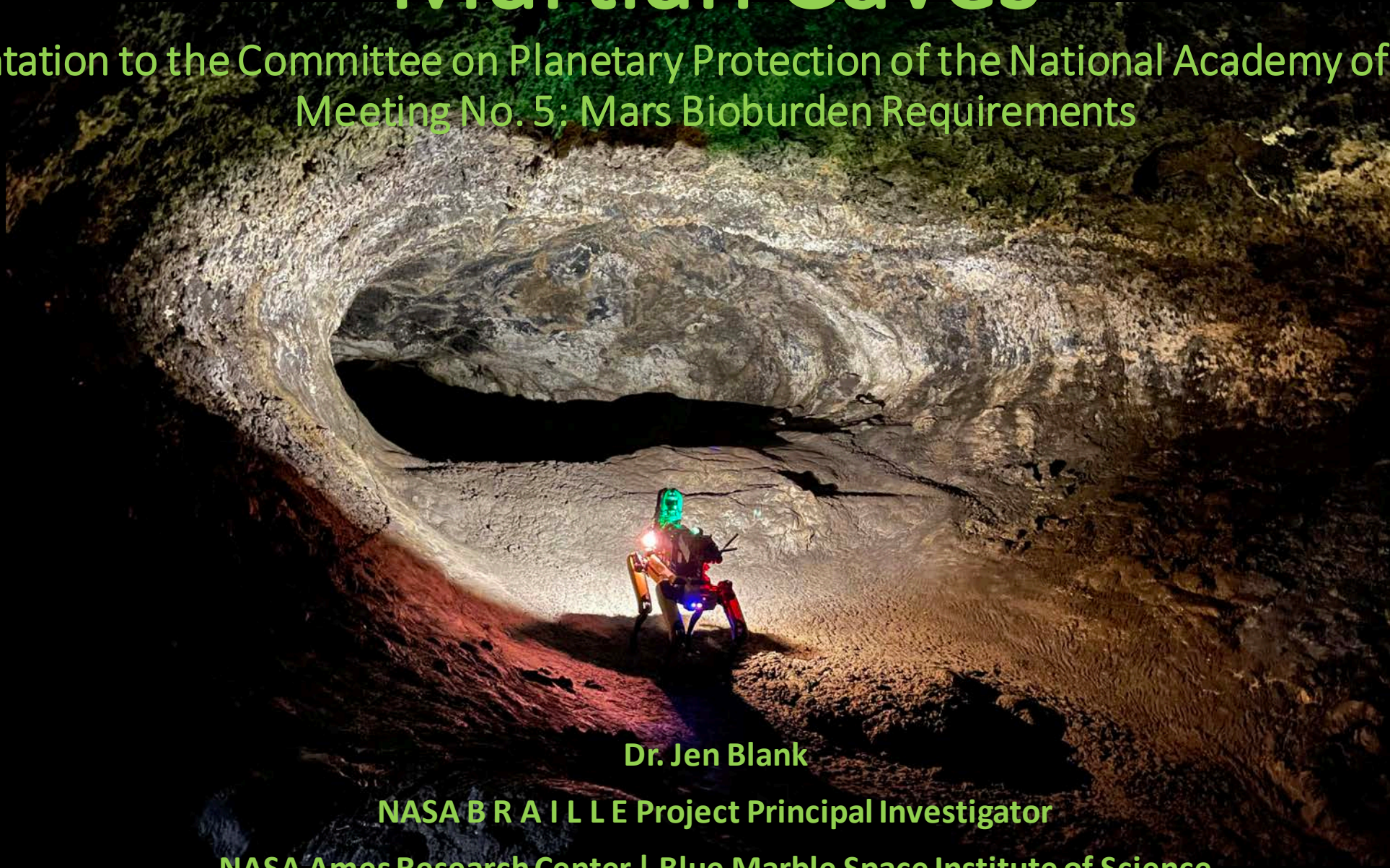


Martian Caves

Presentation to the Committee on Planetary Protection of the National Academy of Sciences
Meeting No. 5: Mars Bioburden Requirements



