Frost Meltwater under Simulated Martian Conditions May not Persist Long Enough to Maintain Habitable Conditions on Mars

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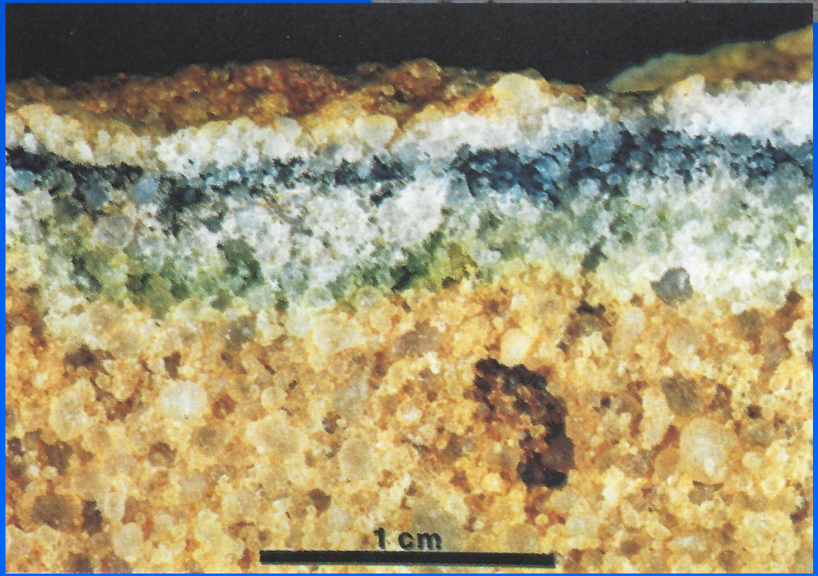
NASA PPR Grants NNX08AQ81A, 80NSSC17K0263, & 80NSSC22K0212

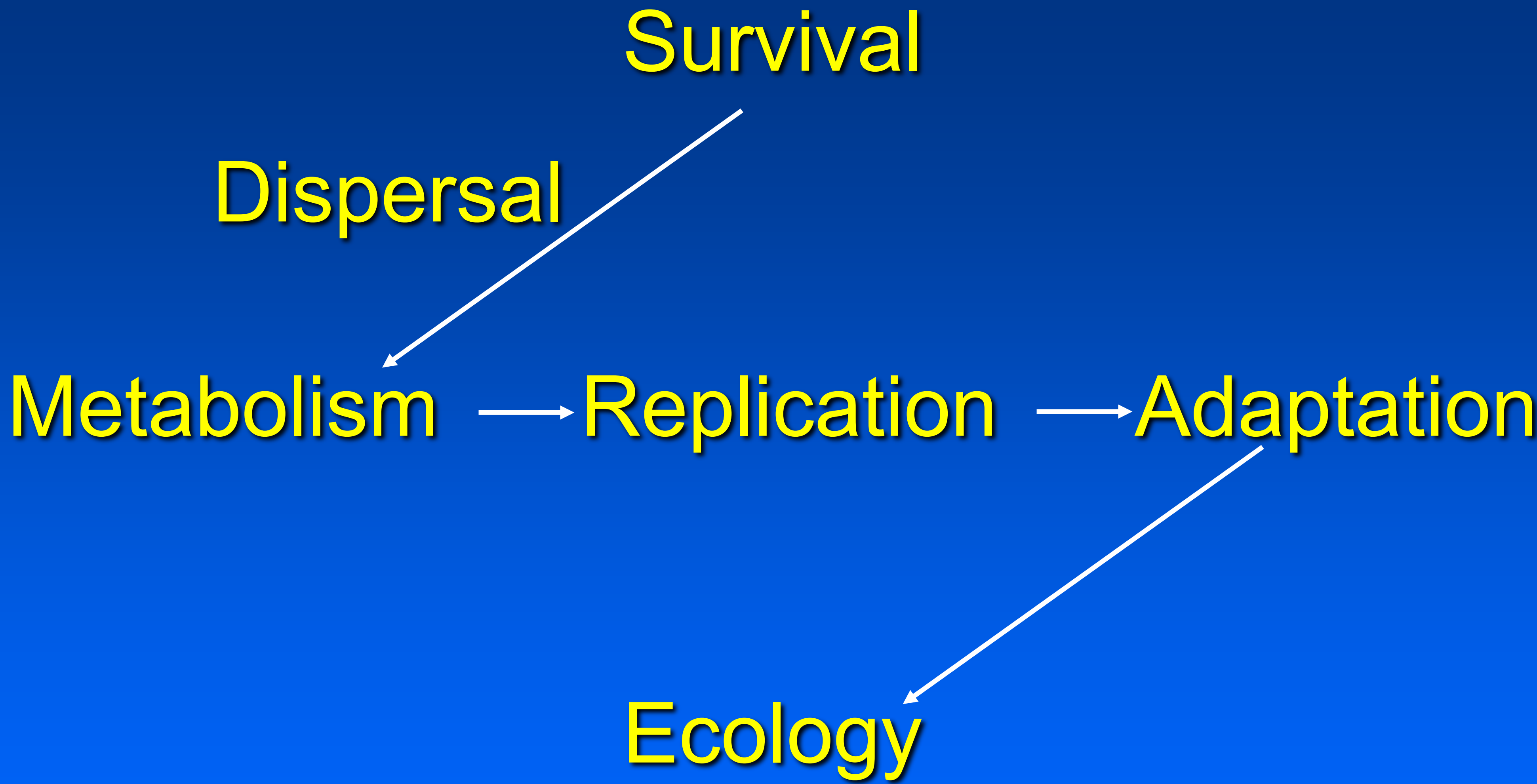
Water Frosts on Mars….Can they create habitable niches on Mars?



Friedmann, 1982, *Science*, 215, 1045-1053.

Liquid Water for Life?

- Frosts (H_2O) must be deposited on terrain.
- Solar heating must be slow enough to reach 273 K before all frost sublimates.
- Liquid water must persist long enough to permit microbial absorption.


Survival
Dispersal
Metabolism
Replication
Adaptation
Ecology

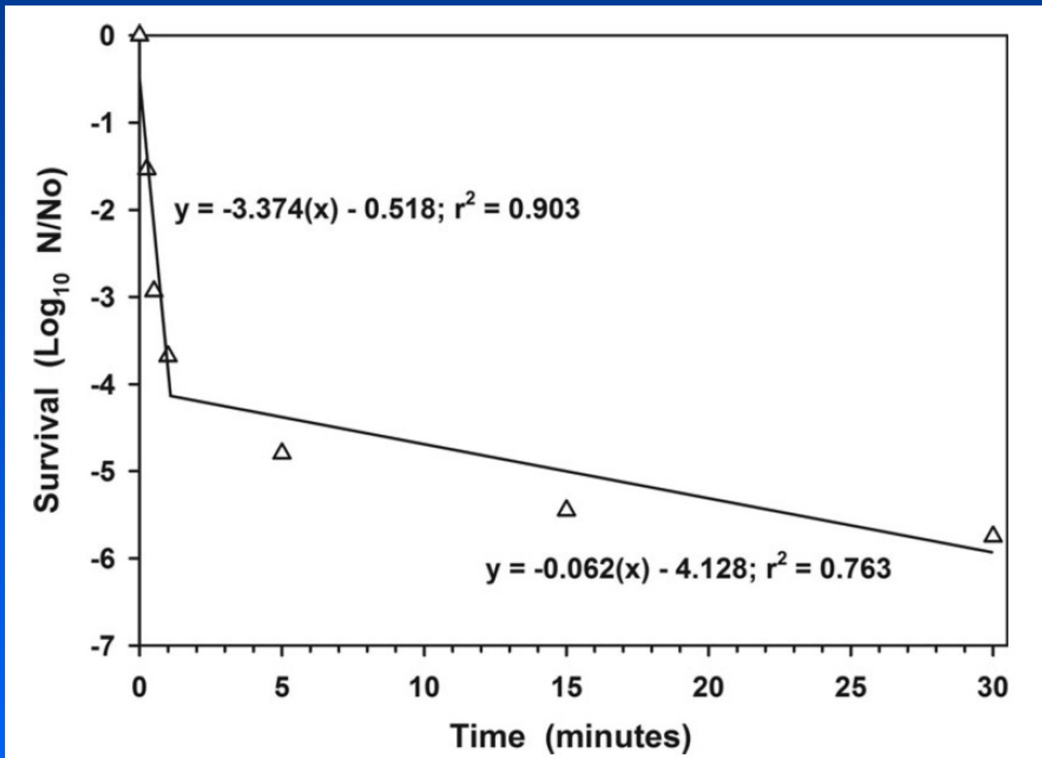
17 Biocidal or Inhibitory Factors on the Surface of Mars

(1) solar UV irradiation
(2) extreme desiccating conditions (i.e., low water activity; a_w)
(3) low pressure (7 mbar)
(4) anoxic CO_2-enriched atmosphere
(5) low temperature
(6) high salts levels [e.g., $MgCl_2$, NaCl, $FeSO_4$, and $MgSO_4$] in surficial soils
(7) galactic cosmic rays
(8) solar particle events
(9) UV-glow discharge from blowing dust
(10) solar UV-induced volatile oxidants [e.g., O_2^-, O^-, H_2O_2, O_3]
(11) globally distributed oxidizing soils
(12) high concentrations of heavy metals in martian soils
(13) acidic or alkaline conditions in martian soils
(14) perchlorates in most soils
(15) lack of defined energy source free of UV irradiation
(16) no sources of available nitrogen and carbon
(17) no obvious redox couples for microbial metabolism

Schuerger et al., 2013, *Astrobiology*, 13, 115-131.

