Exploring the Martian Biosphere

Planetary Science Decadal Survey 2022-2032 Panel PSDS2022

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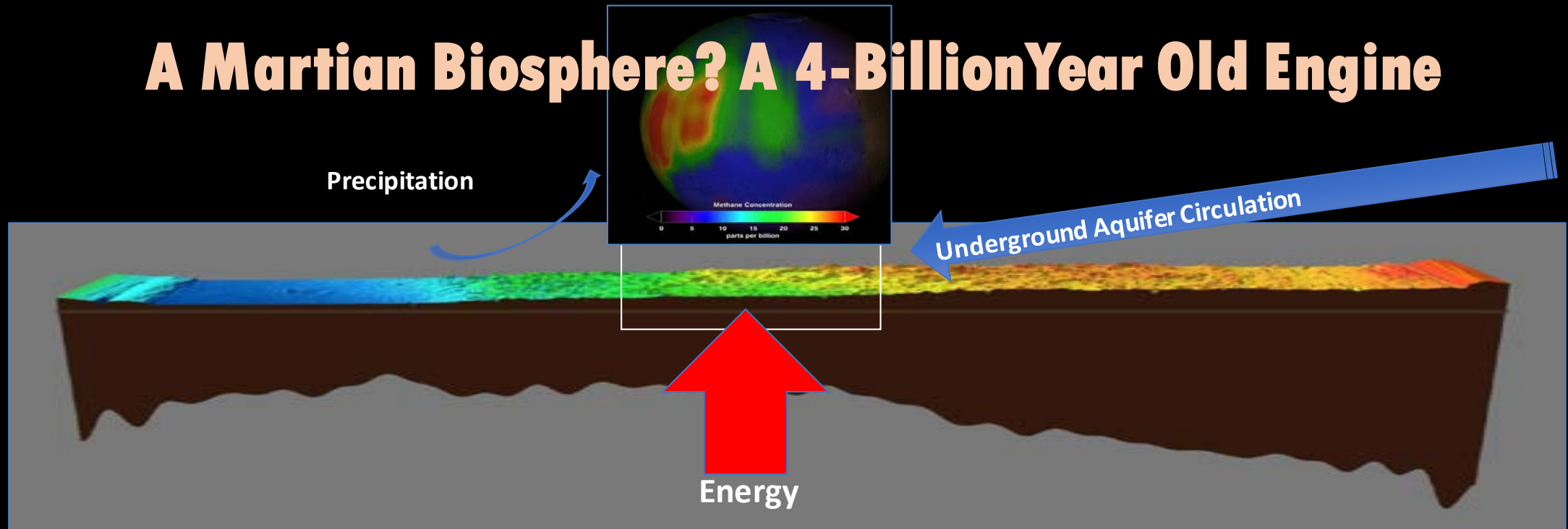
The Scientific Case:
Lessons from Mars & Earth

- There were habitable environments on Mars
- **Did life develop?**
- **Is there an active biosphere on Mars?**
- Coevolution of life and environment
  - Habitats
    - Species & Adaptation
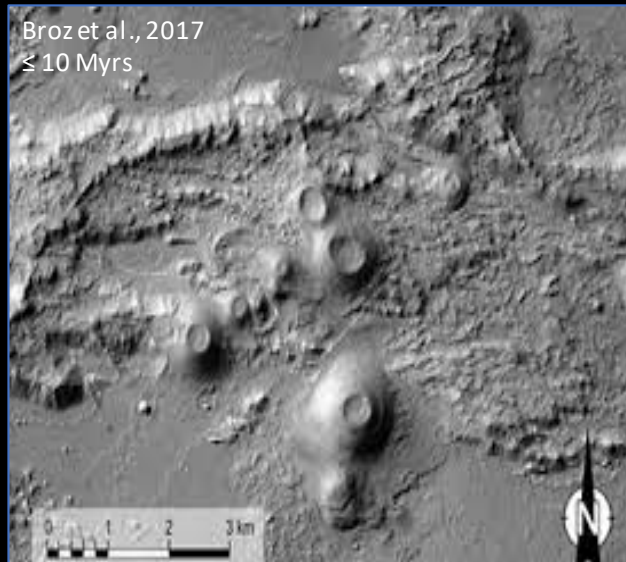- **Biosphere Engine and Biological Dispersal**
- **Strategic Knowledge Gaps**

Where?
When?
What?
How?

