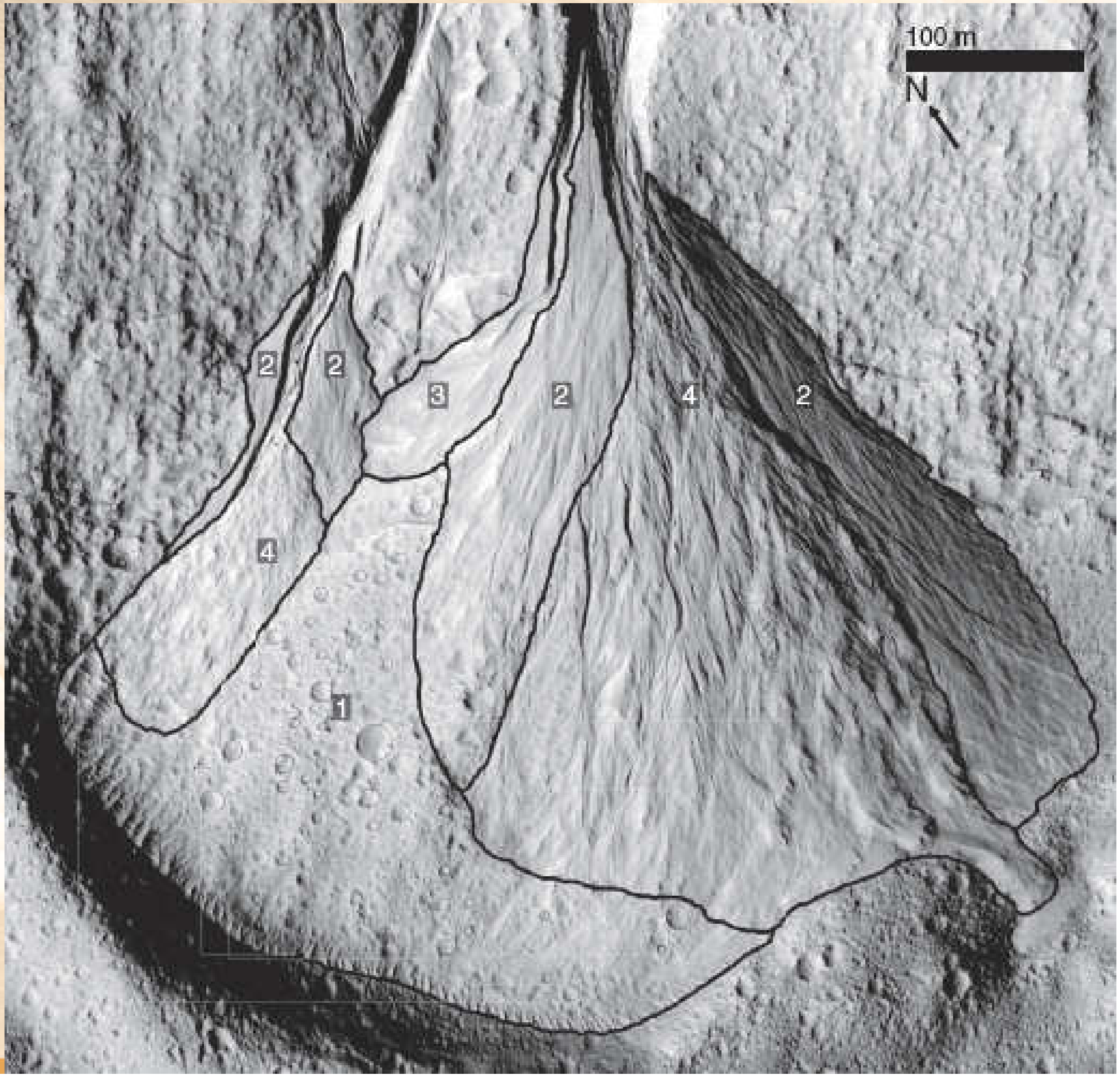
Kevin W. Lewis, Oded Aharonson, John P. Grotzinger, Randolph L. Kirk, Alfred S. McEwen, Terry-Ann Suer

With the tentative, but reasonable assumption that some water was required to lithify the Arabia deposits, the suggestion of orbital cyclicity implies that a hydrologic cycle may have been active at least intermittently over millions of years.