Effects of Mars UV flux on the Survival of *Bacillus* spp.

B. subtilis + Mars UVC flux



Rapid inactivation of seven *Bacillus* spp. under simulated Mars UV irradiation ☆

Icarus 181 (2006) 52–62

Andrew C. Schuerger [a,*], Jeff T. Richards [b], David A. Newcombe [c], Kasthuri Venkateswaran [c]

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Research Articles

A Lunar Microbial Survival Model for Predicting the Forward Contamination of the Moon

Andrew C. Schuerger,[1] John E. Moores,[2] David J. Smith,[3] and Günther Reitz[4,5]

ASTROBIOLOGY
Volume 20, Number 12, 2020
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DOI: 10.1089/ast.2019.2205

A Cruise-Phase Microbial Survival Model for Calculating Bioburden Reductions on Past or Future Spacecraft Throughout Their Missions with Application to Europa Clipper

John E. Moores[1] and Andrew C. Schuerger[2]

JGR Planets

RESEARCH ARTICLE
10.1029/2023JE007975

UV Reflectance of Spacecraft Materials and Analog Soils: Implications for Bioburden Reductions on the Undersides of Mars Rovers

Andrew C. Schuerger[1] and John E. Moores[2]

Key Points:

- Reflected UVC can sterilize the undersides of landed rovers

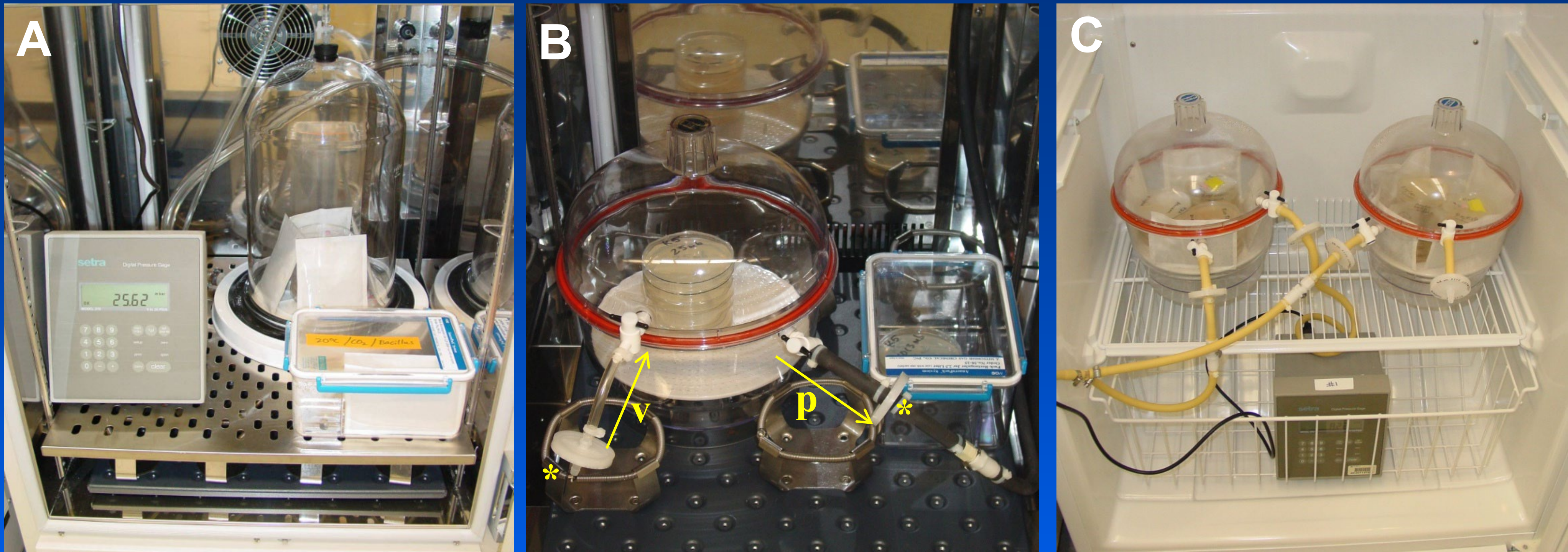
microorganisms doi.org/10.3390/microorganism12101976 MDPI

Article

Synergistic Interactions among Vacuum, Solar Heating, and UV Irradiation Enhance the Lethality of Interplanetary Space

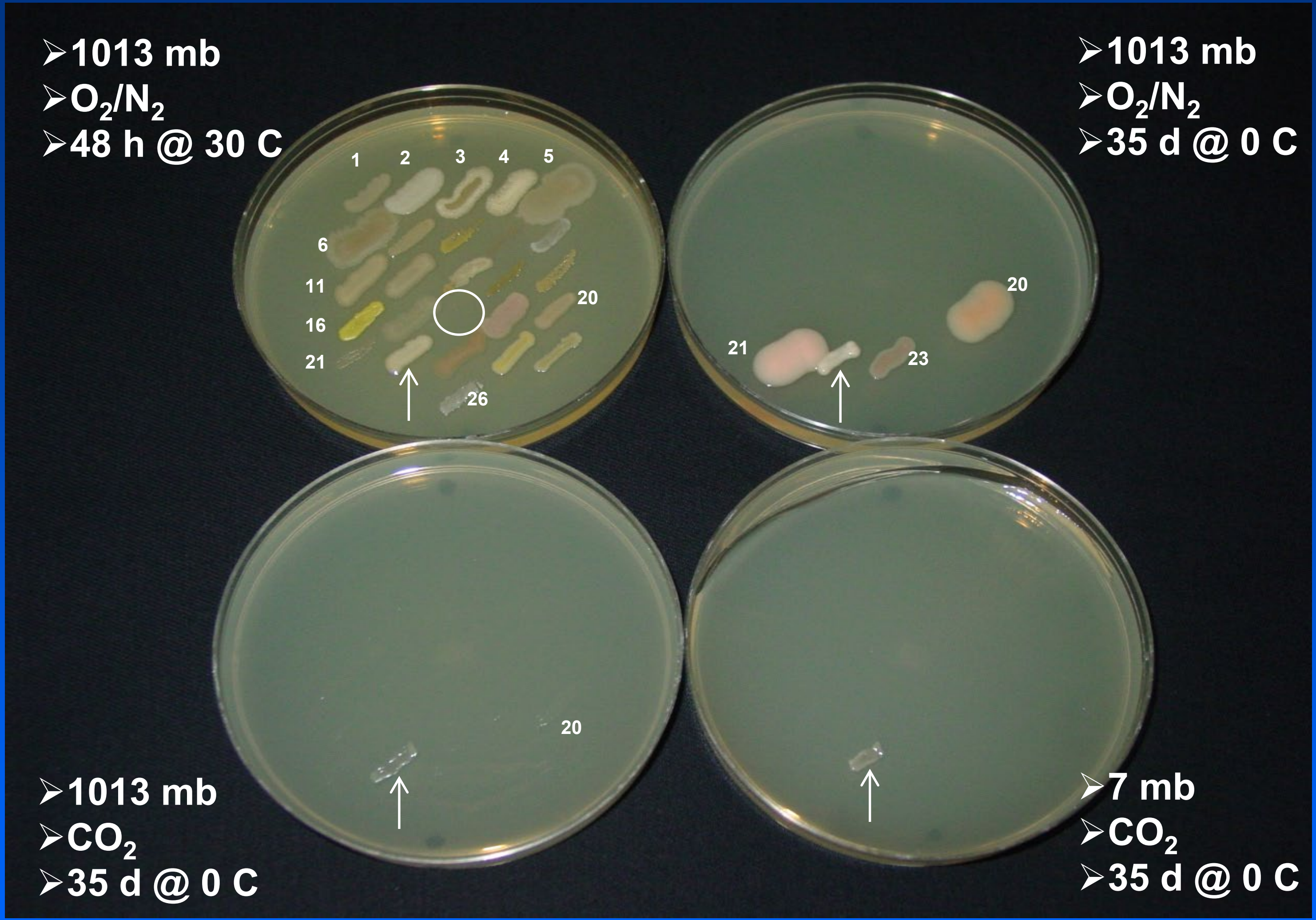
Andrew C. Schuerger [1,2]

Hypobaric Chambers & Conditions



1) TSA = trypticase soy agar; LB = Luria-Bertani broth.
2) 1000’s of strains of mesophilic & psychrophilic bacteria + fungi.
3) Pressure = 1013, 100, 75, 50, 25, or 7 mbar.
4) Temperature = 30, 25, 15, 10, 5, or 0 °C.
5) Atmosphere = O_2/N_2 or CO_2-enriched anoxic atmosphere.