A Martian Biosphere? A 4-BillionYear Old Engine

Precipitation

Methane Concentration

parts per billion

Underground Aquifer Circulation

Energy

Elysium /Cerberus Fossae

Horvath et al. submitted: 2020
53,000 years

Tharsis / Valles Marineris

Broz et al., 2017
≤ 10 Myrs

Subglacial Lakes

Lauro et al. 2020
Present

Environmental Habitability (Where & When?)

Noachian   Hesperian   Amazonian

4.1   3.8   3.4   0.01

PD   Loss of magnetosphere   End of HB   Most recent volcanic Activity in VM

VM/Th   Oceans/Seas?

Elysium

Valley networks, lakes- but
?

Subaeria Habitats

Subsurface Habitats

Deep Underground Habitats

− Microbial Habitats/Ecotones/Dispersal Pathways +

−   Environmental Polyextremes   +
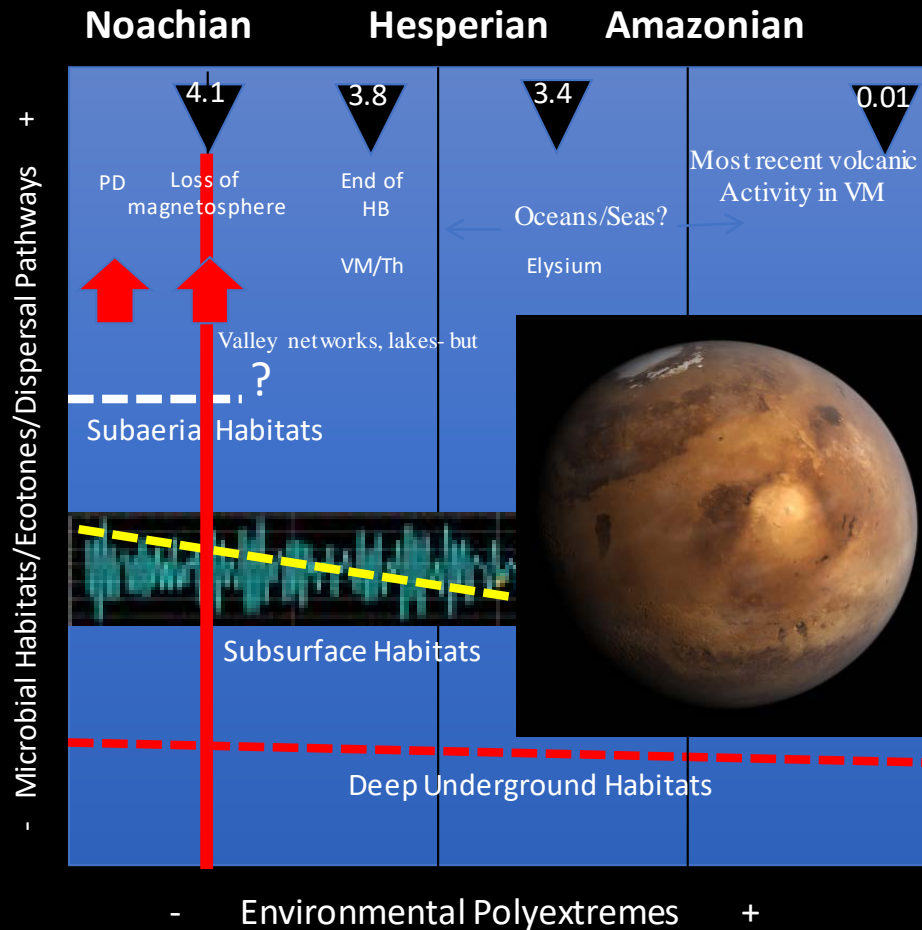
Hypothetical Biosphere Profile

Polyextreme (3.7 Ga →)