Unique chronostratigraphic marker in depositional fan stratigraphy on Mars: Evidence for ca. 1.25 Ma gully activity and surficial meltwater origin. *Geology* Mar. 2009

Samuel C. Schon, James W. Head, Caleb I. Fassett

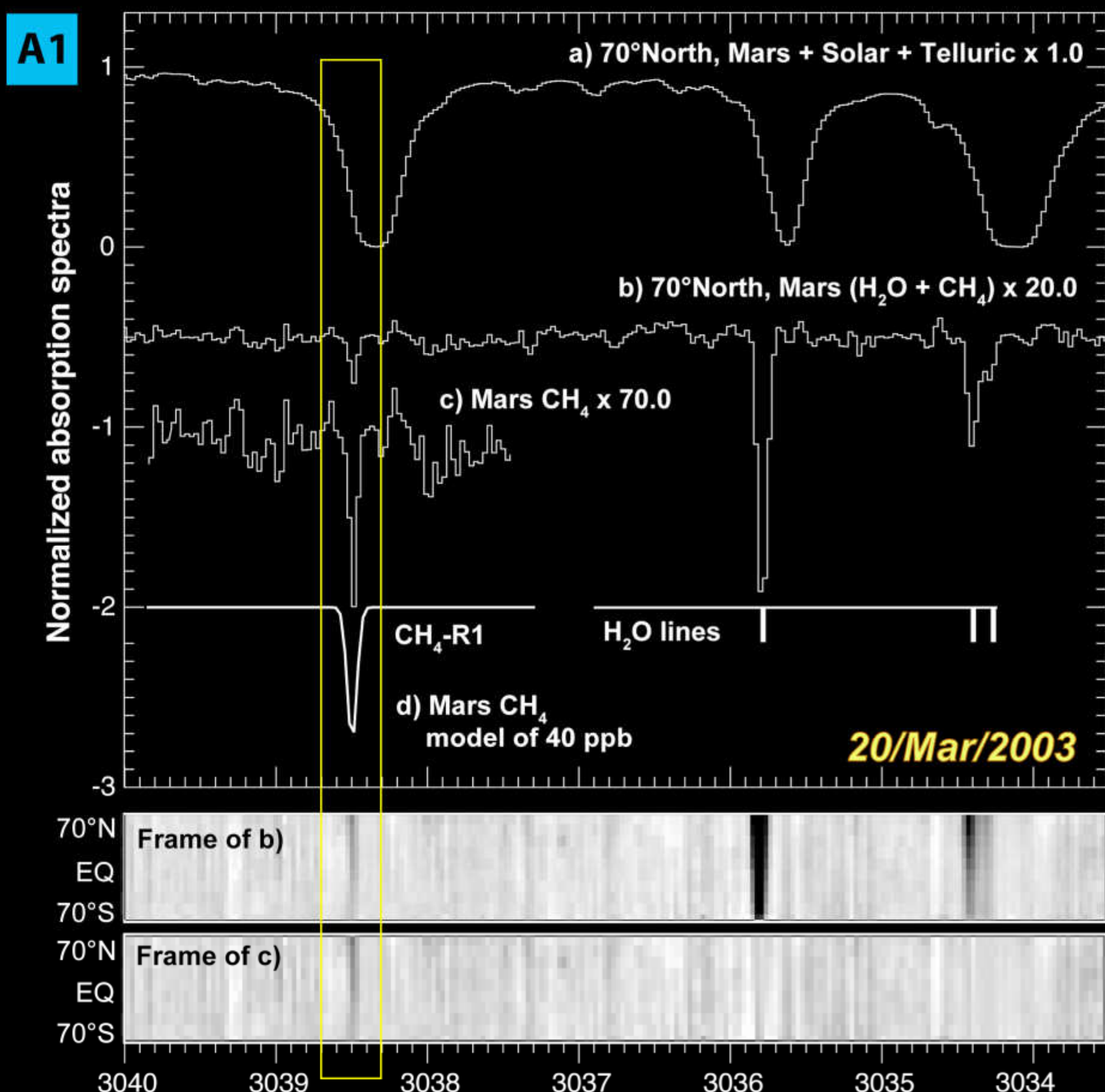


Eastern Promethei Terra Crater

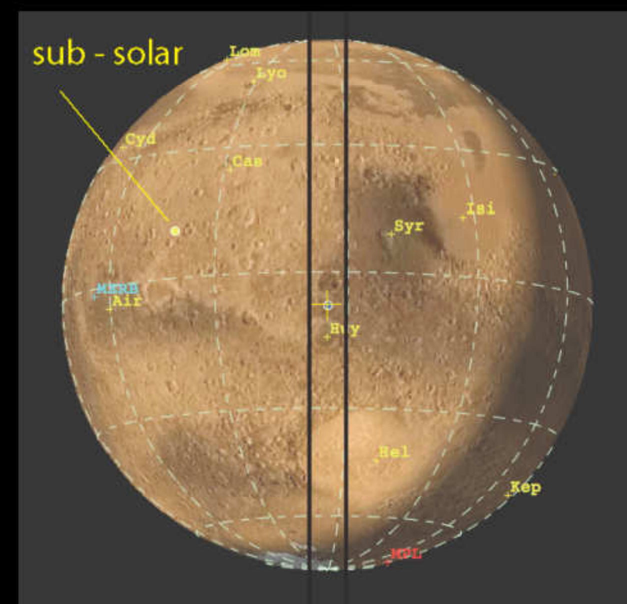
Methane on Mars

Mumma, Villanueva, Novak, et al. Science (submitted)

