We Must Search for Extant Life on Mars Prior to Human Exploration

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Presented at Science and Planetary Protection in Advance of Human Missions Seminar
Oct. 30, 2024

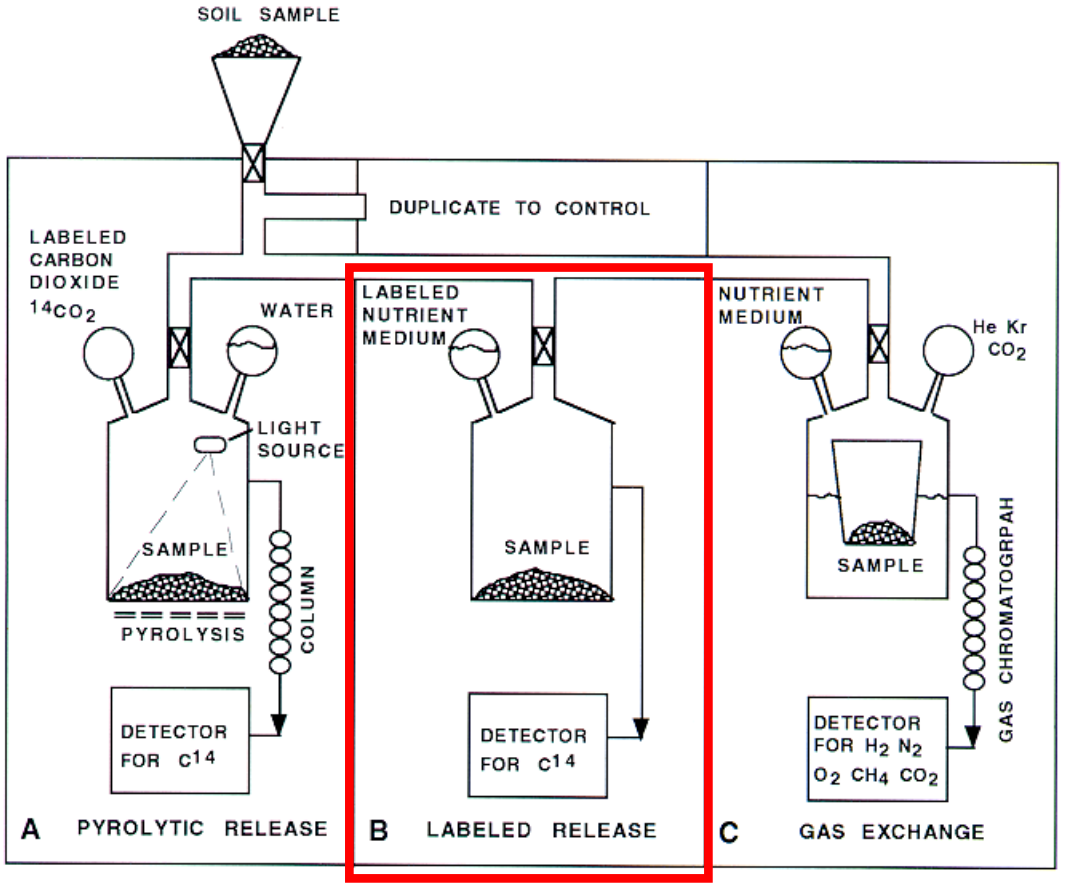
Viking in 1976 the only missions to ever search for extant life on Mars

Young Carl Sagan with Viking Lander

- First successful Mars landers
- 2 Identical landers: Lander 1 at low latitude site and Lander 2 at high latitude site
- 3 life detection instruments searched for evidence of metabolism of soil bacteria via soil culturing methods
- Organic analysis instrument (GCMS) looked for organic compounds in soil

Viking Biology Experiments

Attempted to culture microbes with nutrients and water and look for evidence of metabolism



Results

- Soil was unexpectedly reactive. Reactions were seen by all 3 instruments.
- Control experiments preheated the soil to sterilize it. In 2 experiments (PR and GEX) some reaction still occurred.
- Labeled Release instrument results not seen in control. PI Gil Levin believed the instrument detected life.
- GCMS organic analysis showed no organics in the soil at levels of ppb. This was thought to rule out biology. This was a False Negative Result!