Dr. Jen Blank

NASA B R A I L L E Project Principal Investigator

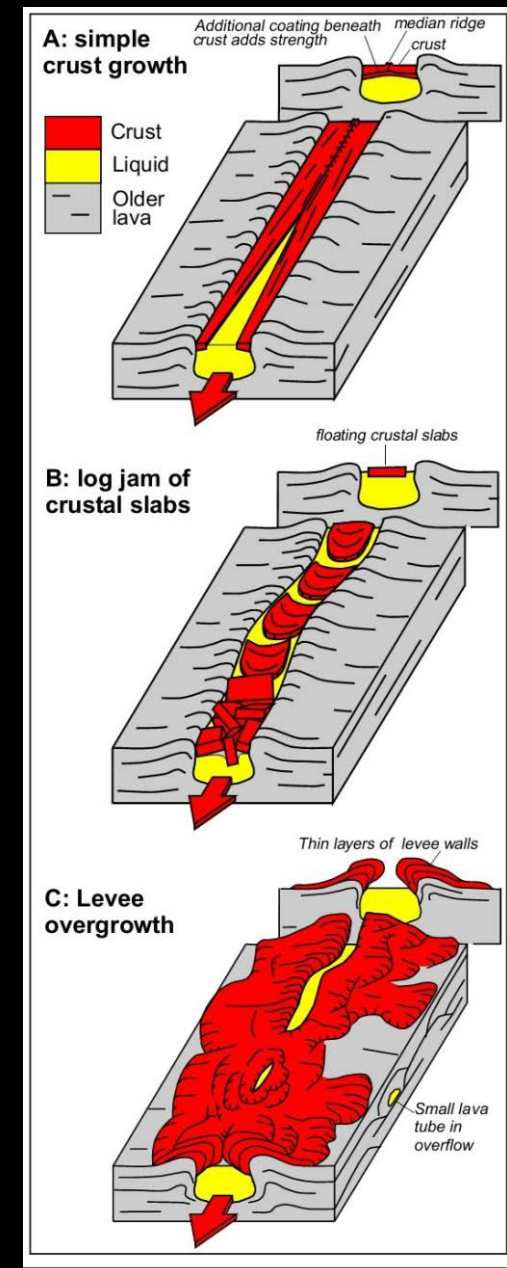
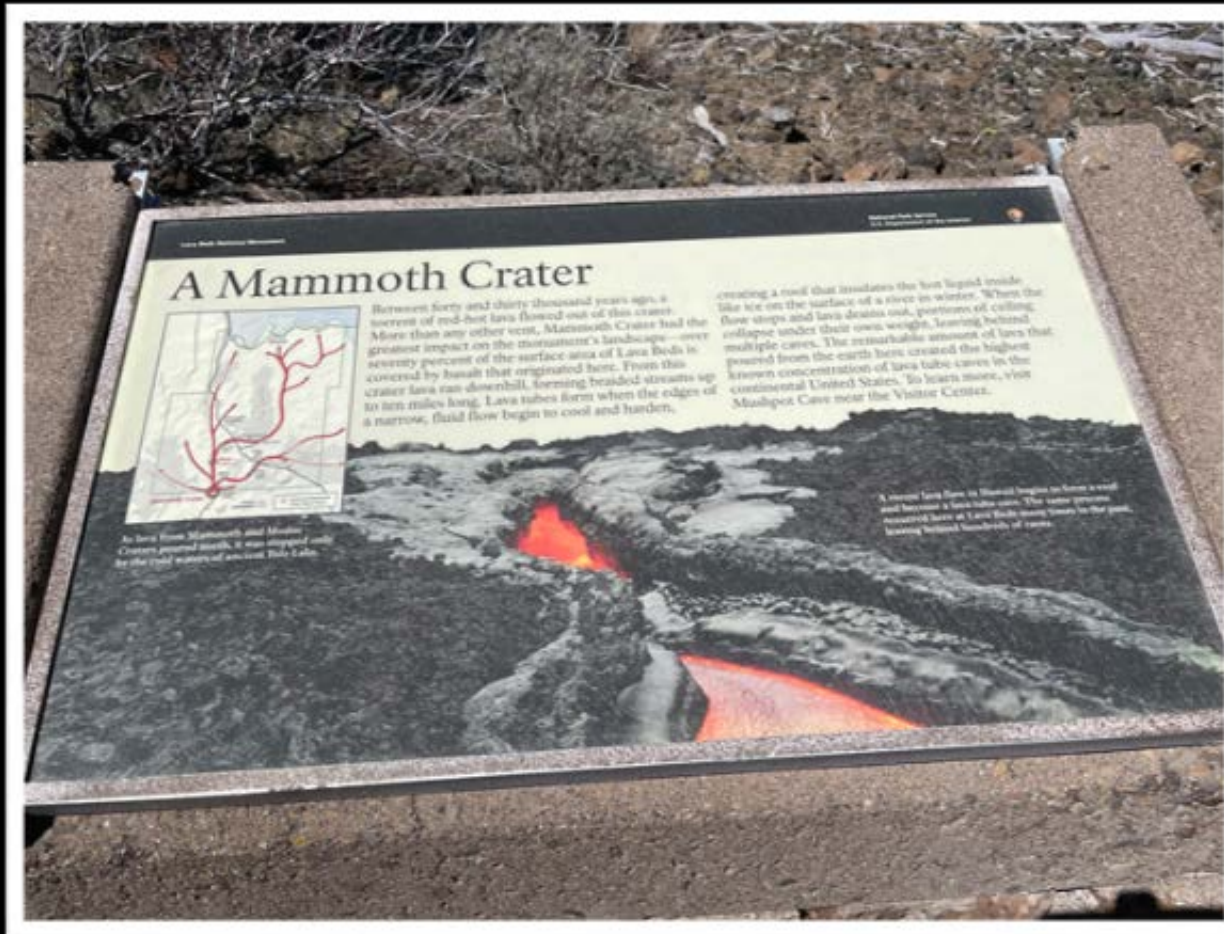
NASA Ames Research Center | Blue Marble Space Institute of Science