Serratia liquefaciens can grow in 7 mbar, 0 ºC, & CO_2-anoxic atmospheres.



↑ = *Serratia liquefaciens* ATCC 27592

○ = *Proteus mirabilis*

20 = *Pseudomonas fluorescens*
21 = *Psychrobacter cryohalolentis*
23 = *Sporosarcina aquamarina*

Schuerger et al., 2013, Astrobiology, 13, 115-131.

Thermodynamics of Liquid Water on Mars

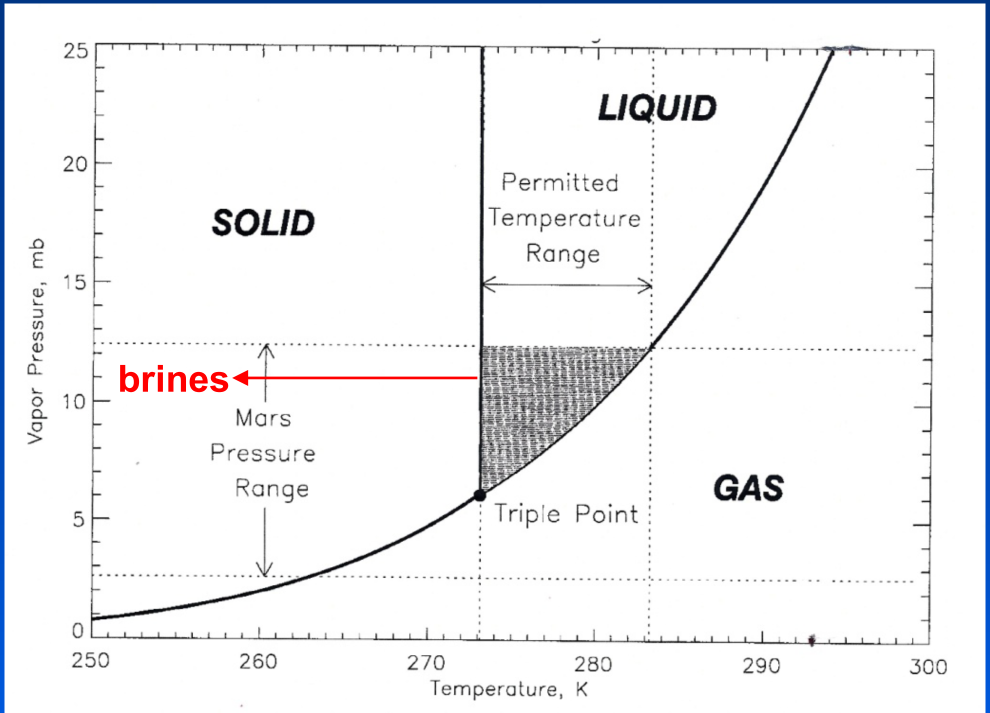


Figure 1. Phase diagram of water on Mars.

Haberle et al., 2001, *JGR*, 106(E10), 23317-23326.

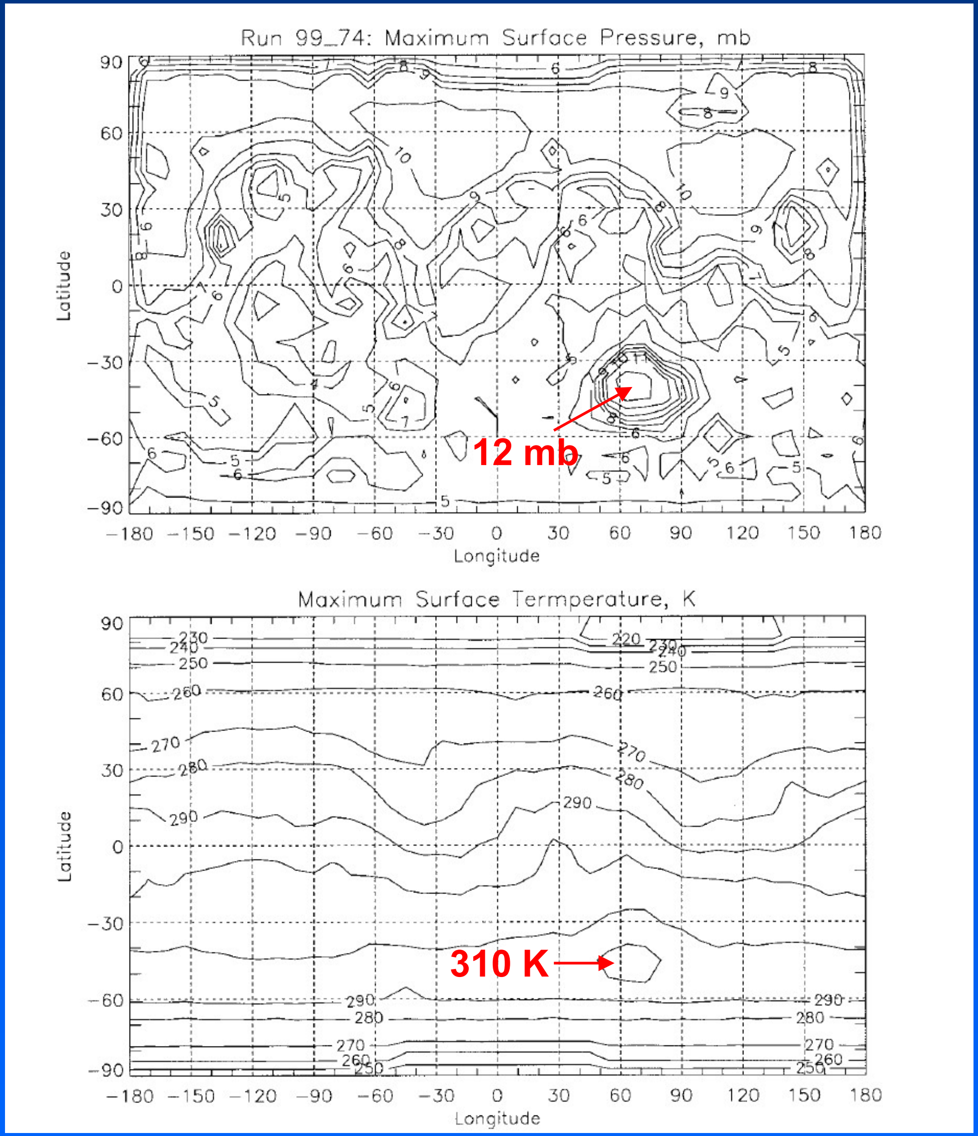
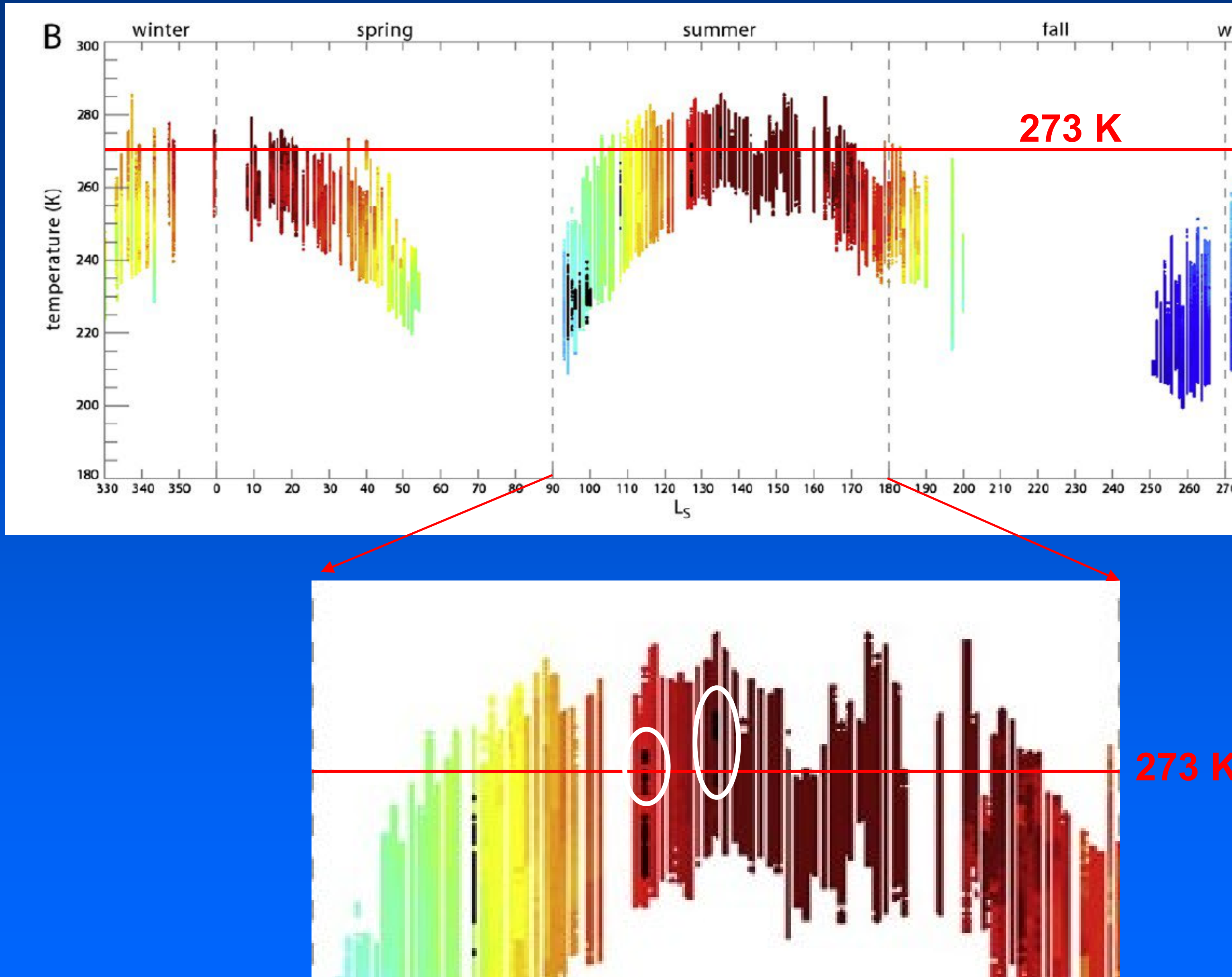