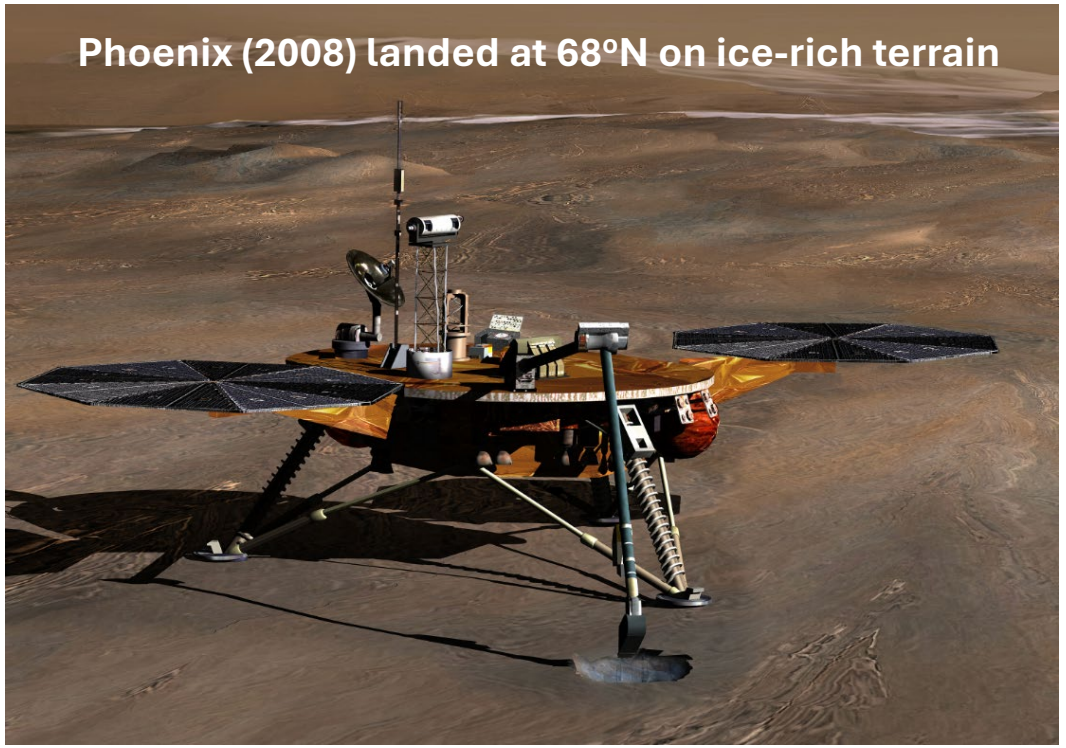
• Final reports stated that reactions were more likely chemical than biological. This was simplified by press and science community to imply “no extant life on Mars”

Phoenix Mission Discovery

~ 0.5% of Mars soil is Perchlorate salt

$(Na,Mg,Ca)\ ClO_4 * 8\ H_2O$

Hecht et al., Science 324,64,2009

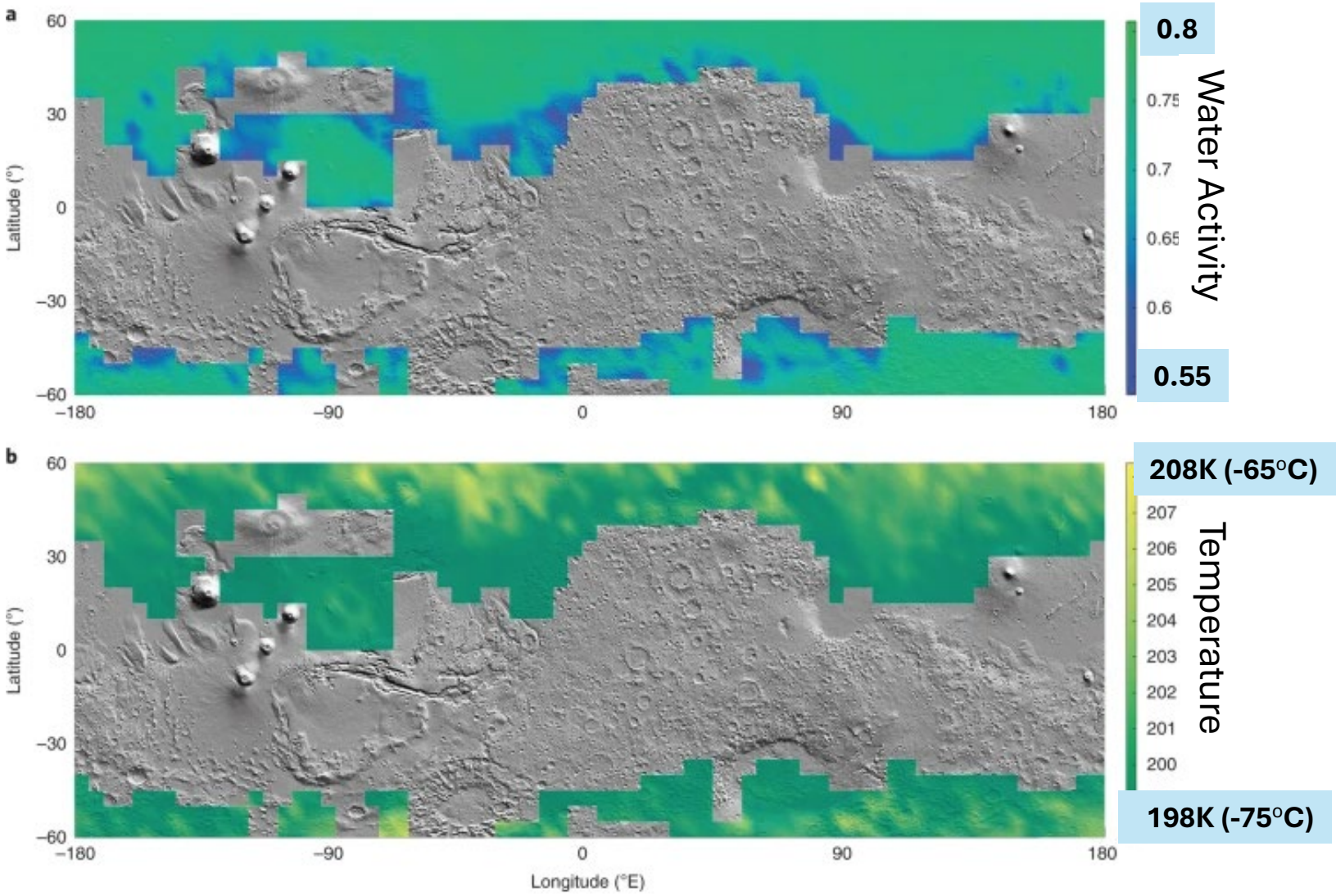


Why is Perchlorate important?