17 May 2021

How does a volcanic cave form?

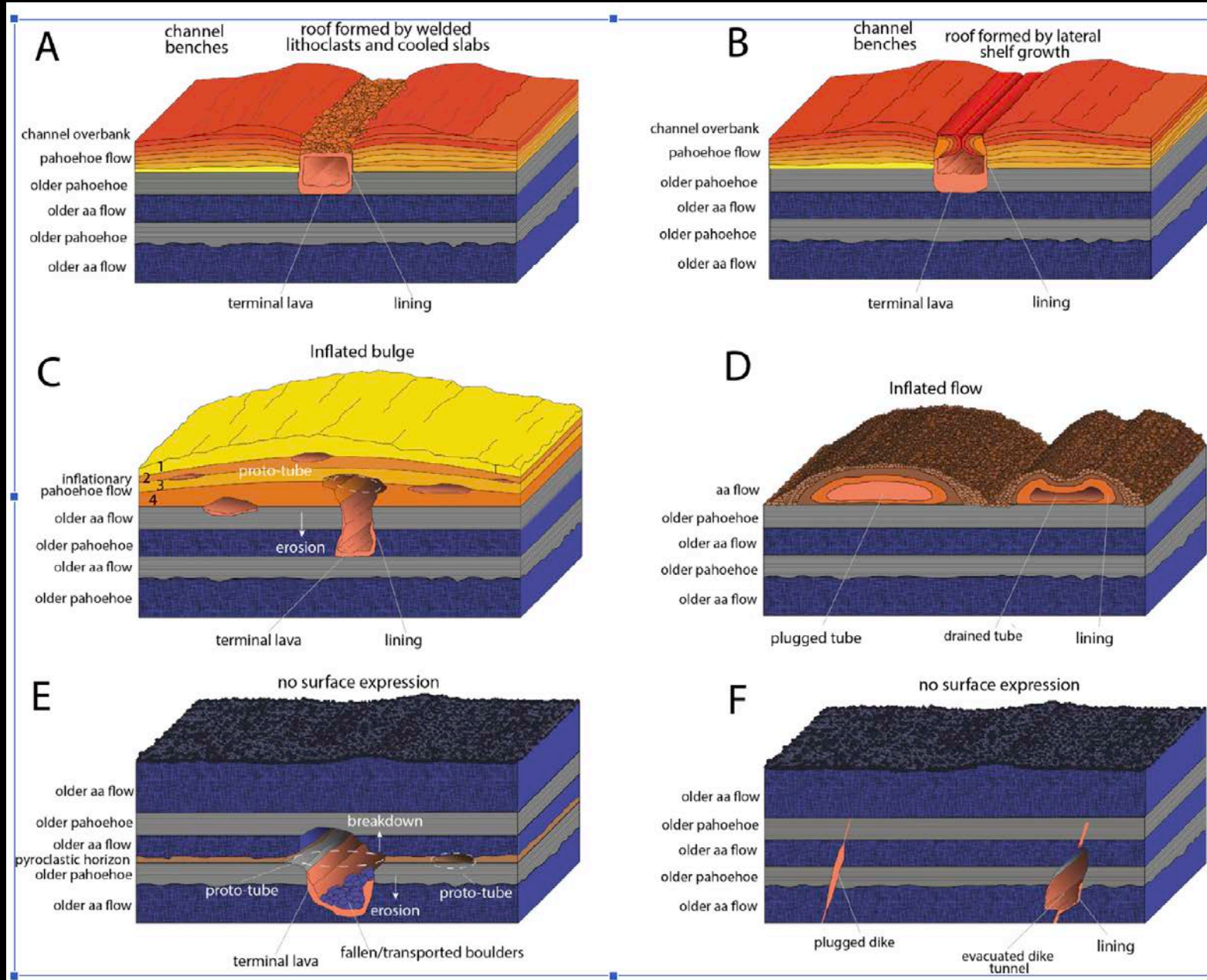
Rock type – basalt (most common rock type in the solar system)