Stability

Cyclic

Permanent

Communication
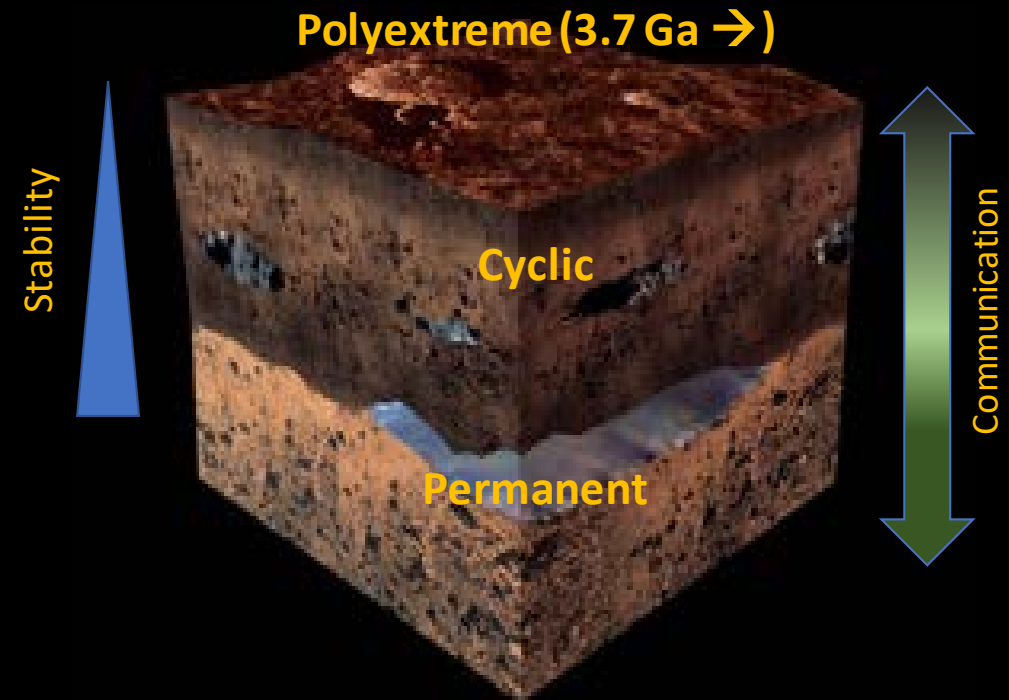
Illustration by Medialab, ESA 2001

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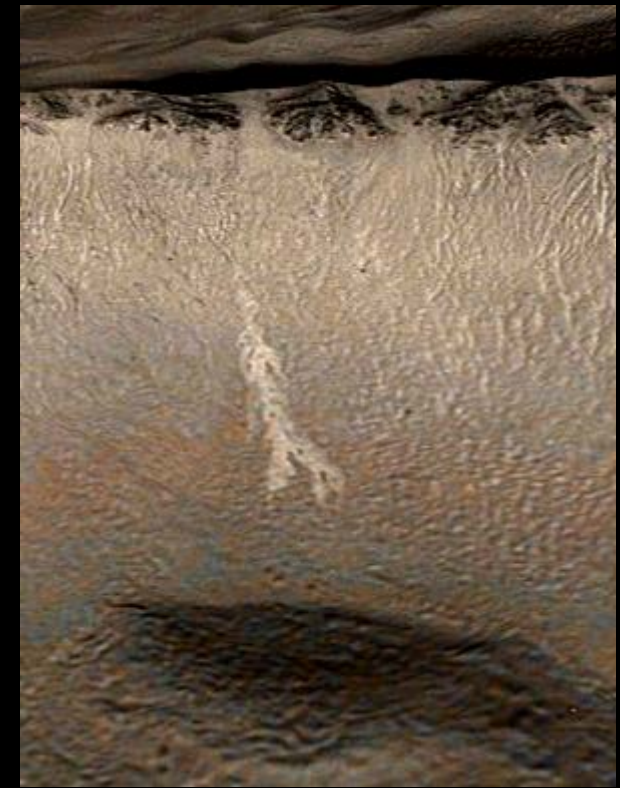
Primary Subaerial Dispersal Pathways
(Transport ≠ Seeding)