- **It is fuel: It burns organic carbon: likely caused the non-detection of organic carbon by Viking GCMS.**
- **It is food: Can be metabolized by many terrestrial microorganisms**
- **It is antifreeze: At its eutectic, the freezing point of liquid solution is ~-75° C**
- **It is deliquescent: Perchlorate salt crystals become water drops at 80% relative humidity, and remain liquid down to 1% humidity**

Deliquescence in perchlorate salts may occur on present Mars

See Rivera-Valentine *et al*. Nature Astronomy 2020) *doi.org/10.1038/s41550-020-1080-9*



(Credit Figure 3 Rivera-Valentine *et al*. Nature Astronomy 2020)

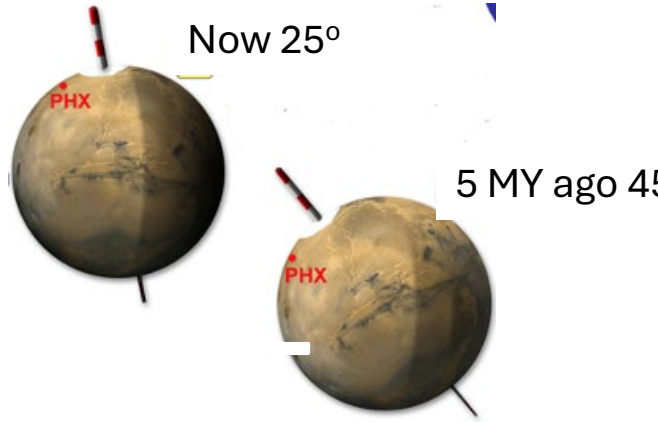
Formation of $CaClO_4$ brines by deliquescence

Brines can form when humidity is high, but will effloresce when humidity drops below ~1%.

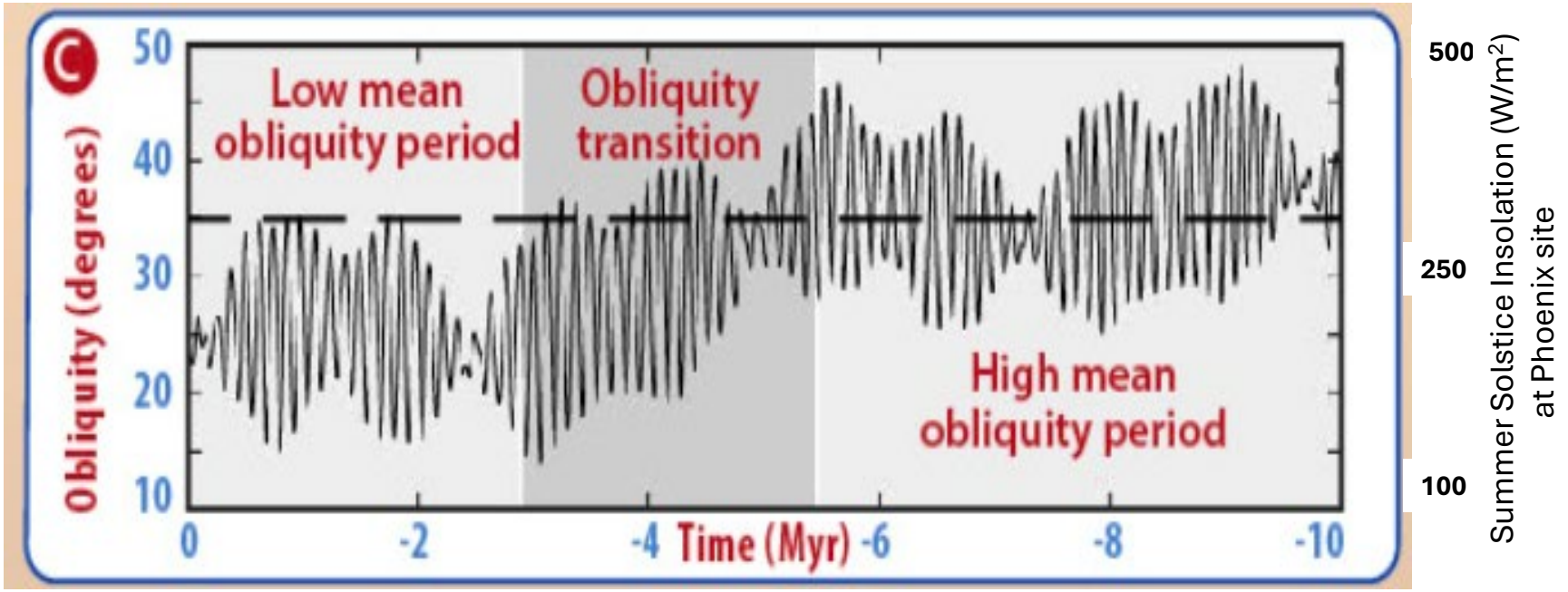
Temperatures of $CaClO_4$ brines far below habitable limits for known terrestrial organisms.