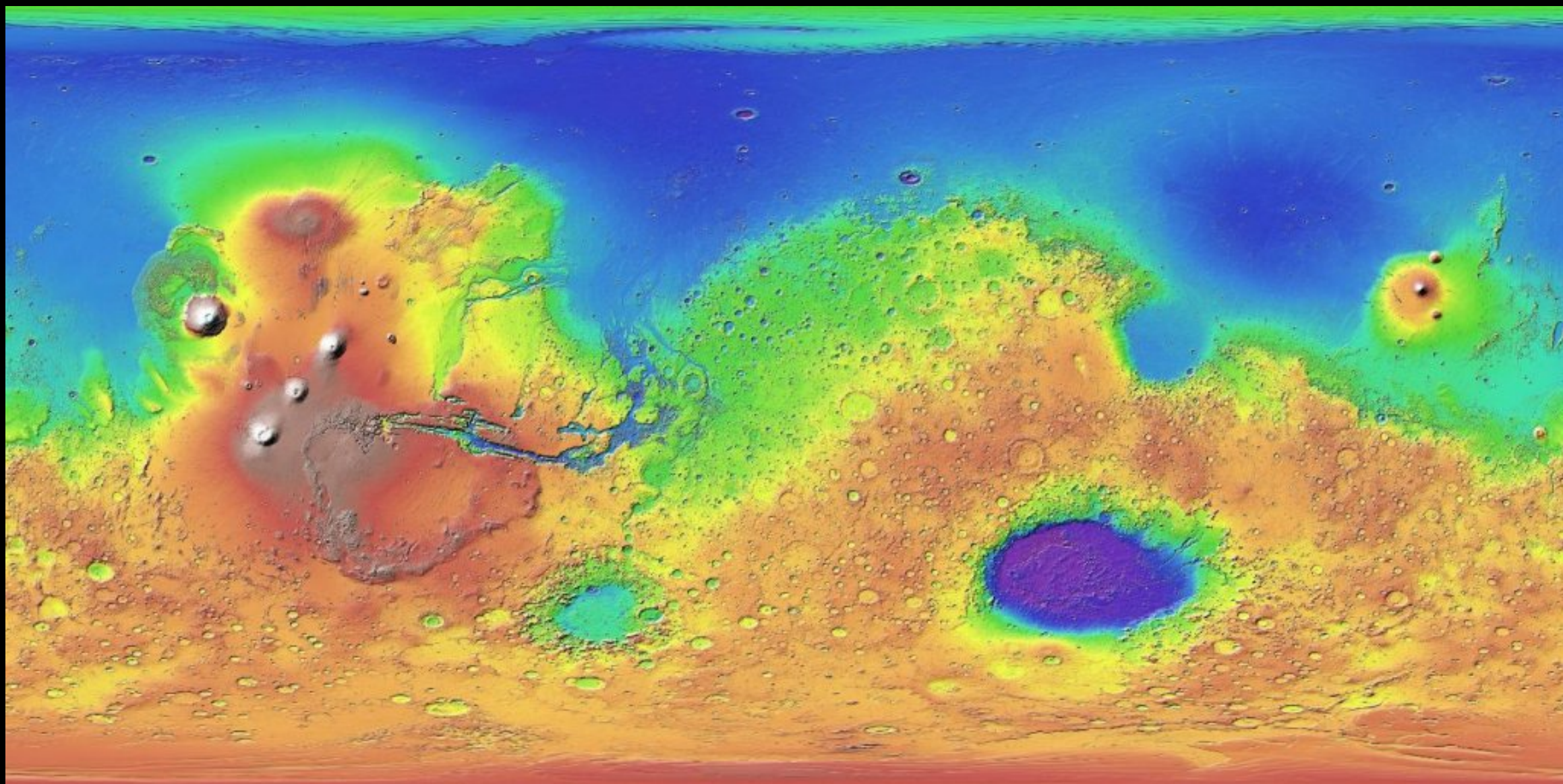
Flow type – gravitational flow; channel or breakaway from flow obstruction