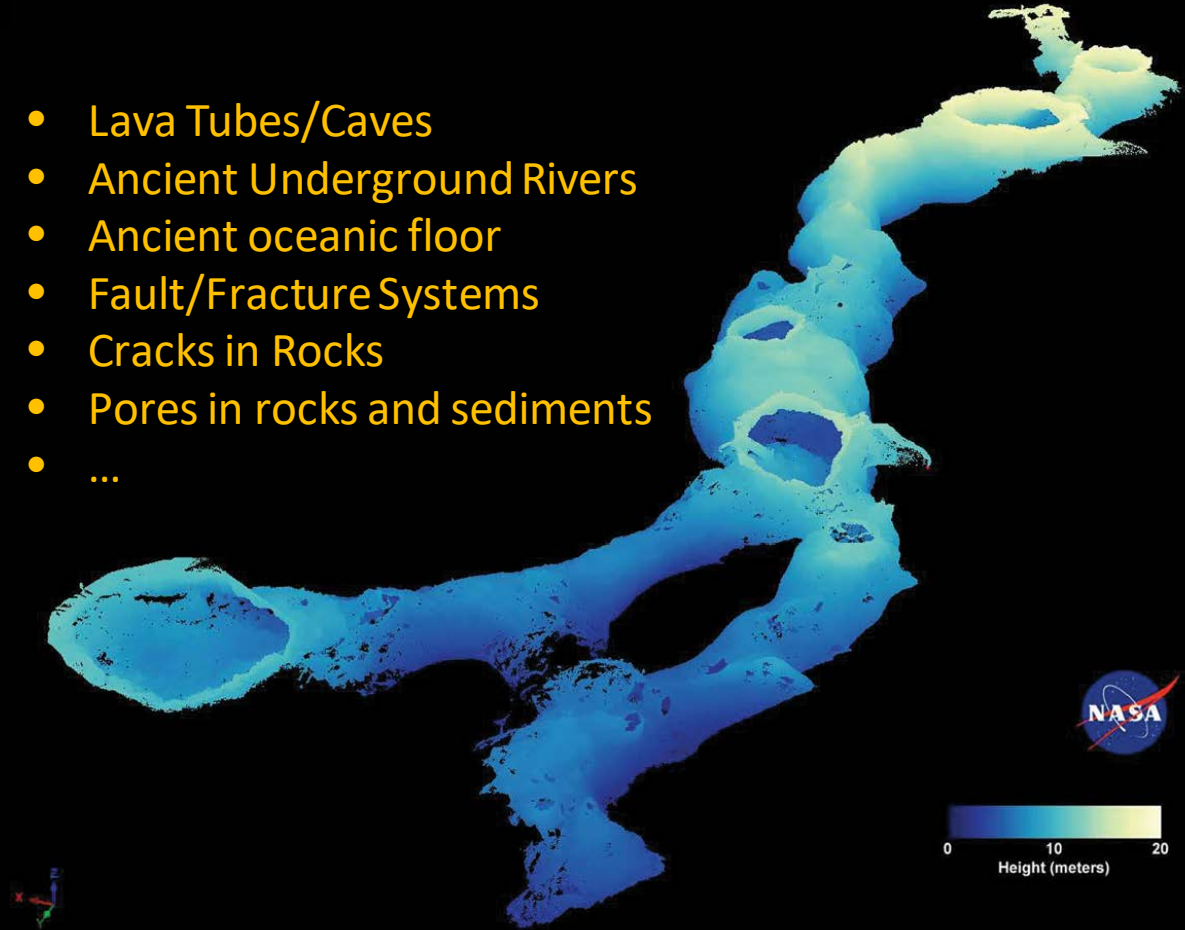**Primary Hydrogeological Dispersal Pathways**