Ice

Changes in Obliquity Drives Climate Change on Mars

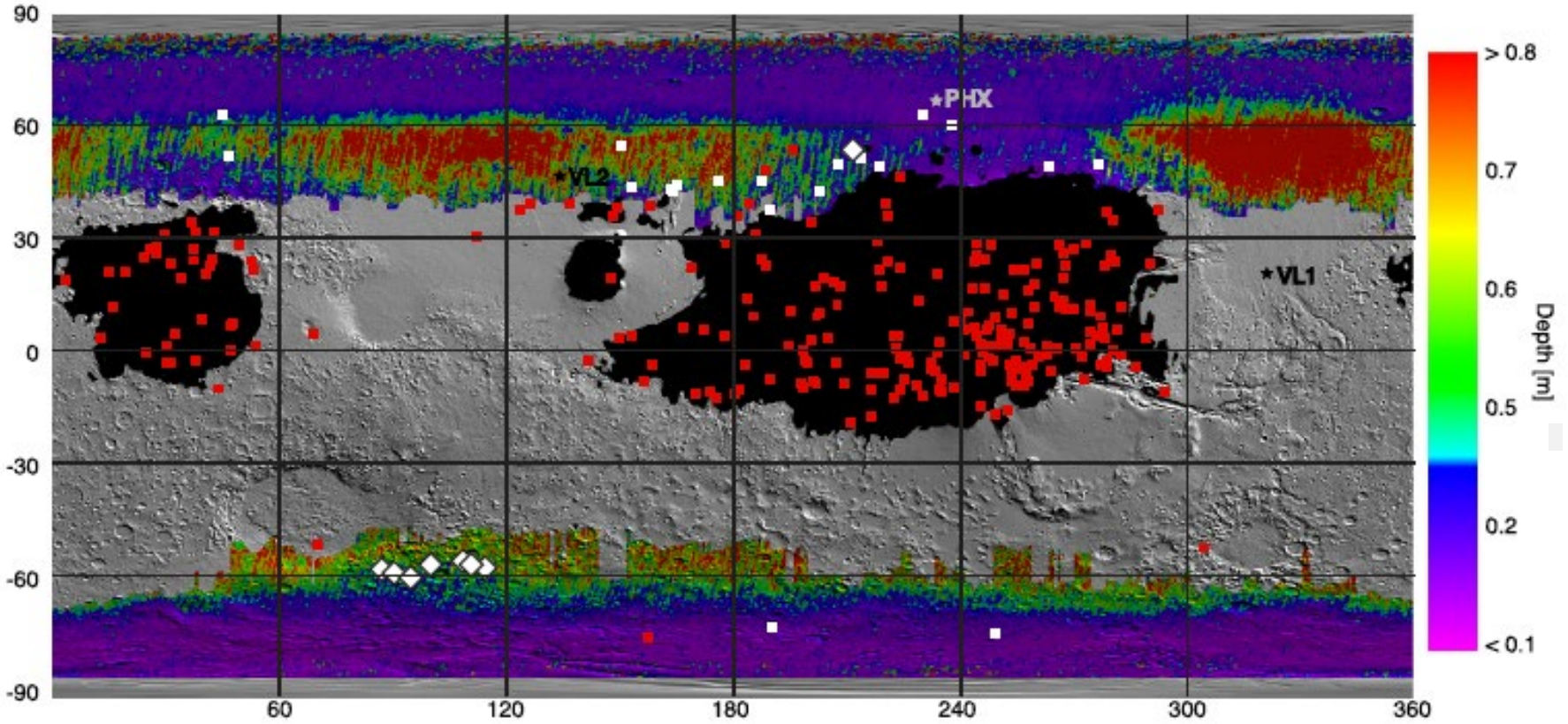


Mars obliquity varies over time. Insolation at high latitudes increases at high obliquity. This causes redistribution of ground ice from high to low latitudes

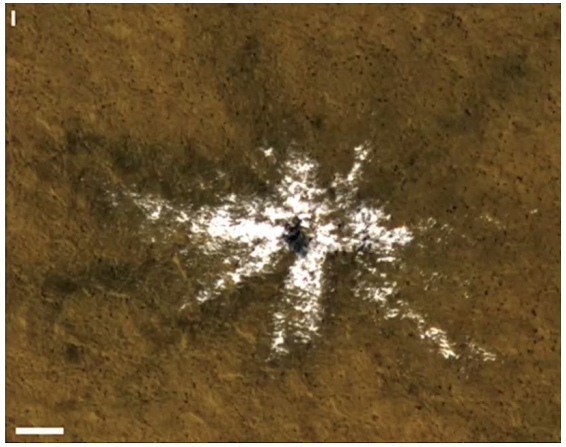


Water vapor in the Mars atmosphere, in equilibrium with soil, is deposited into the pore spaces in soil. This occurs rapidly compared to the time scales of climate change.

Current Ground Ice Location



Map of ground ice from Piqueux et al. Geophys. Res. Lett. 2019



HIRISE image of fresh crater exposing nearly pure ice within 1 m of surface (Byrne et al. 2009).

- All latitudes above ~45° N currently show ground ice within 1 m of the surface.
- White squares are the locations of fresh impact craters revealing optically white ice.
- White diamonds are exposed ice in cliff faces.
- Red Squares are impact craters without ice signatures.
- Black areas are covered by dust that would hide the ground ice signatures.

Time History of Habitable Ground Ice on Mars (Recent work by Mellon et al. Icarus 2023)

Conditions for Habitability

Fall under four categories:

1) source of energy;

2) available chemical nutrients;