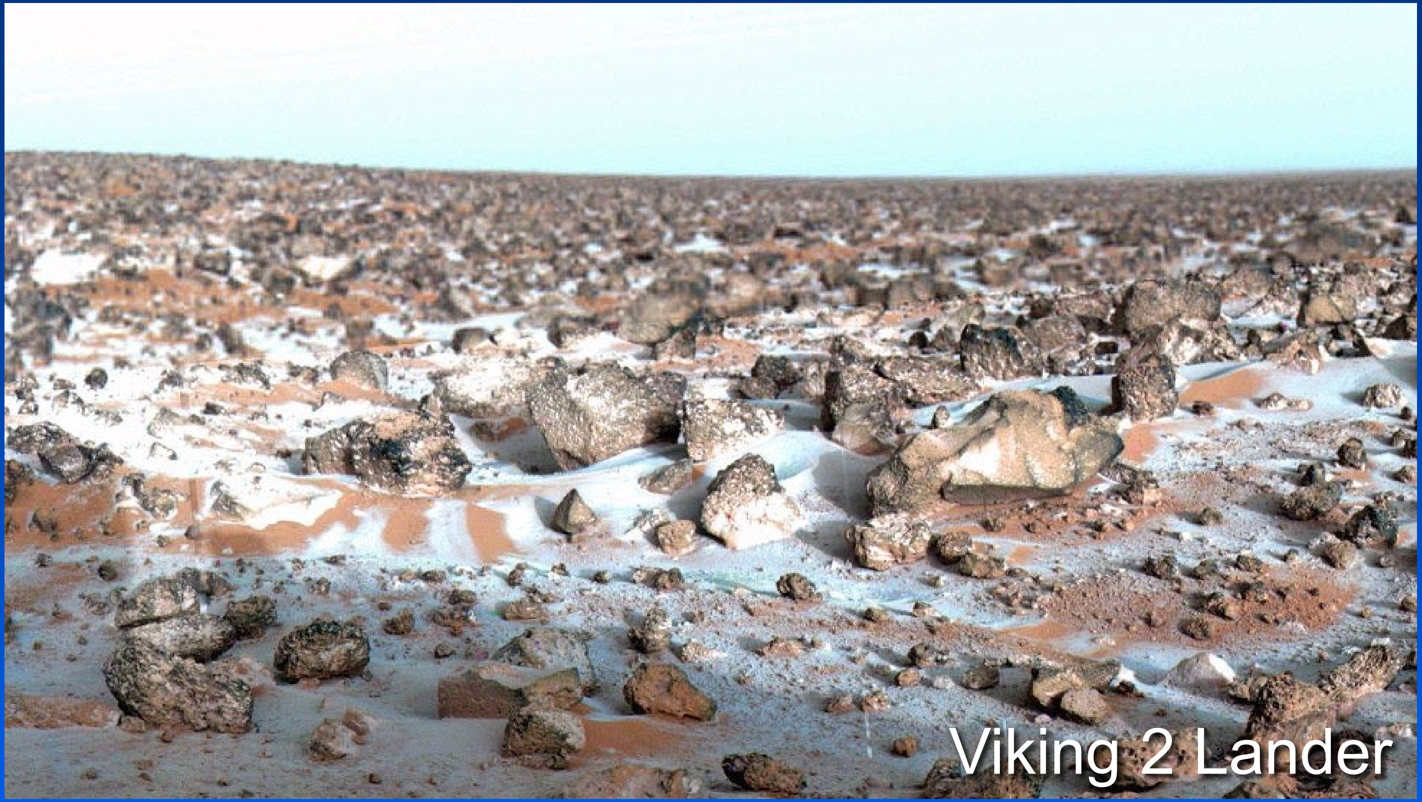
Figure 4. Top = pressure; bottom = temperature.

Detection of Frosts on Mars with OMEGA (Mars Express Orbiter)



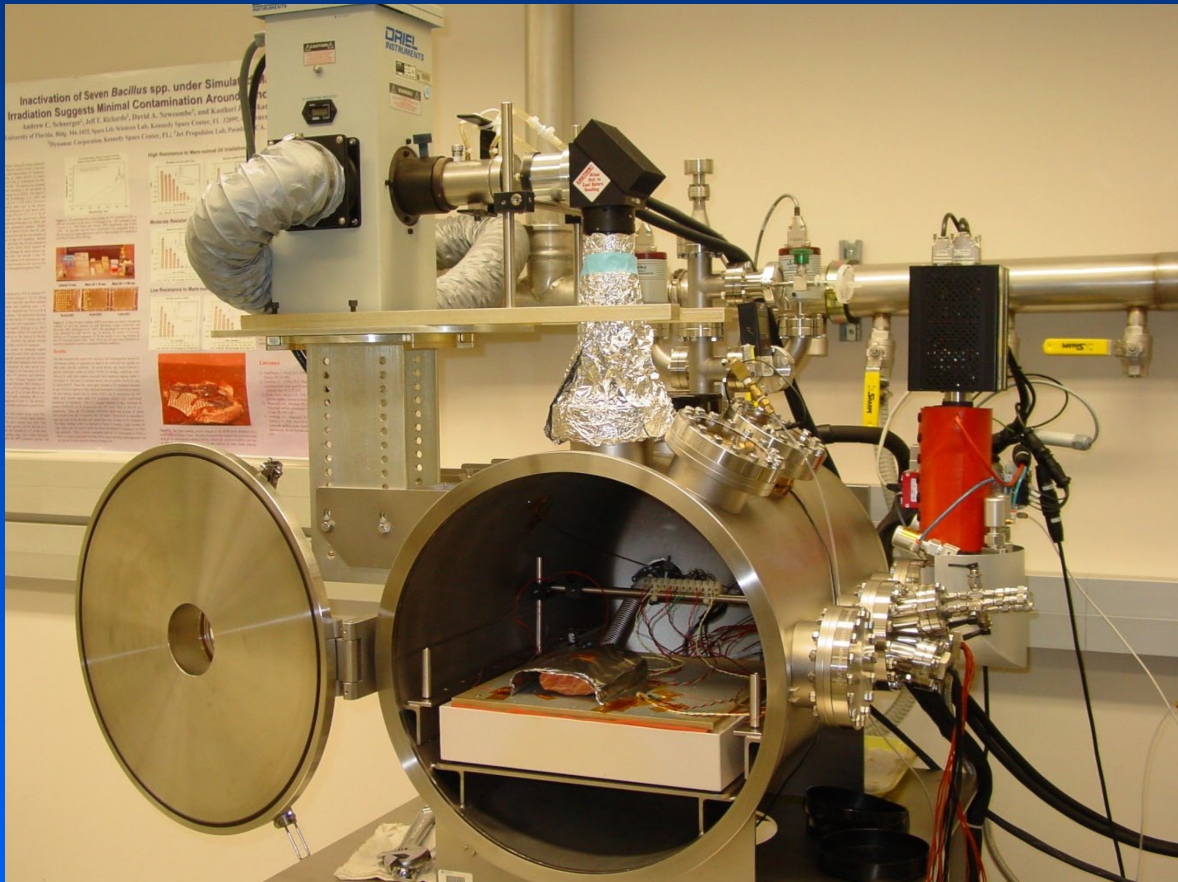
Carrozzo et al., (2009), *Icarus*, 203, 406-420, doi:10.1016/j.icarus.2009.05.020.

Cold-Trap Model of Frost Build-up on Martian Terrain



- *Cold-Trap model* for developing up to "…a few millimeters of frosts…" on Mars (Wall, 1981, *Icarus*, 47, 173-183).
  - Svitek and Murry (1990), *JGR*, 95 (B2), 1495-1510.
  - Schorghofer and Edgett, (2006), *Icarus*, 180, doi:10.1016/j.icarus.2005.08.022.
  - Head et al. (2011), *JGR* 116(E09007), doi:10.1029/2011JE003826.
  - Schorghofer (2020), *The Astrophysical Journal*, 840(49), doi.org/10.3847/1538-4357/ab612f

Mars Chamber
(Schuerger et al., 2008, *Icarus*, 194, 86-100.)