Cabrol NA, *Astrobiology*, 2018
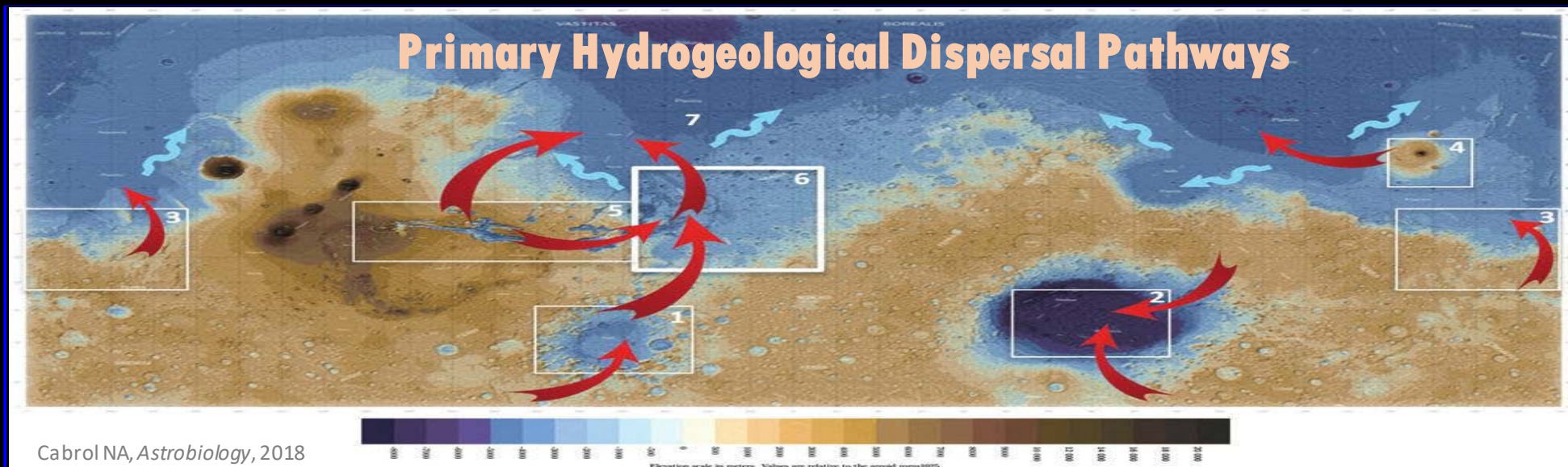
Subsurface & Depth Dispersal Pathways
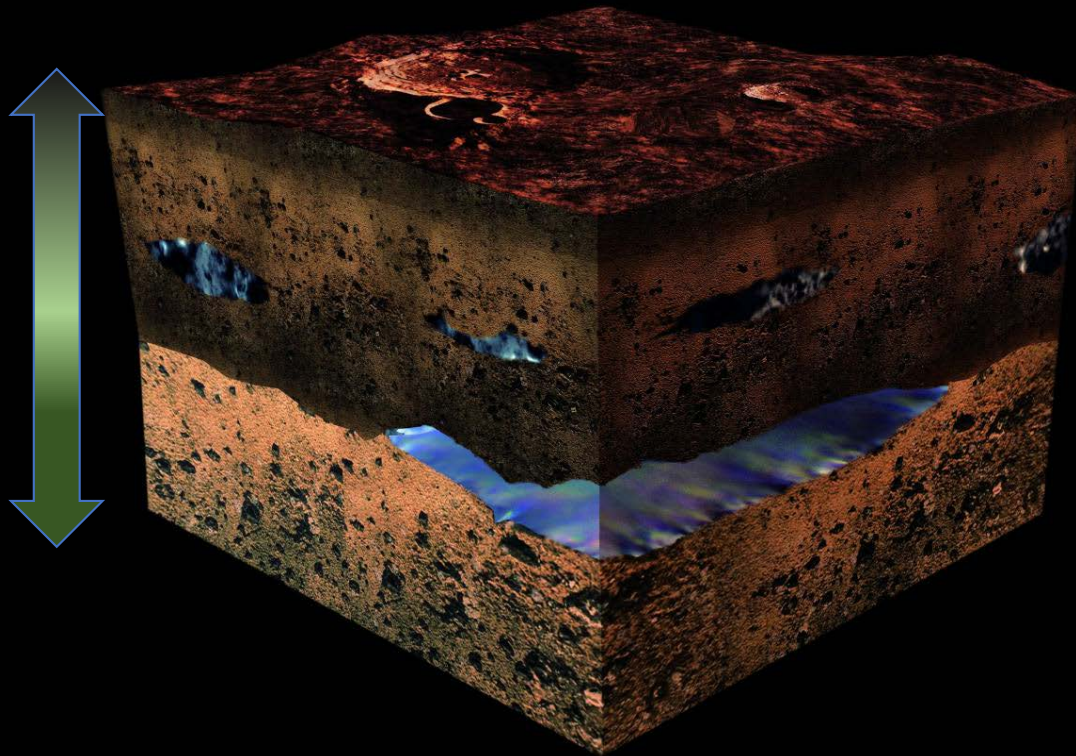
- Lava Tubes/Caves
- Ancient Underground Rivers
- Ancient oceanic floor
- Fault/Fracture Systems
- Cracks in Rocks
- Pores in rocks and sediments
- …

