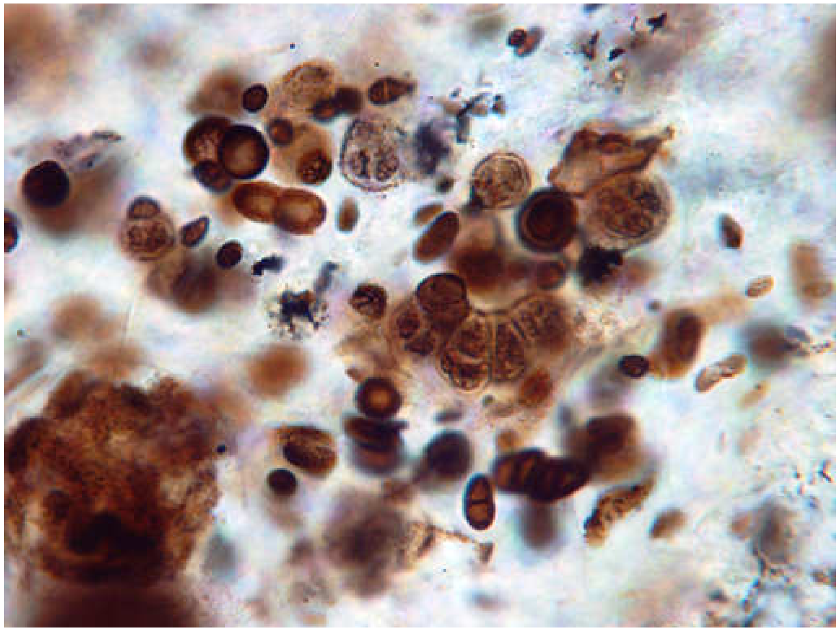
Where should we go on Mars to seek signs of life?



AbSciCon 2010

"This session will focus on the geology and mineralogy most likely to preserve signs of martian life (if any), the evidence for such geology and mineralogy on Mars, and possible targets for future landed missions"

Session Chairs:

CARL ALLEN, *NASA Johnson Space Center*

ABIGAIL ALLWOOD, *JET PROPULSION LABORATORY, CALIFORNIA INSTITUTE OF TECHNOLOGY.*

Insights from Earth's earliest fossil record

Abigail Allwood (JPL)

What does terrestrial paleobiology tell us about key geological characteristics of a site that can improve the prospects for determining whether life existed?

The paleoenvironmental setting,
the types of potential biosignatures,
The amount/nature of outcrop
These should favor:
formation and preservation of evidence that is **detectable and interpretable**

The paleoenvironmental setting:

- GOOD: **Sustained, subaqueous** environment Note: terrestrial studies show hydrothermal settings pose unique challenges to ancient biosignature interpretation.
- EVEN BETTER: **stability** → promotes benthic community formation at sediment-water interface → more obvious and diverse clues
- BETTER STILL**: syngenetic mineralization**→ formation and preservation of diverse clues to life and environment

Insights from Earth's earliest fossil record

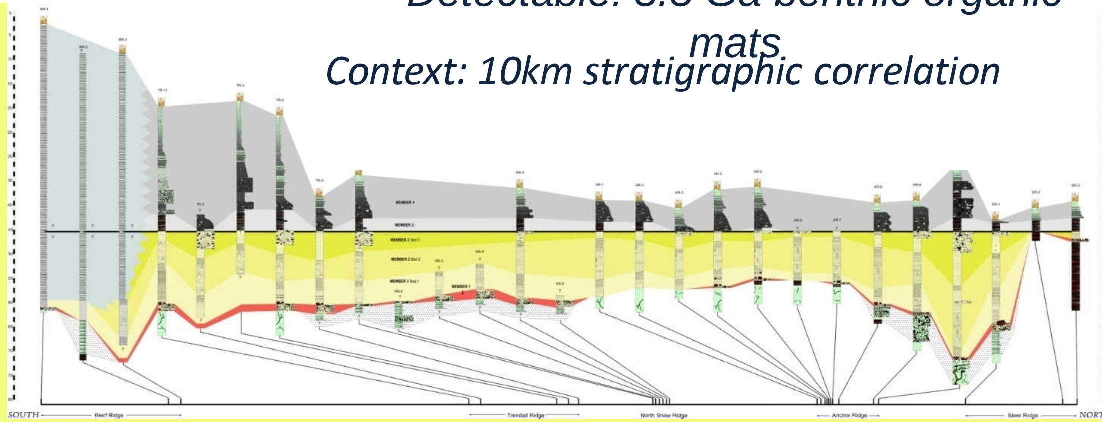
The types of biosignatures that may be present there:

•GOOD: **readily detectable or visible signatures**→ easier assessment of multiple lines of evidence against palaeoenvironmental backdrop. If **benthic communities** could have formed, there's more likelihood of a variety of detectable clues at different scales.

Detectable: 3.5 Ga benthic organic mats

Amount/nature of outcrop:

•Good outcrop exposure & preservation allows us to build up a sedimentological and stratigraphic framework at large and small scales.

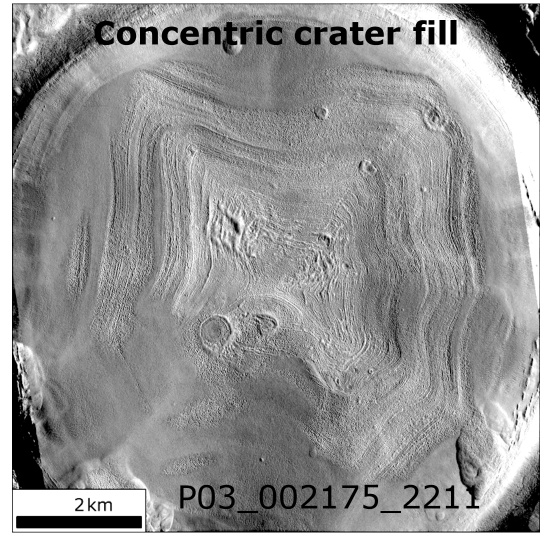


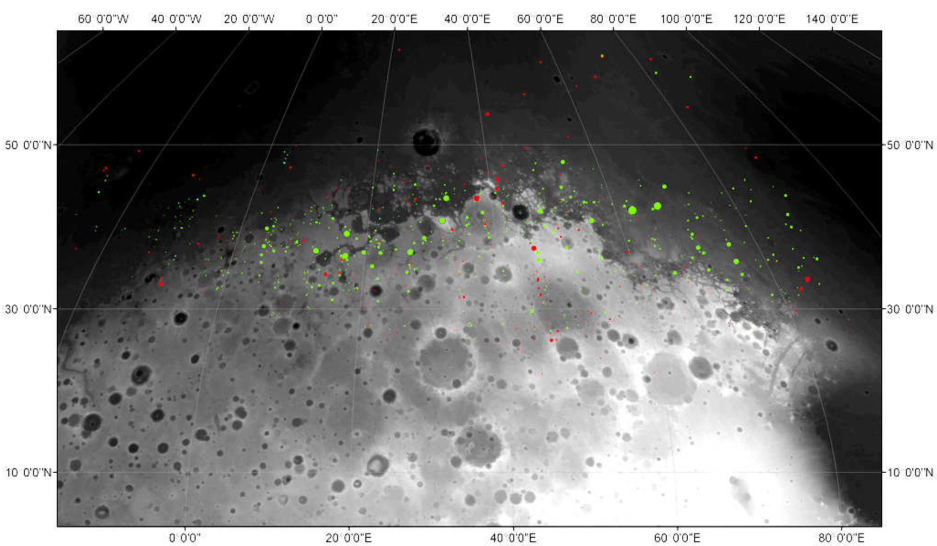
Context: 10km stratigraphic correlation

Martian Debris-covered Glaciers

Joseph Levy (Portland State), James Head (Brown Uni.), David Marchant (Boston Uni.)