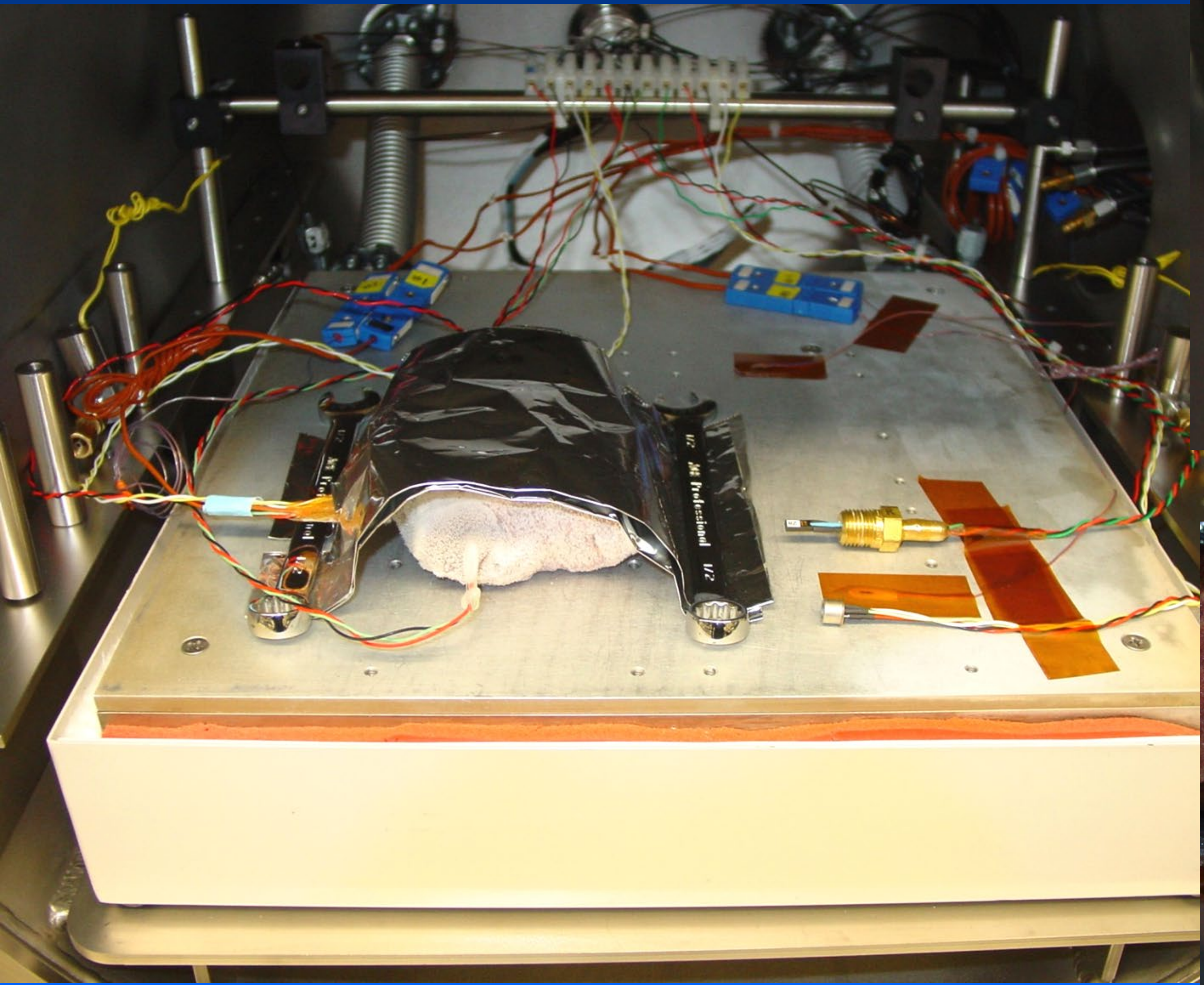
Basalt

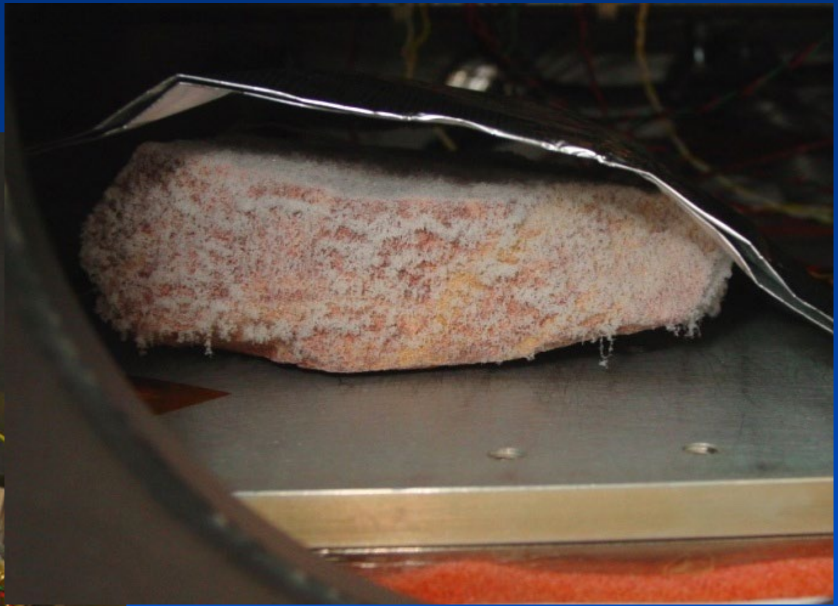
Red-Ochre Hematite

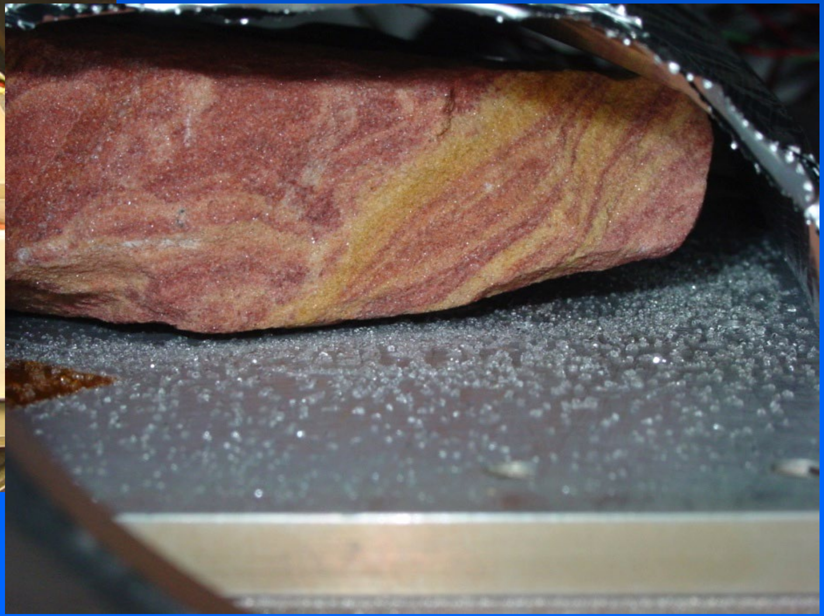
Fe-Banded Sandstone

- Pressure: 8 mbar
- Temp: –100 to 25^{o}C
- Gases: Mars mix (top 5 gases)
- UV-VIS-NIR: UV equatorial flux
- Dust loading at *tau* 0.5