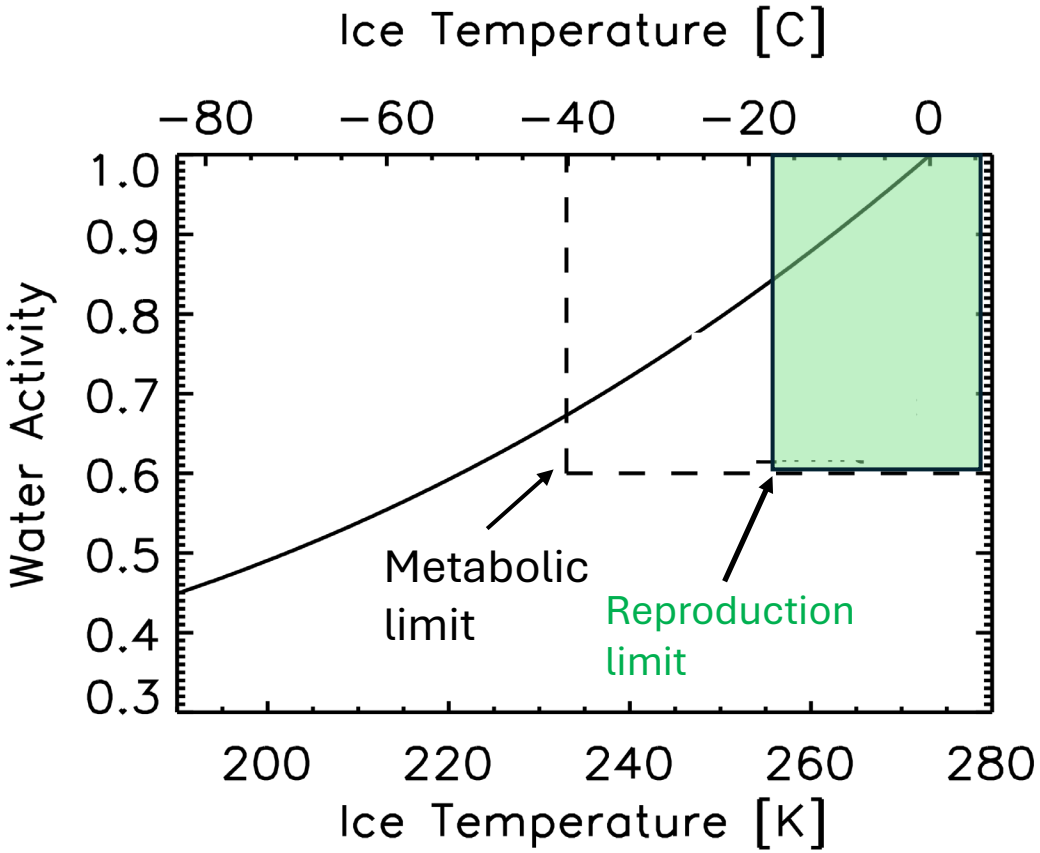
3) favorable environmental conditions;

4) accessible water.

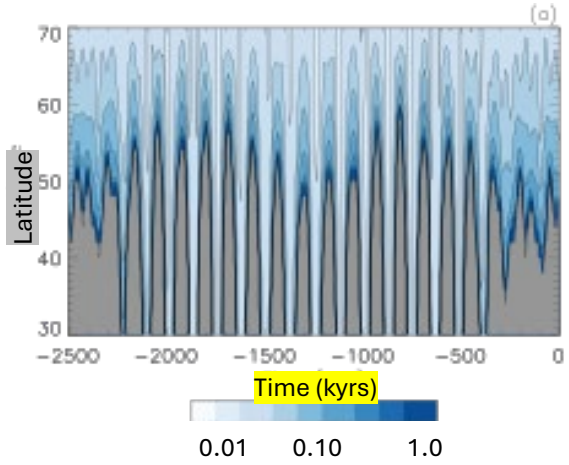
Based on Earth-extremophile* studies:

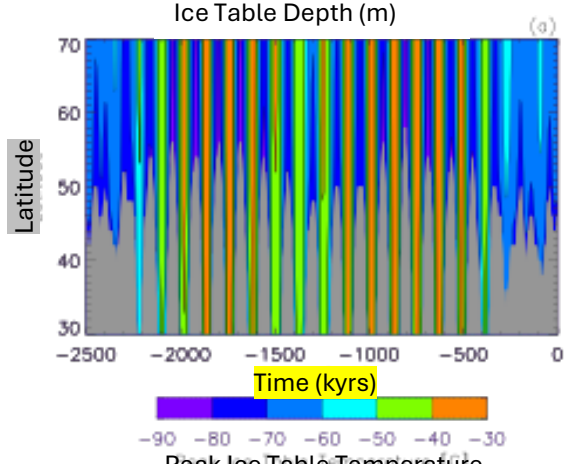
- Propagation Limit
  T = -18°C ; a_w = 0.6
- Extreme Metabolic Limit
  T = -40°C ; a_w = 0.6

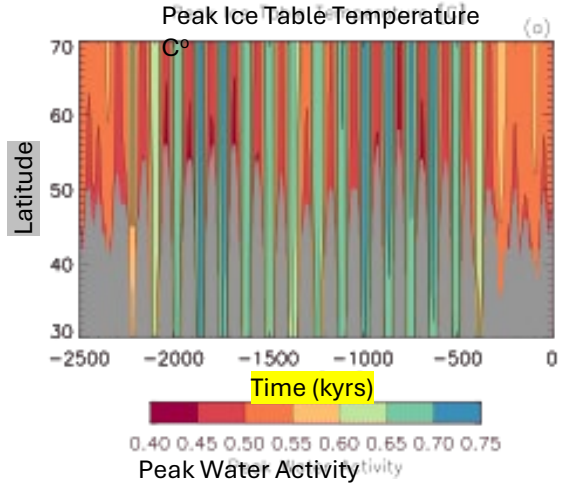
* Mars organisms may have different limits