Credit: ESA

Credit: NASA, B. Gary. TLS LiDAR – FINESSE Program

Height (meters)
0   10   20

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If life started on Mars, it is still there (*engine*), it will be *EVERYWHERE* it can be (*dispersal*)

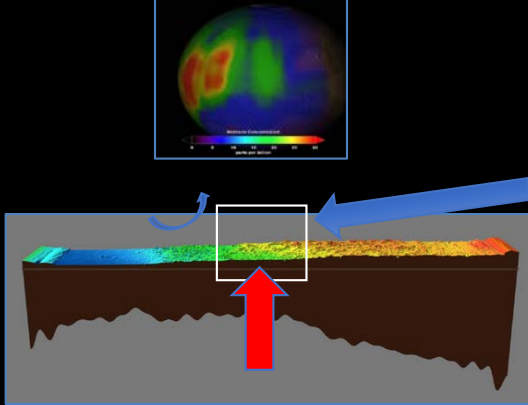*"Follow the Metabolism"*

1

Discovery

Existing Data/Missions

1 Site: Y/N Answers
High Risk

2

Deep Biosphere Model

Existing Data/Missions
+ Modeling
Deep Drilling
Complex. Better suited for
human missions
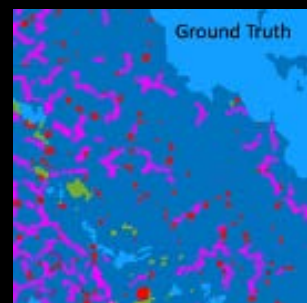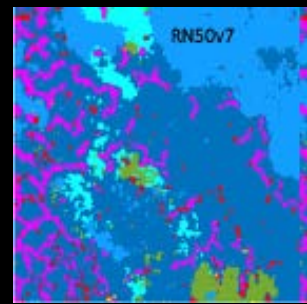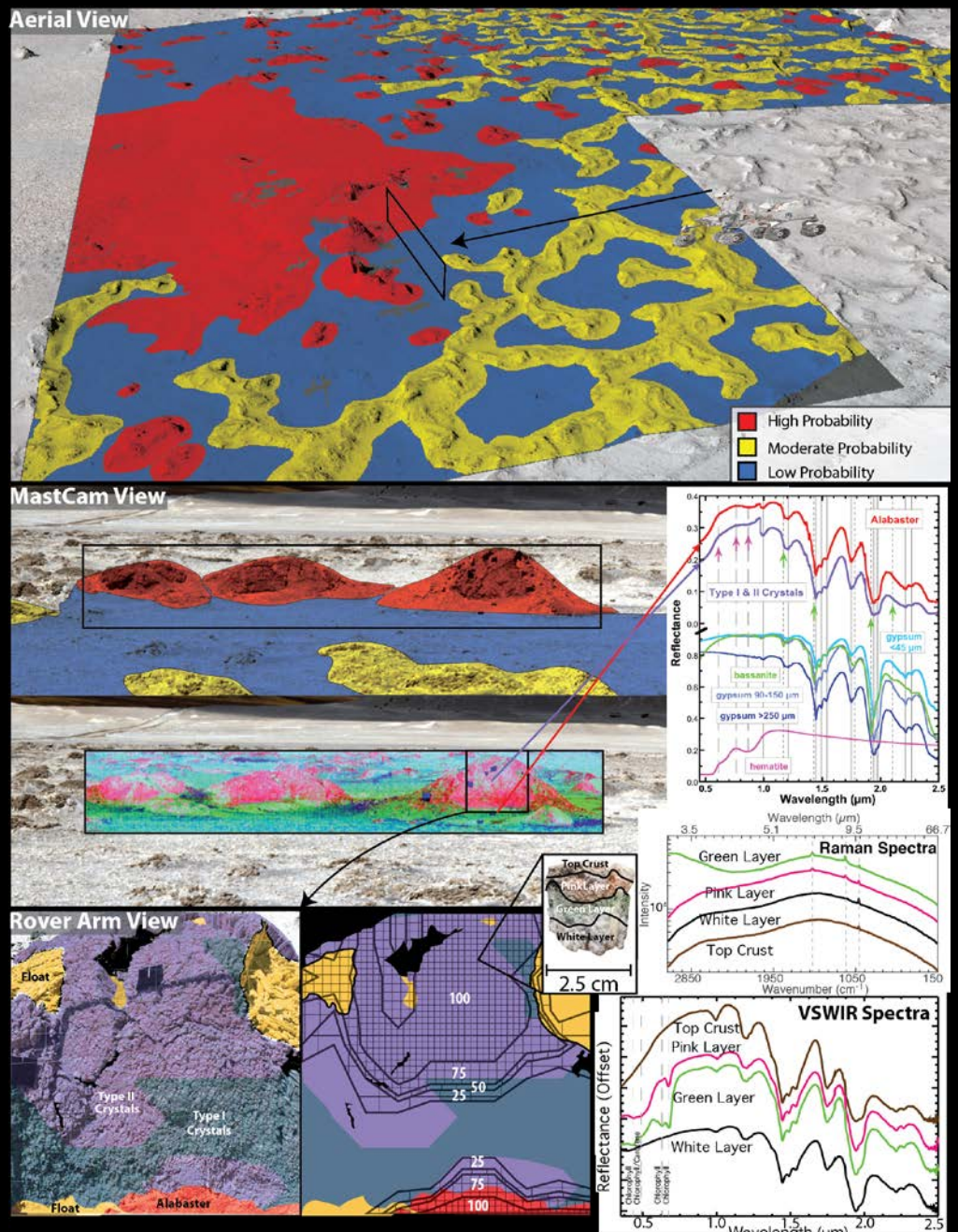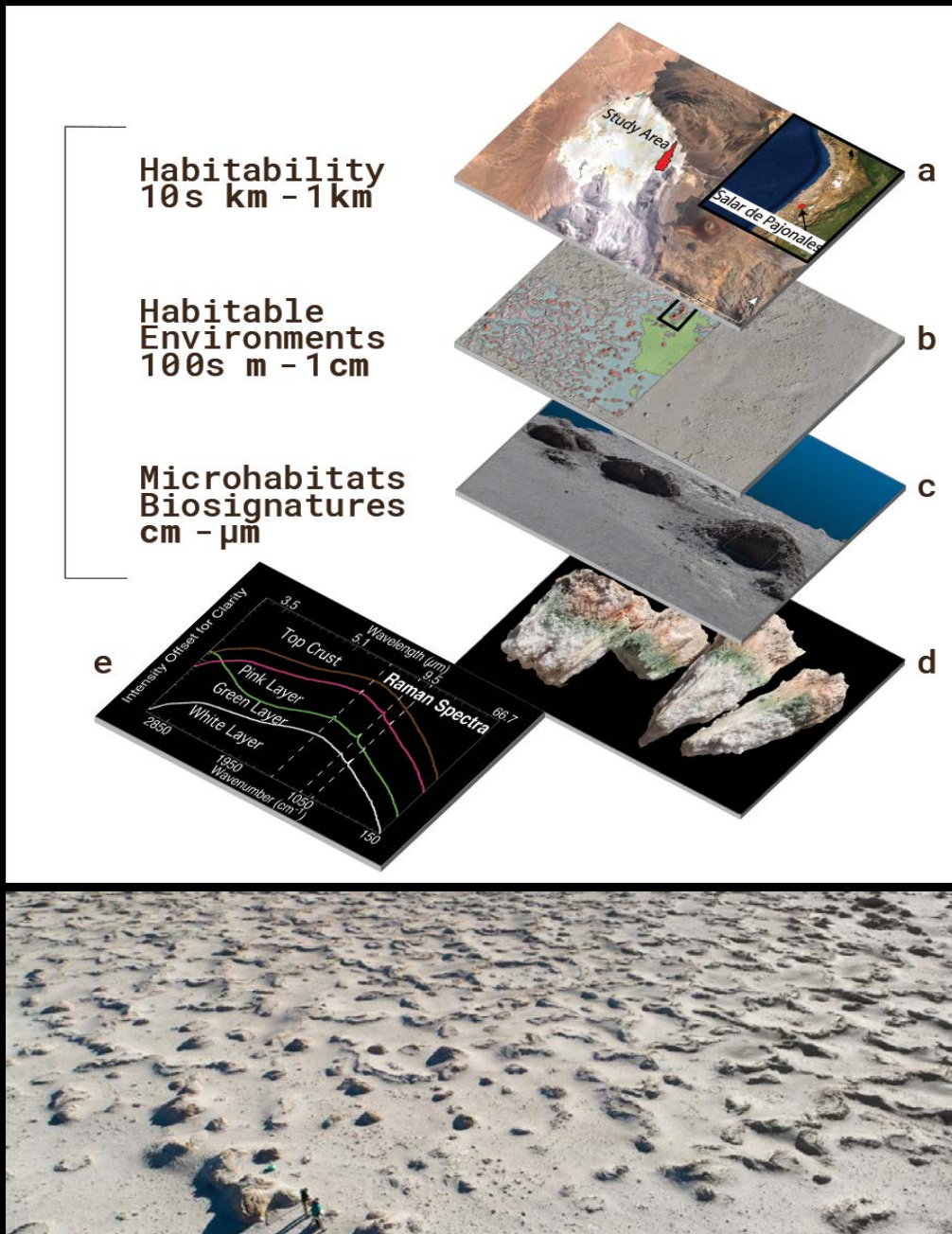
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Polyextreme Environment Model