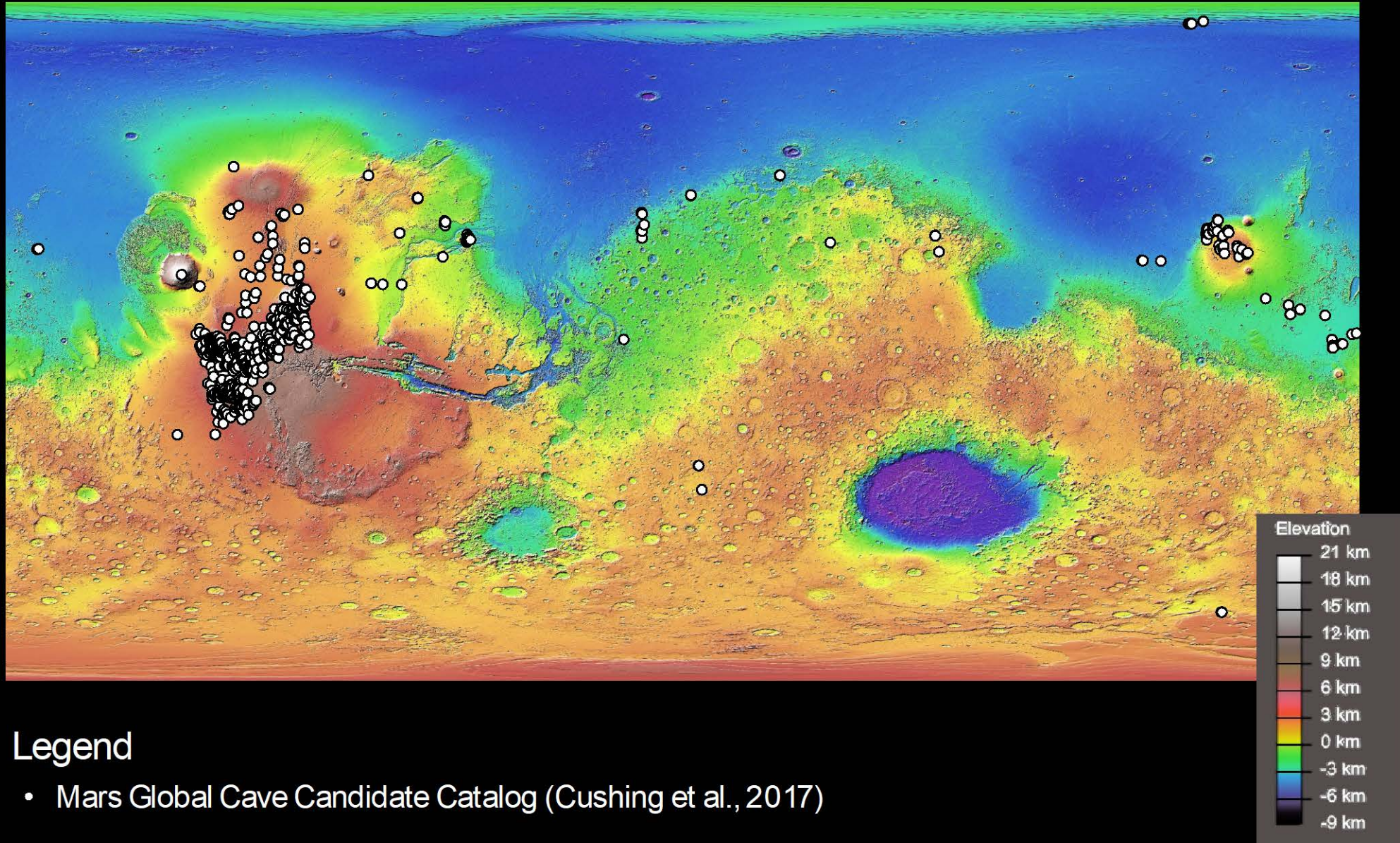
- Grimes (2005)

There are multiple formation models for the creation of volcanic caves.