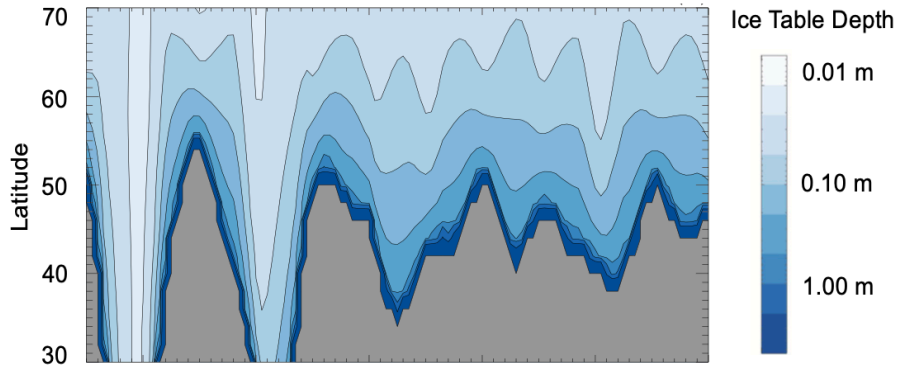
Relationship between water activity and temperature at the ice table. Also shown are the metabolic limits observed in terrestrial microbes. Within the extreme limit they can maintain basic cell functions and repairs. Outside these limits they are dormant.

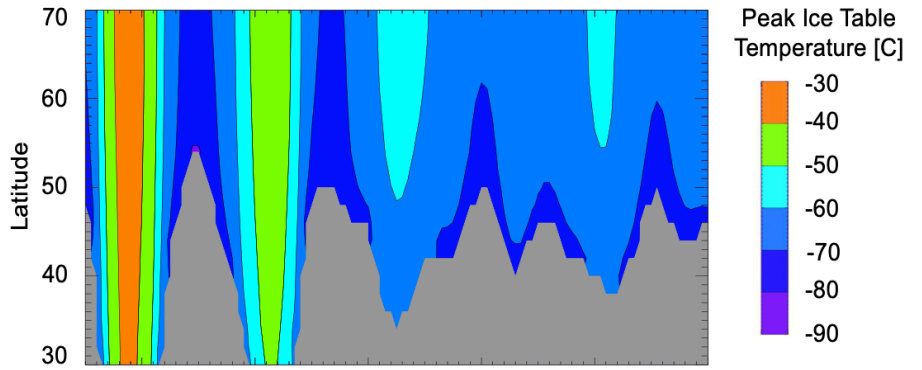


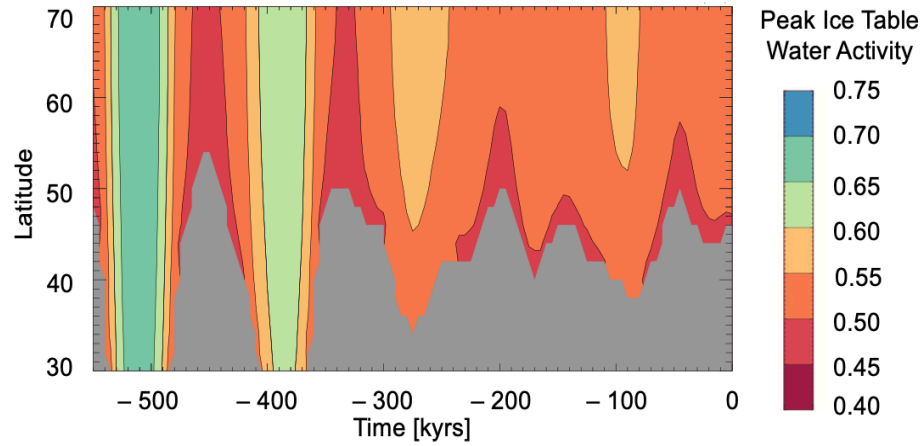




Model Results Mellon et al. 2023







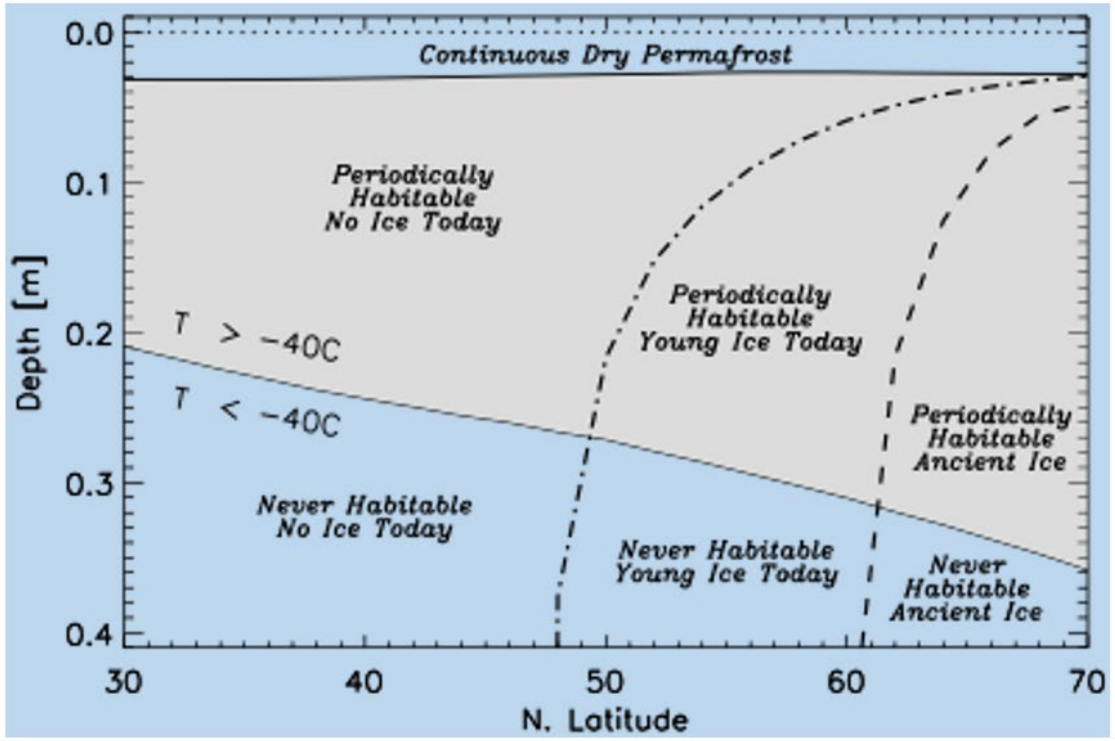
Ice is has disappeared from low latitudes in the present epoch.