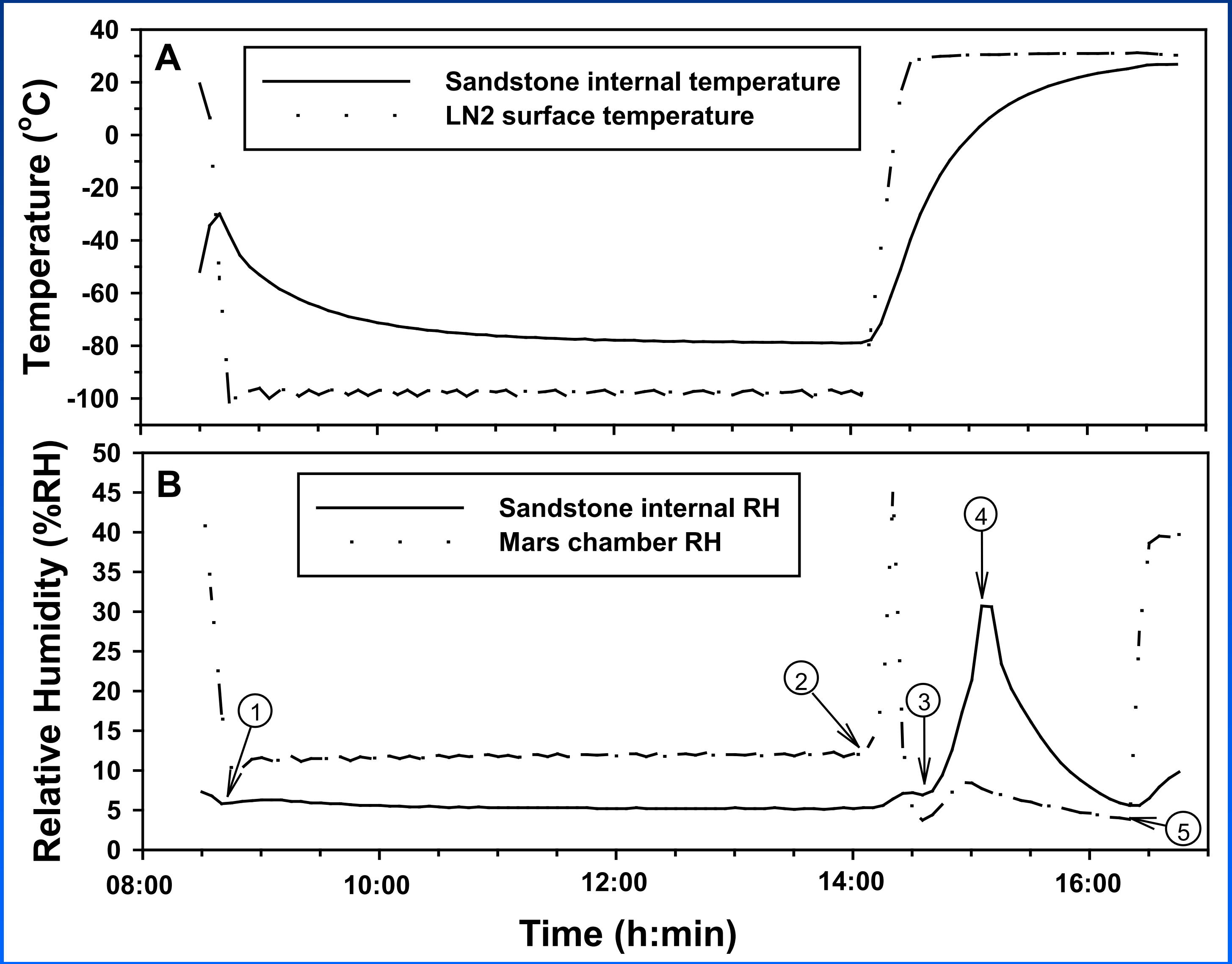
Fe-Banded Sandstone



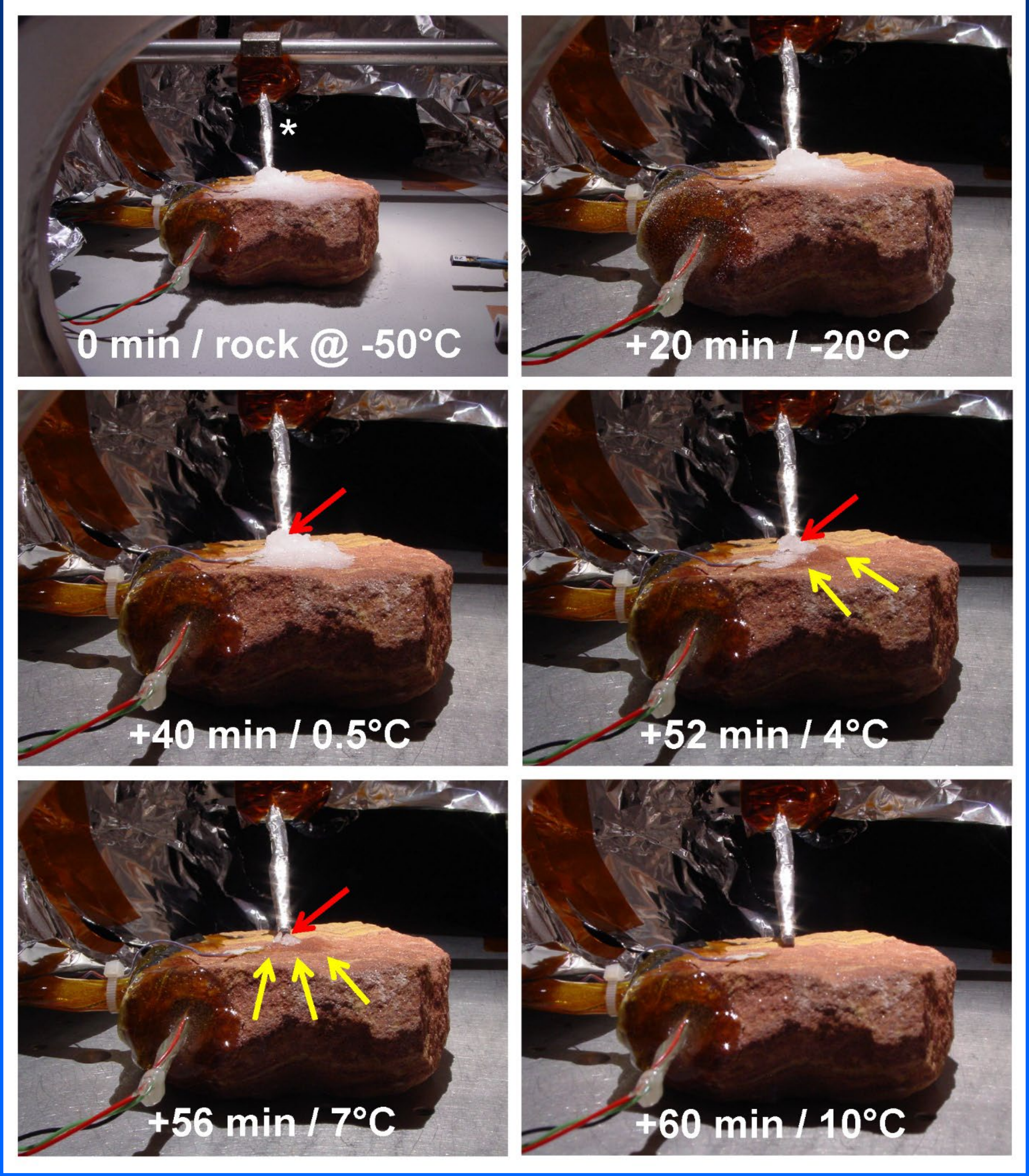




Sandstone….pre-frozen at –70°C



1) LN2 set to –95 C.
2) LN2 warm up.
3) Sublimation on rock surface.
4) Peak RH = 32% (peak a_w = 0.32).
5) Repress of chamber.



1) Rock surface at –50°C.

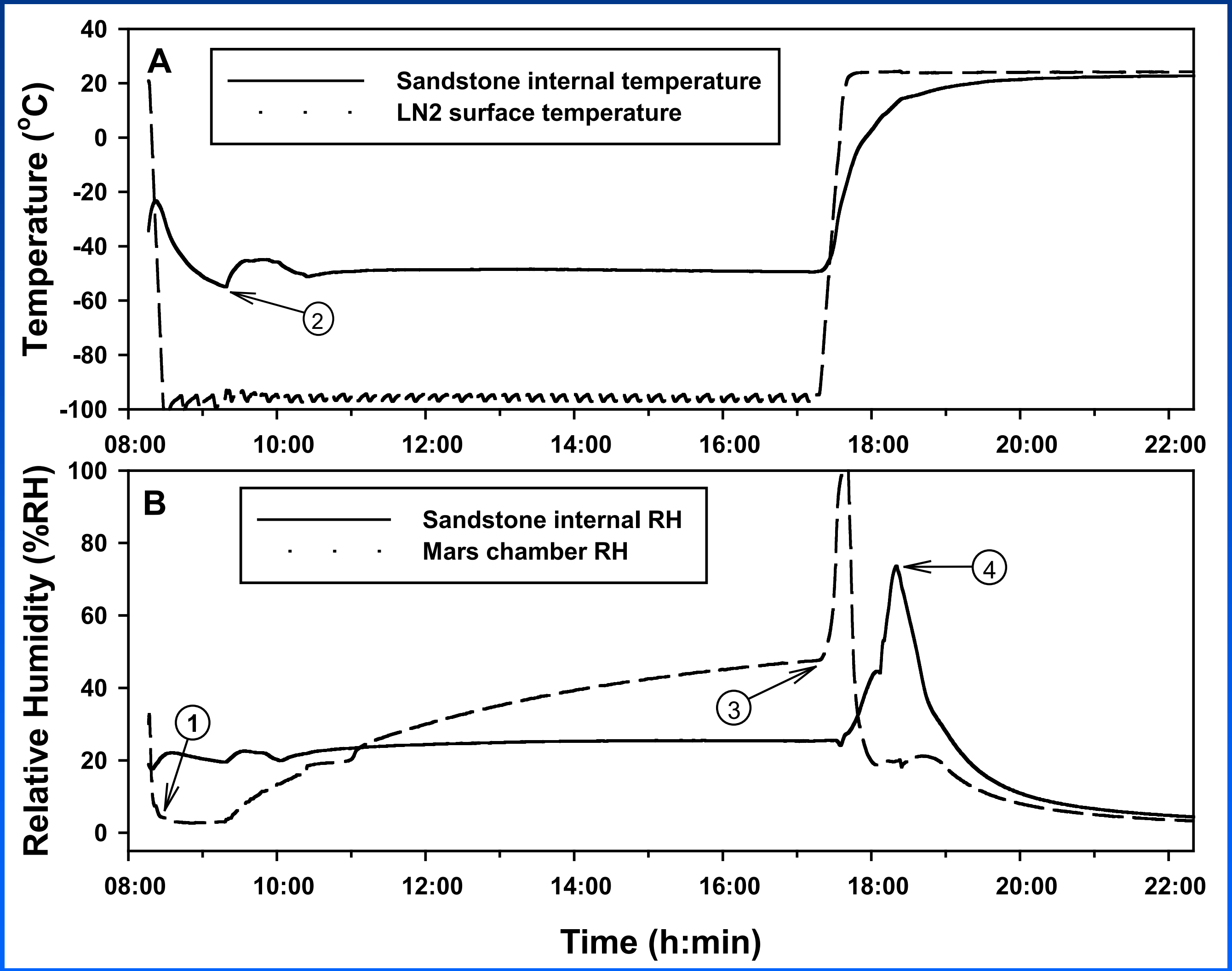
2) LN2 warm up.