- Ground Ice/Glaciers are important biomarker accumulation and storage sites on Earth, containing:
  - microbial ecosystems, particularly in inter-ice-grain brine pockets.
  - Biomarkers (intact DNA and fragments)
  - Evidence for life up to 8 My old (at -25°C)
  - atmospheric biomarkers integrated from large areas
- Terrestrial glacier/ground ice can be ancient: up to 8.1 My old
- Debris-covered glaciers represent one of the largest reservoirs of non-polar ice on Mars
- Identified by morphology (e.g. concentric crater fill) and Radar detection of subsurface ice

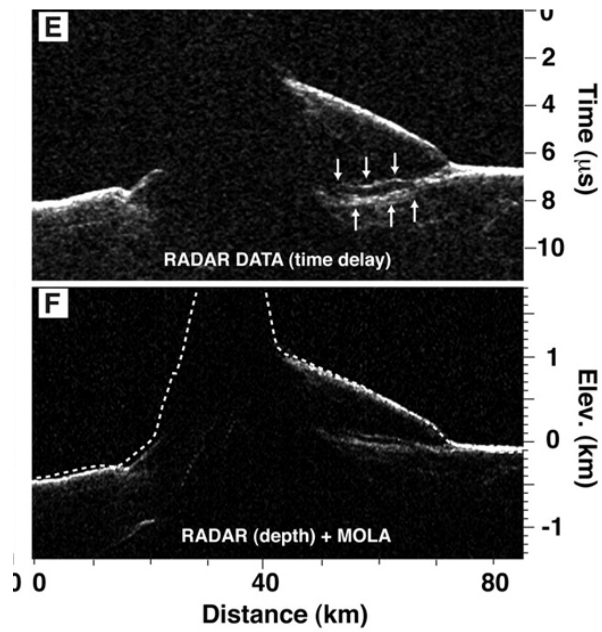




Left: Concentric ice filled craters on Mars are common

Green= 'classic CCF'

Red = low grade CCF



Radar image of ice-rich crater fill on Mars.

Bottom: Holt et al., 2008, Science

Phoenix landing site

Peter Smith (Uni. Arizona)

Water Ice 5 cm below surface
- Deeper in troughs
- Both pure ice lenses and pore ice are seen

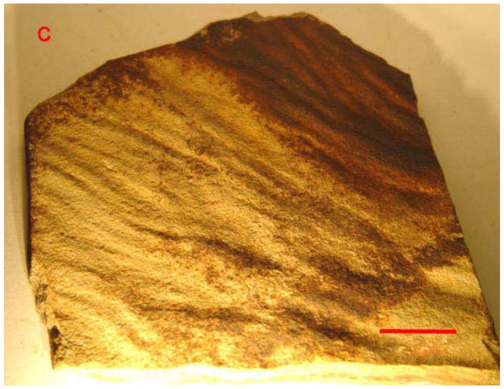
Water in soil
- Ca-carbonate 4-5%
- Hydrated minerals observed
- 3-µm band seen from orbit
- Deliquescent salt (0.5%)
- Thin films possible

Atmospheric water
- Ice clouds and precipitation
- Humidity measured ~1.8 Pa
- Surface frosts

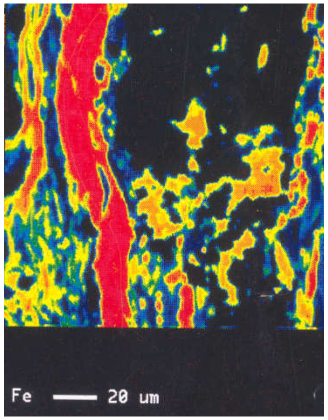
Clastic facies: microbially-induced sedimentary structures (MISS)

Nora Noffke (Old Dominion Uni.)