Support from Past/Current mission Data
Terrestrial Analogs + Lab
AI Modeling

Example Strategic Knowledge Gaps

The most critical at this point is an integrated (eco)systemic approach of Mars

- **DEEP BIOSPHERE**.

- SKG: Dynamic understanding (continuum/system) of the martian environment through space and time at multiple scales: *e.g.,* the role of the dichotomy, geography, topography (up to microtopography), atmosphere, hydrosphere, geosphere, dispersal pathways from "highways" to pores in rocks.
  - ➡ **Ex. Inv:** Data Mining: AI modeling with existing Mars data + field investigations in extreme environments.

- **POLYEXTREME ENVIRONMENTS.**

- SKG1: Interactions of polyextreme factors and their feedback mechanisms. Extreme parameters *do not* add up. They combine (*e.g.,* UV, T, aridity) or (UV, Ice).

- SKG2: Impact of polyextreme environments on microbial habitat types, abundance, and distribution.
  - ➡ **Ex. Inv1**: (a) Systemic, statistical ecological approach of field investigations in extreme environments and data modeling and (b) characterize the patterns of microbial life and habitats. Extreme microbial life and habitats show repeatable patterns at integrated scales (*Warren-Rhodes, Cabrol and the SETI Institute NAI Team, submitted*).

    - Relevant to extant life because today's Mars is not too dissimilar to Mars 3.5 Ga, and transit between habitat zones can continue to take place in (*e.g.,*) during cyclic climate changes.

  - ➡ **Ex. Inv2**: Characterize the conditions (minerals, topography, other) that can maintain life close to the surface (~5 cm), *e.g., Ertem et al. 2020, in press.*

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Habitability
10s km - 1km

Habitable
Environments
100s m - 1cm

Microhabitats
Biosignatures
cm - μm

Warren-Rhodes, Cabrol and the SETI Institute NAI Team, submitted

Some Takeaway & Discussion Points

- If life started, it is everywhere it can be (follow the metabolism)

- We need to stop thinking of Mars through its "geological/climatic headlines" but rather map it as an environmental continuum in time and space (zones in the crust are not necessarily compartmented). Dispersal can continue to happen today (cyclic climate change is only one way of making it happen)

- Achieving a systemic understanding is possible more rapidly today: Mars data, extreme environments, lab and strong emphasis should be put on AI solutions (modeling using all these datasets)

- Microbial life and habitats show repeatable and predictable patterns at integrated scales. Current studies focus on surface/near surface. Can be adapted to other environments;

- Near surface (< 10 cm) is still possible today (extreme oases can be extremely small and local). It is critical not to neglect them. There too, modeling necessary (*e.g.,* latitude, topography, mineralogy)

- Future missions need to include environmental and ecological survey methods and collect data that matter at the microbial habitat level: (a) Precursor mission + return to same site; (b) Integrated mission including survey, data integration, and sampling.