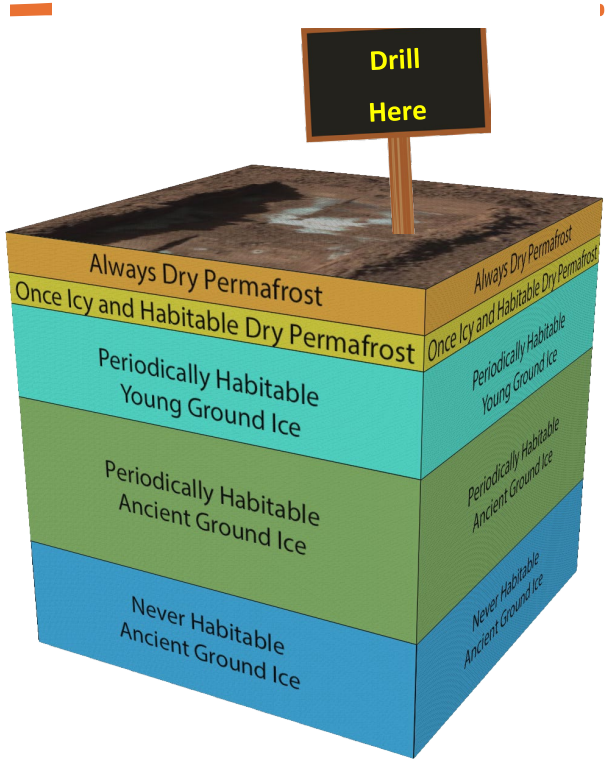
Ice is near the surface at low latitudes within the last million years and repeatedly over geologic time.

Temperature and water activity are in the “habitable” range periodically.

Highest T =-33°C

Where to search for life in ground ice?





High Latitude sites (> 61N) have highest likelihood of supporting life:

- Current ice
- Both young and ancient ice
- Diverse stratigraphy
- Longest periods of habitability (10s of Kyrs)
- Deepest depths of habitability
- All accessible in 1 m depth

Article IX Outer Space Treaty

"Parties to the Treaty shall pursue studies of outer space, including the Moon and other celestial bodies, and conduct exploration of them so as to avoid their harmful contamination and also adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter and, where necessary, shall adopt appropriate measures for this purpose."

- This is the basis for COSPAR regulations related to Planetary Protection
- Sample returns from beyond the Moon (Stardust, Genesis, Hayabusa) were unrestricted.
- Sample return from Mars is restricted for robotic missions.
- Human return from Mars would be a restricted sample return.
- In the USA compliance with treaties has the force of federal law on all US entities including private space companies (by the Supremacy Clause of the Constitution.)

Do humans ruin or help the search for life?

- The view that human exploration of Mars will permanently ruin all life search on that planet has no basis in field microbiology.
  - the human microbiome is not suited for extremes
  - we can recognize contamination from humans

- Humans and the drilling infrastructure they will have could greatly help the search for life on Mars.

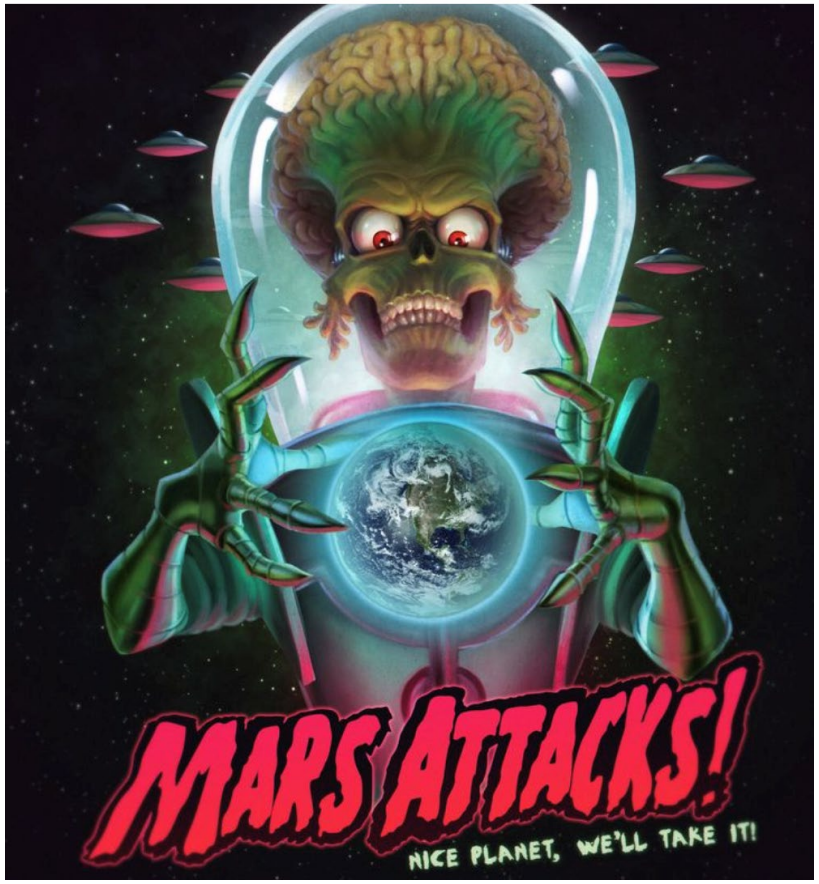
- Field studies on Earth, especially deep drilling, provide important operational analogs for aseptic drilling on Mars with human operators.