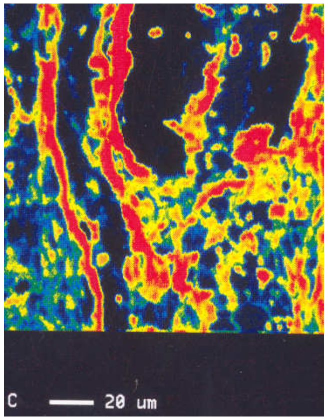
- Search for depositional facies suitable for biofilms
- Confirmation requires a search for biotic textures in candidate structure by microscopic techniques
- Differentiation requires quantification of microscopic textures, comparison with similar but abiotic textures such as veins, or stylolites



Original Photo of Microstructures



Distribution of Iron Minerals

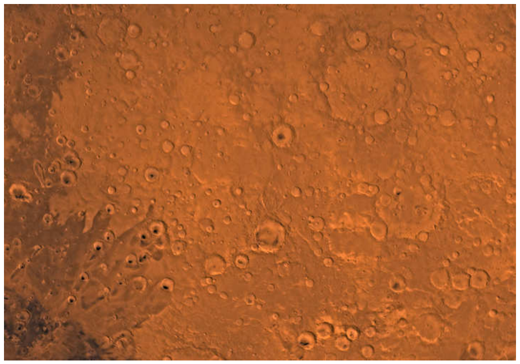


Distribution of Organic Carbon

Martian Impact Craters

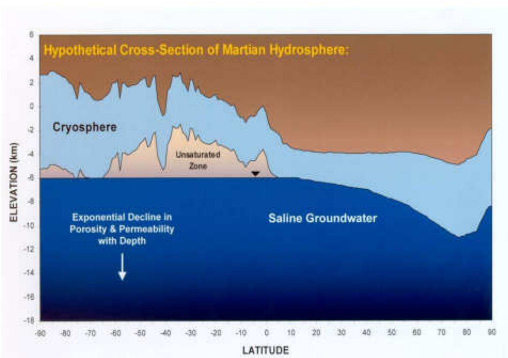
S. P. Schwenzer[1,7], O. Abramov[2], C. C. Allen[3], S. Clifford[1], J. Filiberto[1,4], D. A. Kring[1], J. Lasue[1,5], P. J. McGovern[1], H. E. Newsom[6], A. Treiman[1], D. T. Vaniman[5], R. C. Wiens[5], A. Wittmann[1].

1: LPI, 2: U. Colorado, 3: NASA JSC, 4: Rice U. 5: Los Alamos, 6: U. New Mexico, 7: Open Uni.

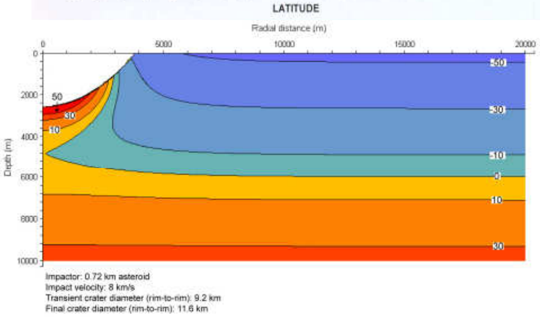


Mars in the Noachian: water, impacts and ice

Mars, along with the other terrestrial planets was struck by the inner solar system cataclysm.
Cratering re-distributed material and produced heat sources, which may have caused major hydrothermal activity.



Towards the end of the Noachian, Mars turned into a cold and dry place. Cryosphere thickness is modeled to be a maximum of 2 km at the equator and 6 km at the poles in late Noachian.