A detection theorem satisfied: CH_4 R1 and H_2O (3 lines) are detected



Mid - summer
(North, L_S= 155°)

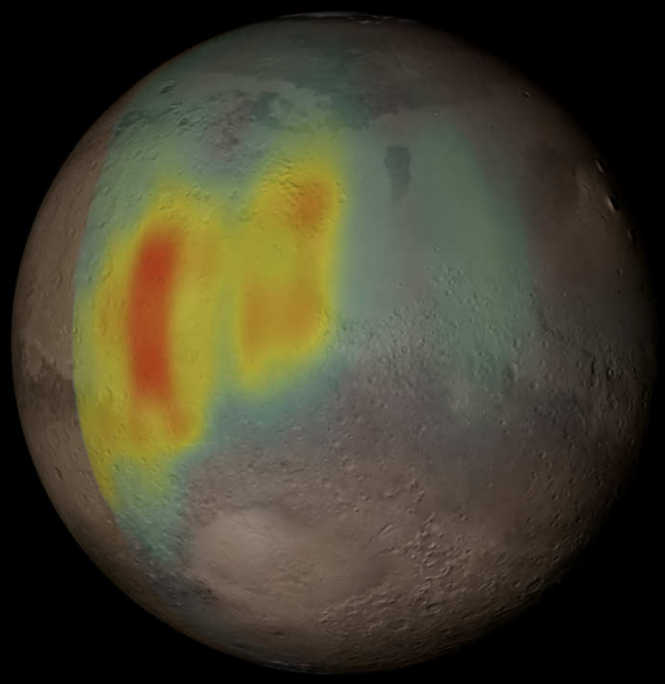


Both gases are enhanced in North

Strong Release of Methane on Mars in Northern Summer 2003

M.J.Mumma, G.L.Villanueva, R.E.Novak, T.Hewagama, B.P.Bonev, M.A.DiSanti, A.M.Mandell, M.D.Smith. ***Science*** Jan. 15, 2009

R1 &R0 methane lines are detected and mixing ratios vary from <3ppbv – 60ppbv



- ***Methane varies with location, source strength rivals terrestrial gas seeps***
  - o ***A strong peaks are seen over Terra Sabae, Nili Fossae, and Syrtis Major (SE quadrant)***
  - o ***The source strength > 0.6 kg/sec***
- ***Methane and water are sometimes correlated, but not always so***
- ***Lifetime of methane is <4 years***
  - o ***Methane lifetime from photo-chemical destruction is ~350 years***
  - o ***Need new model for its destruction, perhaps oxidants on airborne dust***

The big question: Is methane produced biologically or geologically?

Either way, Mars must be active today

WHAT NEXT?
Where are our discoveries leading us?

- **Ancient life—potential has increased**
  - Lots of ancient liquid water, surface and ground
  - Past geological environments that have reasonable potential to have preserved the evidence of life, had it existed.
  - Understanding variations in habitability potential is proving to be an effective search strategy
  - ⇒ SUMMARY: We have a means to prioritize candidate sites, and reason to believe that the evidence we are seeking may be preserved and is within reach of our exploration systems.
- **Modern life—possible**
  - Evidence of modern liquid water at surface is equivocal—probable liquid water in deep subsurface
  - Methane may be a critically important clue to subsurface biosphere
  - ⇒ SUMMARY: We have not yet identified high-potential surface sites, and the deep subsurface is not yet within our reach.
- **Mars is more diverse than previously thought**

Mars Goals

FOLLOW THE WATER
READ THE HISTORY

Life — Understand the potential for life elsewhere in the Universe

Climate — Characterize the present and past climate and climate processes

Geology — Understand the geological processes affecting Mars' interior, crust, and surface