3) Sublimation of thin frosts on rock and LN2 surfaces from –50 to 0°C.

4) Liquid water flowing from frost and into sandstone between 0 and 5°C.

5) All visible signs of liquid water gone after 20 min after frost has melted.

Sandstone….2 - 4 mm frost on upper surface



1) LN2 set to –95 C.

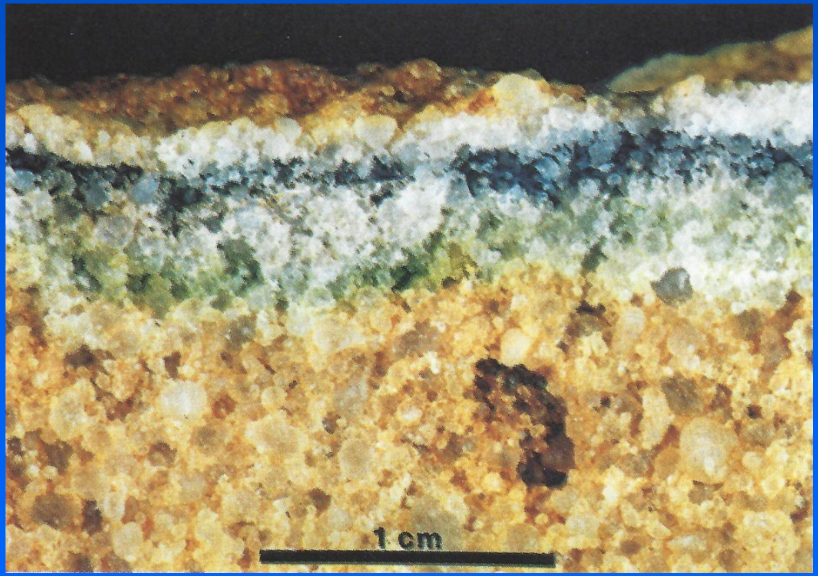
2) UV-VIS-NIR lamp on.

3) Sublimation on rock surface.

4) Peak RH = 70% (peak a_w = 0.70).

5) Time at a_w > 0.61 = 20-30 min.

Meltwater from frosts can flow into porous rocks



Friedmann, 1982, Science, 215, 1045-1053.

Caveats/questions:

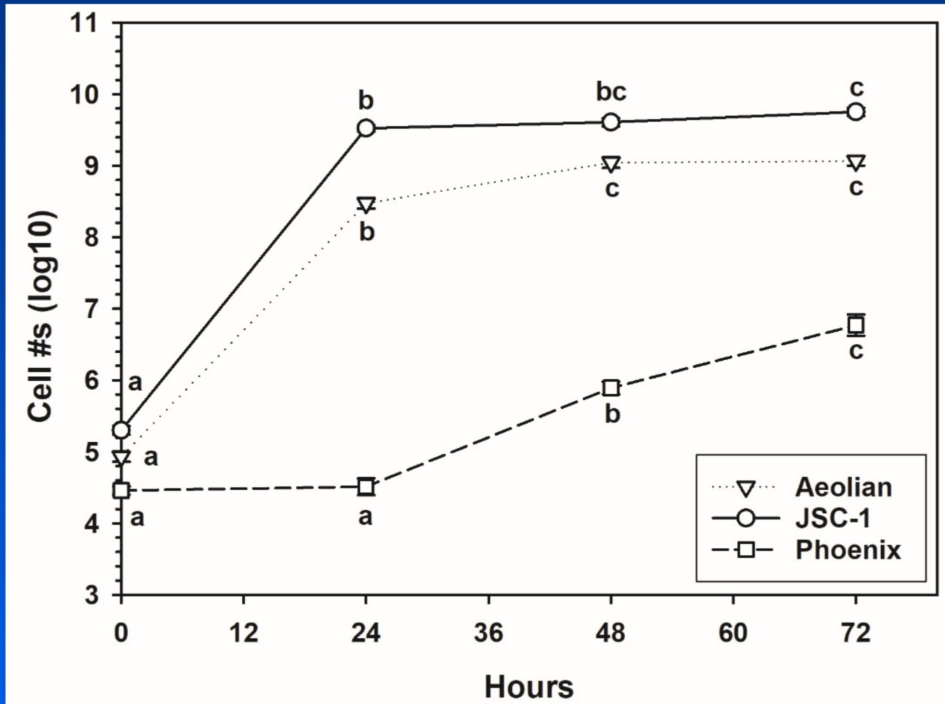
1) Must invoke *liberal* interpretations of thermodynamics of liquid water on Mars.

2) Internal a_w did not *exceed* 0.70, and persisted for no more than 20 min even with obvious meltwater flowing into sandstone.

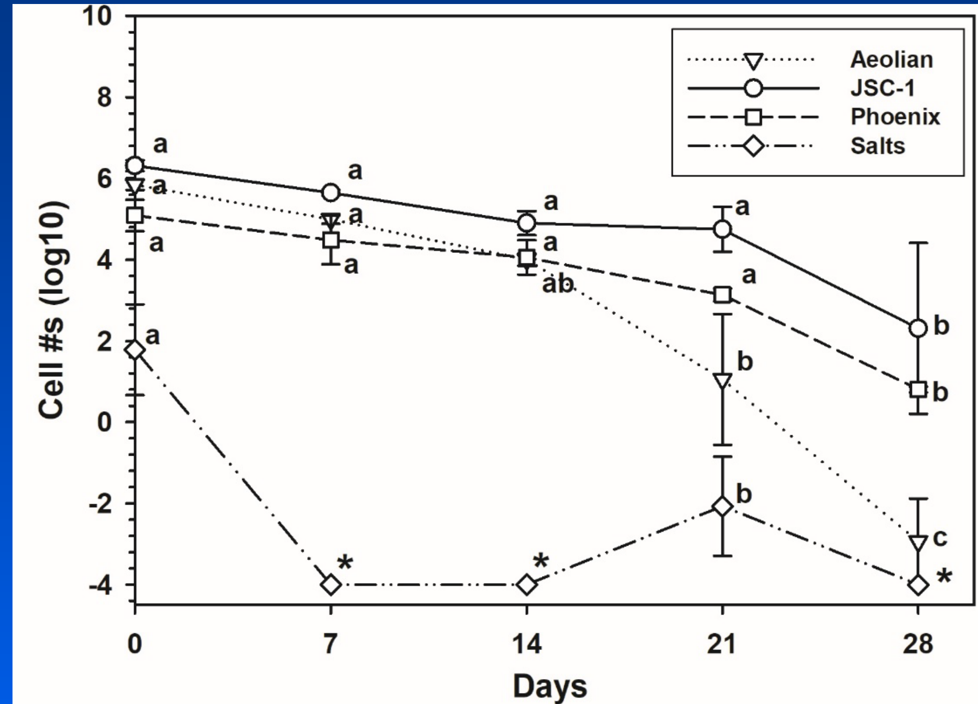
3) Is *20 min* at > 0.61 long enough for microbial life to absorb liquid water and induce metabolism?