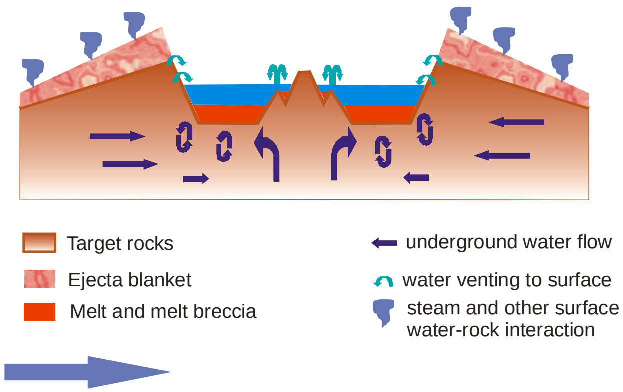


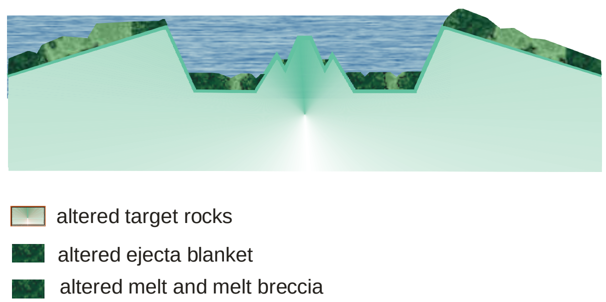
Impacts that produced craters as small as ~12 km in diameter would have penetrated 6 km of ice saturated basaltic crust. Associated heating could have driven warm to hot water through the crust and towards the surface and provided habitable environments while the warm and wet climate period at Mars' surface waned.

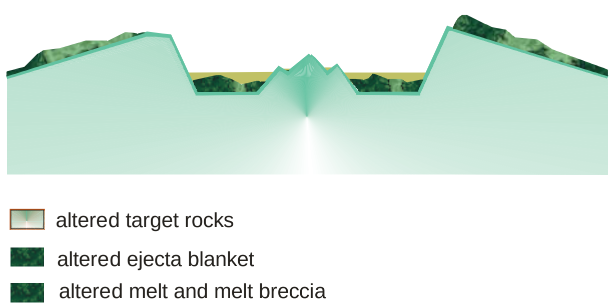
This work is under review at Icarus with the title "Targeting Noachian Impact Craters: An Exploration Strategy for Studying the Martian Subsurface, Hydrothermal Systems and Potential Habitats for Life".

Martian Impact Craters

Gale crater: multiple habitable environments through time!







Gale crater is a ~150 km diameter, Noachian crater. An impact of this size should have caused a major hydro-thermal system lasting for on the order of 300,000 y. It should have vented to the surface and provided habi-table conditions in terms of temperature, liquid water (where there may have been ice otherwise), minera-logy (clays!), and nutrient availability.

Later in Gale's history it was flooded, and hosted lakes. After the initial impact-generated habitable phase, every phase of liquid water is a new, independent event of habitability.

Consequently, it is worthwhile to investigate (1) the remnants of the central peak, (2) check for the presence of remotely detected clays and sulfates, (3) lacustrine deposits, and (4) evidence for hydrothermally altered rocks. Good places to look are any smaller craters puncturing Gale.

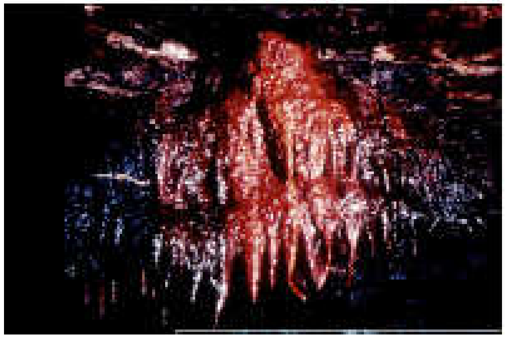
☞Noachian craters provide multiple places that may offer habitats to life, had it ever existed on Mars.

Lava Tubes and Caves

Léveillé and Datta

AND

Boston et al.