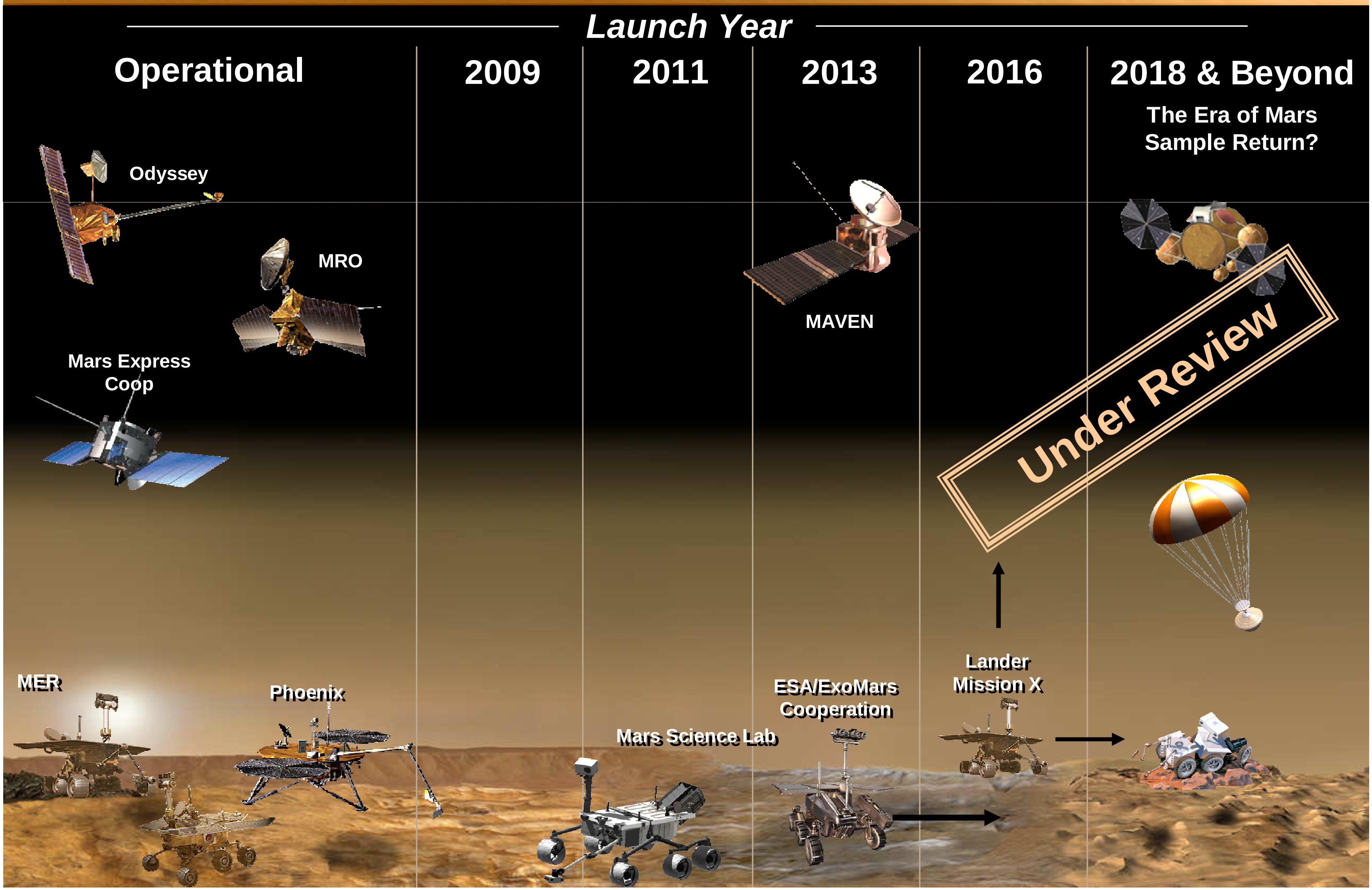
Prepare for Human Exploration — Develop knowledge necessary for eventual human exploration

When
Where
Form
Amount

Changes
Rates
Processes
Environments

The Next Decade

MEP Next Decade—Where to From Here?



Drivers for Planning the Next Decade

- How does Mars Sample Return fit in the architecture?

- What are the driving requirements behind the Program’s baseline content?
  - MSR in 2018 is *not viable* with the FY09 budget, or maybe any budget that can be expected in the near term
  - MEP architecture *must* be viable with or without Mars Sample Return

- What are the drivers for developing Program content?
  - The mission portfolio must reflect methodical scientific progress and stakeholder expectations—alignment with NRC and MEPAG
  - It must include missions for science and infrastructure
  - A new development—possible joint missions with ESA starting with ExoMars in 2016
    - Dialog underway with ESA; Mars community engagement will begin with MEPAG March 3-4, 2009