Humans and materials returning from Mars pose a risk to Earth.

Risk needs to be evaluated realistically with data.

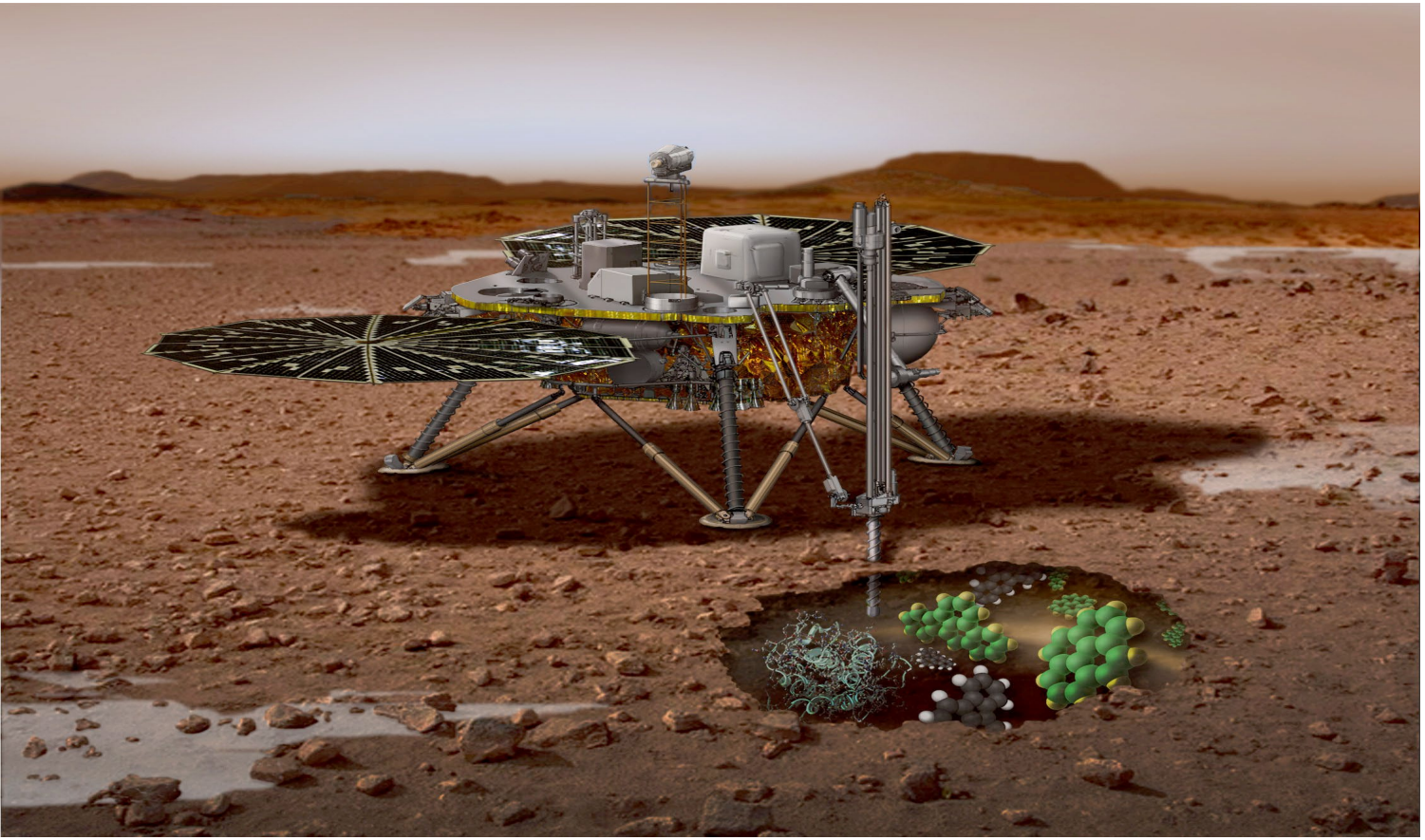
- **Argument:** Low Risk-- Martian materials capable of hosting viable microbes arrive on Earth at average rate 10 kg/yr. Earth may already be contaminated by Mars life.

- **Counterargument:** High Consequence-- Contamination of Earth by competitive “alien species” could be very bad.



There are numerous examples of imported “alien species” disrupting ecosystems on Earth.

Biosafe Mission Strategy



Mars Life Explorer to Search for Signatures of Life in Ice
Recommended by 2020 Decadal Survey

A biosafe mission should be sent to any human landing site well before humans go there.

Analyze samples to depth humans will excavate. If ground ice is target for ISRU, it is important target sample.

Mission payload should include highly sensitive detection of amino acids with chirality, lipids, and large biomolecules.

Detection of only meteoritic patterns of amino acids and lipids indicates biological safety.

MLE is a good example mission.

Questions?