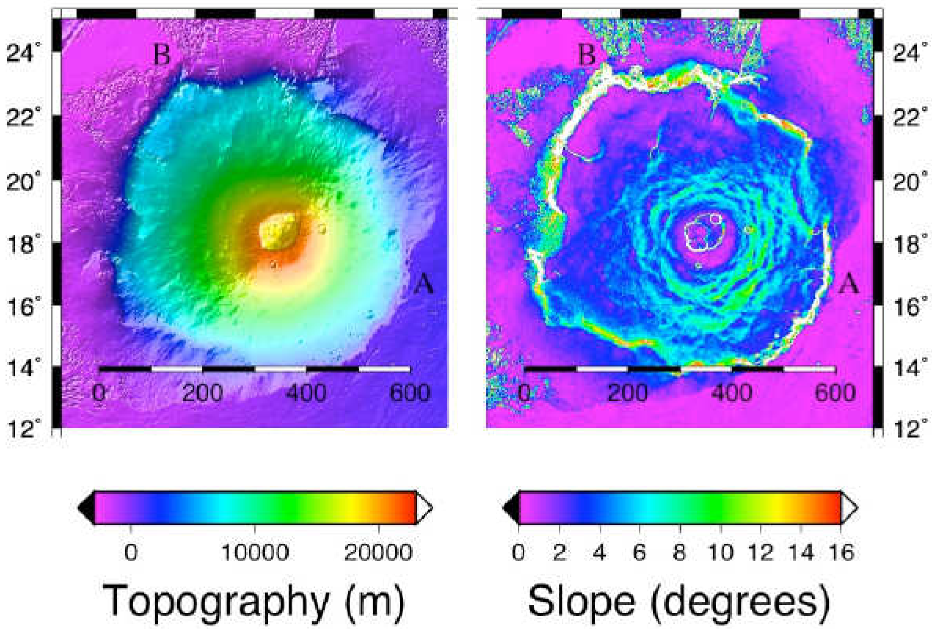
- •Lava tubes and subsurface cave-like features have been identified near a number of volcanic edifices on Mars
- • linear to sinuous elongated depressions, chains of pits or craters, or skylight-like openings
- •may be much older than on Earth due to lesser tectonic activity, erosion and weathering
- • potentially protect life from ionizing radiation, high winds and dust storms, temperature extremes, and possibly highly oxidizing conditions
- •On Earth, stable environmental conditions in caves favor microbial growth. Also favor continued mineral precipitation. Diverse biosignatures are present (microfossils, biomarkers, isotopic signatures, biominerals)
- •*Challenges*: high landing elevations of volcanic edifices hosting caves….Boulders in caves obstructing passage…Cannot use solar power

Top: Chain of collapsed pits on Arsia Mons volcano with putative lava tube skylight (center) or pit crater (HiRISE image: PSP_005414_1735, detail). Leveille & Datta, 2010.
Bottom: Fe-oxide-rich biofilm in a cold, moist cave in New Mexico. Boston et al., 2010

Flanks of Olympus Mons

Patrick McGovern (LPI)

The profile of the volcano has been attributed to movement of the edifice atop a weak basal layer. An overpressured decollement rooted in hydrated clay sediments may account for volcanic spreading.



The basal decollement model implies the presence of liquid water at depth, where T> 0°C

•shielded from radiation, extreme cold, adverse chemistry, and other surface conditions harmful to life.

•Favorable for lithoautotrophs?

Landing sites in the surrounding lowlands may connect to a potential deep biosphere:

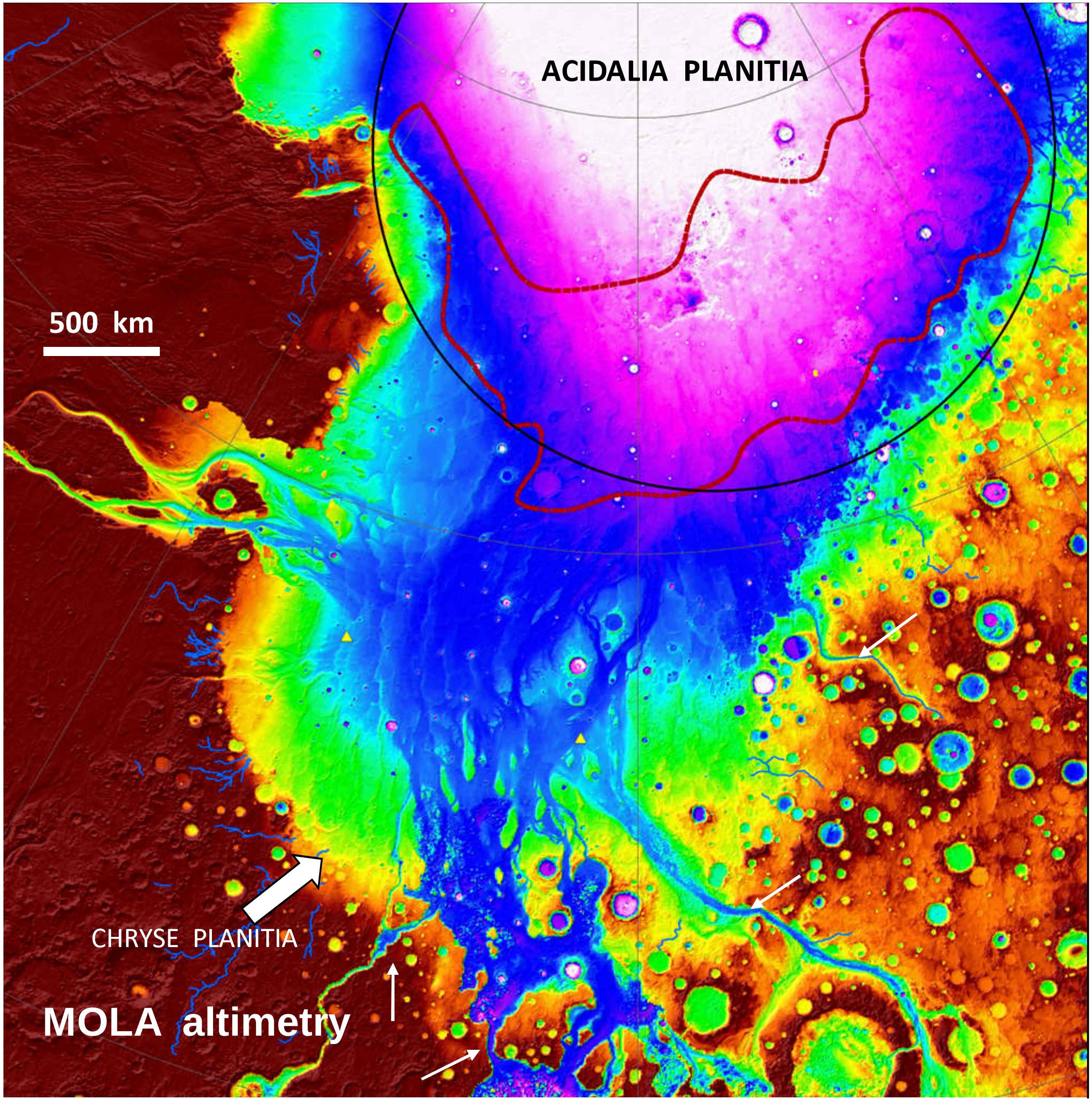
•**A:** Potential paleolake near thrust fault that could transport fluids from decollement (elev +1km)

•**B:** Potential paleolake surrounded by aureole blocks (elev -2km)

Topography and slope of Olympus Mons (MOLA 1/128th degree topography, Horizontal length scales in km). **Proposed landing sites are labeled east (A) and northwest (B) of the edifice.** Credit: McGovern, 2010, and references therein.