S. liquefaciens growth in Mars analog soils

1015 mbar + 30°C + lab air



7 mbar + 0°C + CO_2-anoxic atmo

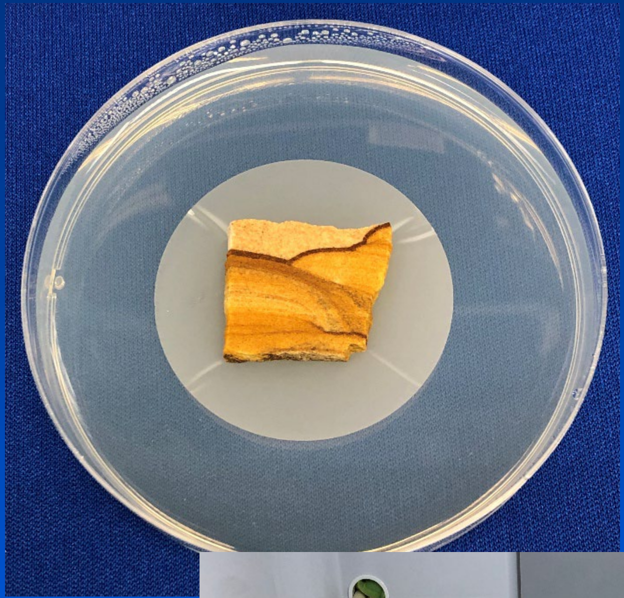


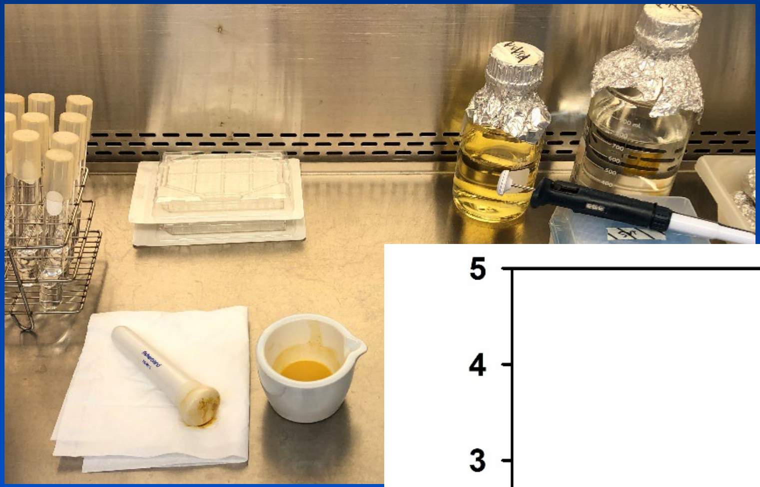
- 5-g of analogs in 50 cc Falcon tubes.
- 5 mL of liquid broth:

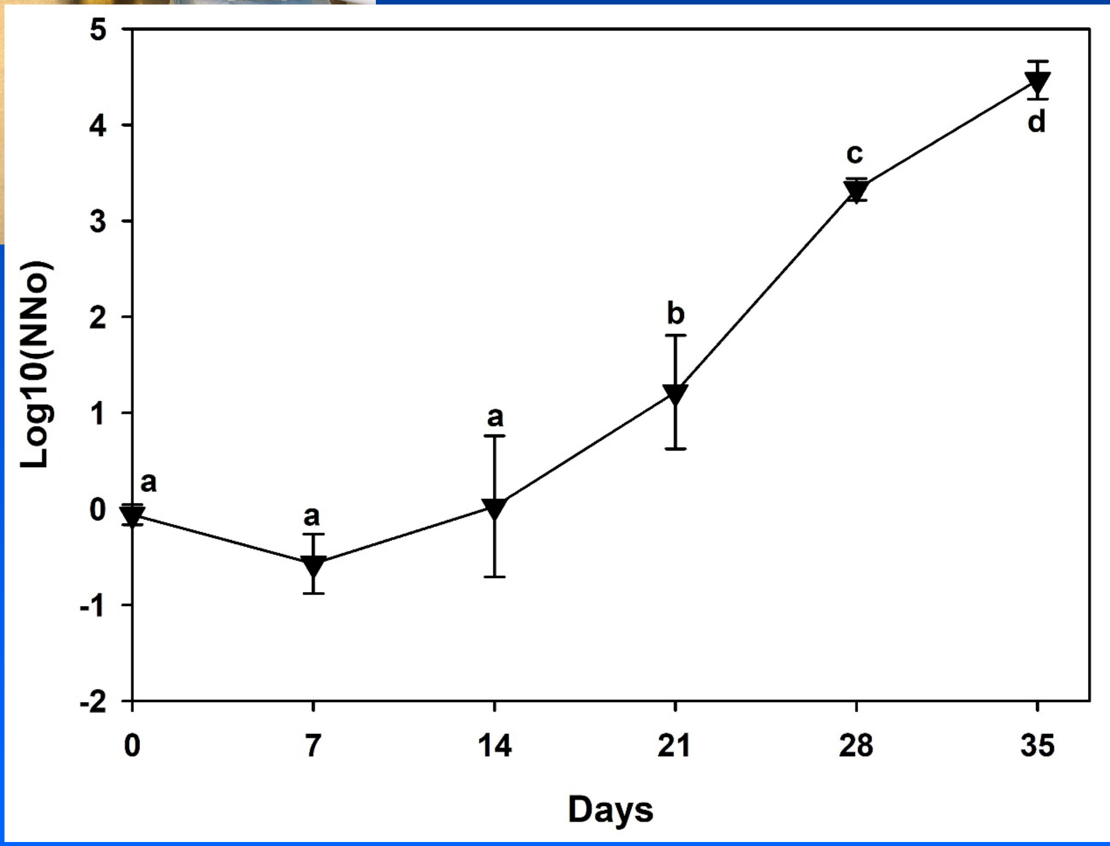
  Spizizen salts + 10 or 20 mM sucrose + micronutrients

Schuerger et al., 2020, *Life*, 10(77), doi:10.3390/life10060077.

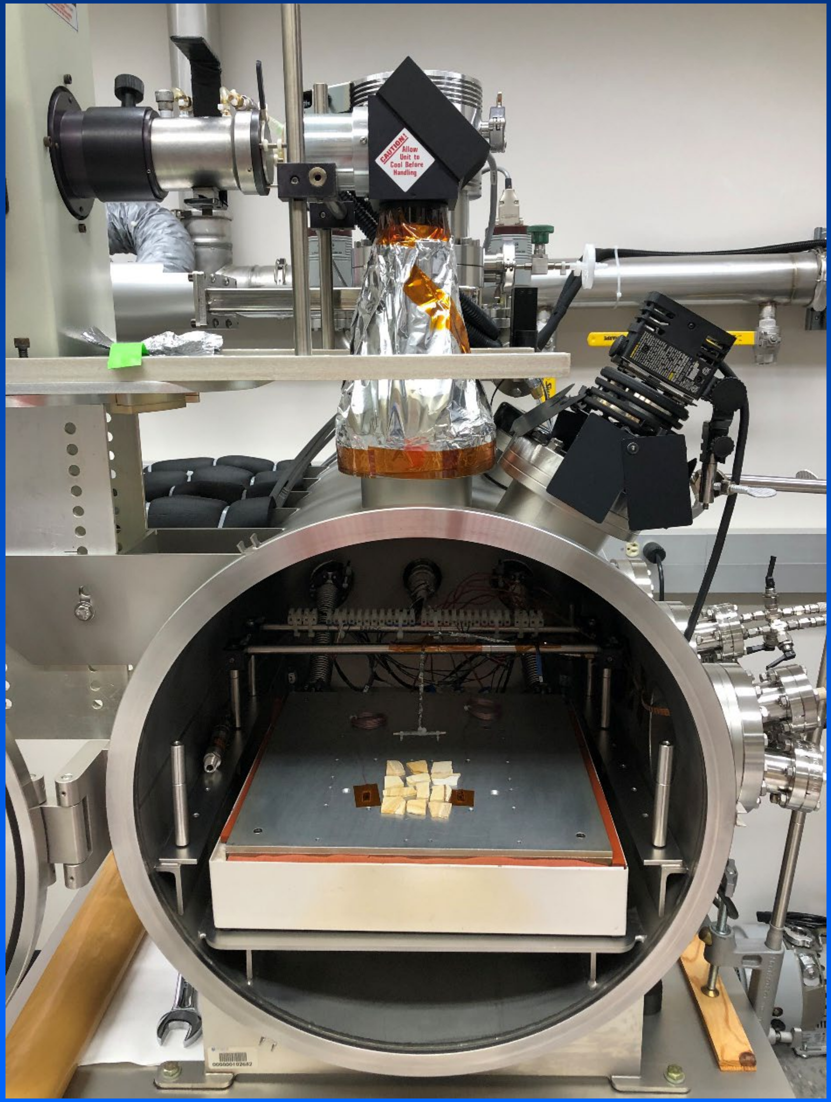
Growth of *S. liquefaciens* in rock chips at 8 mbar.







Frost Meltwater on Rock Chips at 8 mbar



Conclusions

(1) The surface of Mars is extremely harsh with 17-20 biocidal conditions.

(2) Spacecraft microorganisms are unlikely to survive these conditions for long (i.e., from hours to a few sols on upper surfaces).

(3) If spacecraft microbes can be dispersed quickly to protected niches, they may be able to persist, be metabolically active, grow, and evolve if stable liquid water and nutrients are present.

(4) However, even if frost meltwater can flow into porous rocks and regolith, it is unlikely to persist long-enough to support microbial metabolism and growth.

(5) Overall: Spacecraft microorganisms are VERY unlikely to survive, grow, and adapt on the Martian surface.