Mud Volcanoes

Carlton Allen, Dorothy Oehler (Johnson Space Center)



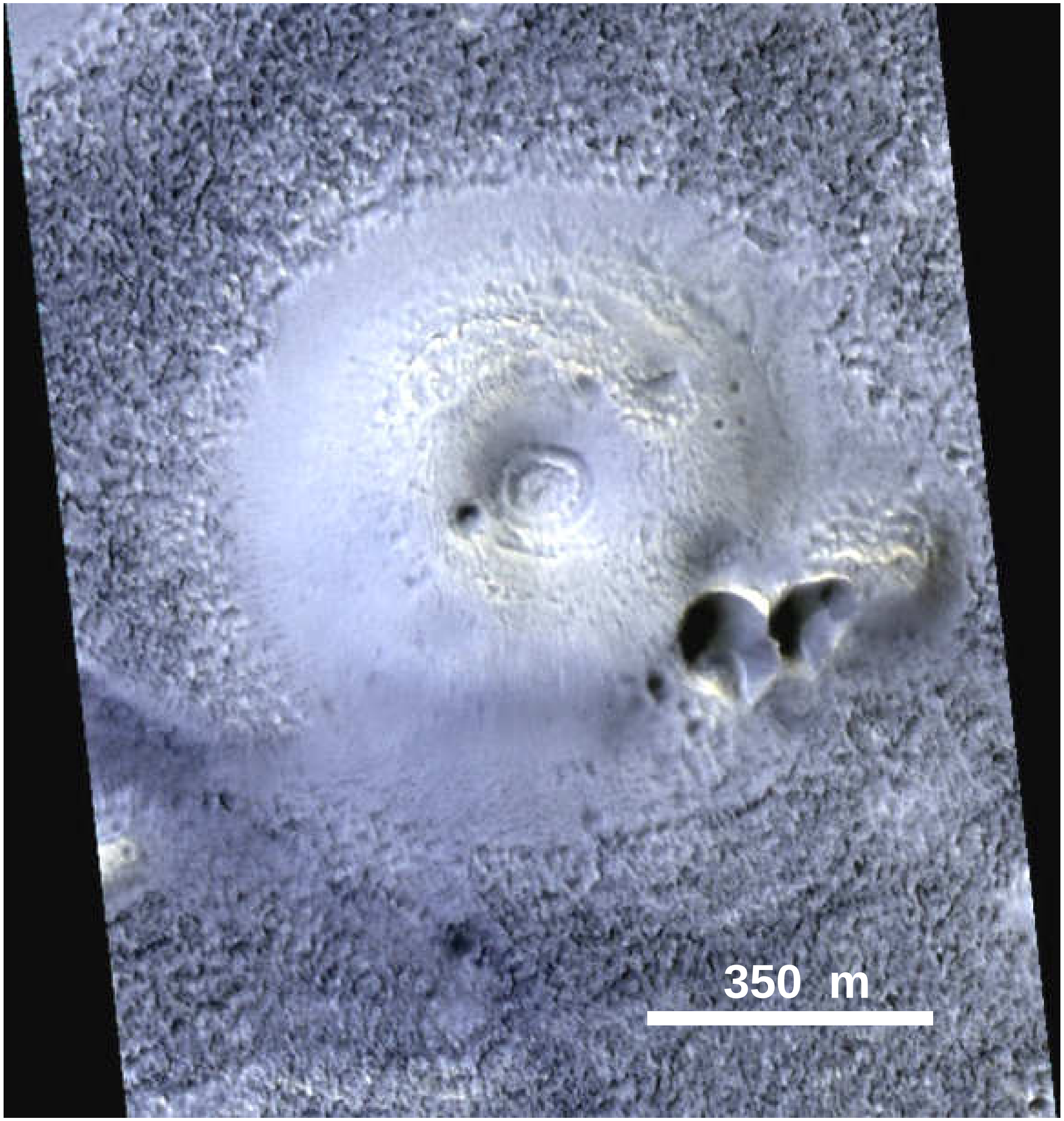
GEOLOGIC SETTING

Downslope from major flood channels into Chryse Planitia

Depocenter for finest-grained sediments

100's m to km of material derived from the highlands

<u>Optimal site for mud volcanism</u>



~ 40,000 high albedo mounds -- probable mud volcanoes -- across the northern plains

Terrestrial mud volcanoes carry minimally-altered sediments from depths to several km, along with biosignatures, microfossils, and methane.

We propose that these mounds constitute an important new class of exploration target for Mars.