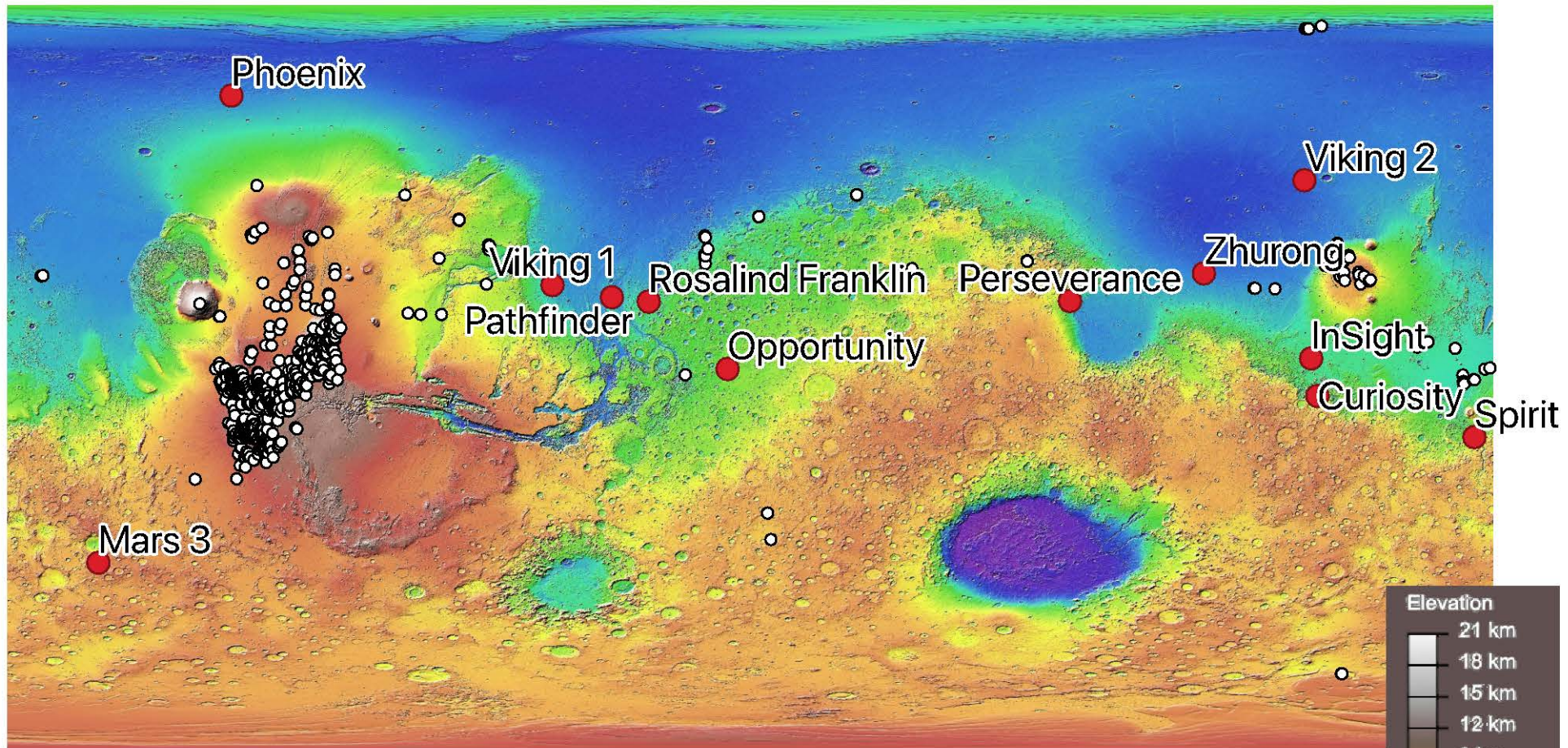
Mars Candidate Cave Sites



Legend

- Mars Global Cave Candidate Catalog (Cushing et al., 2017)

Mars Candidate Cave and Mission Landing Sites



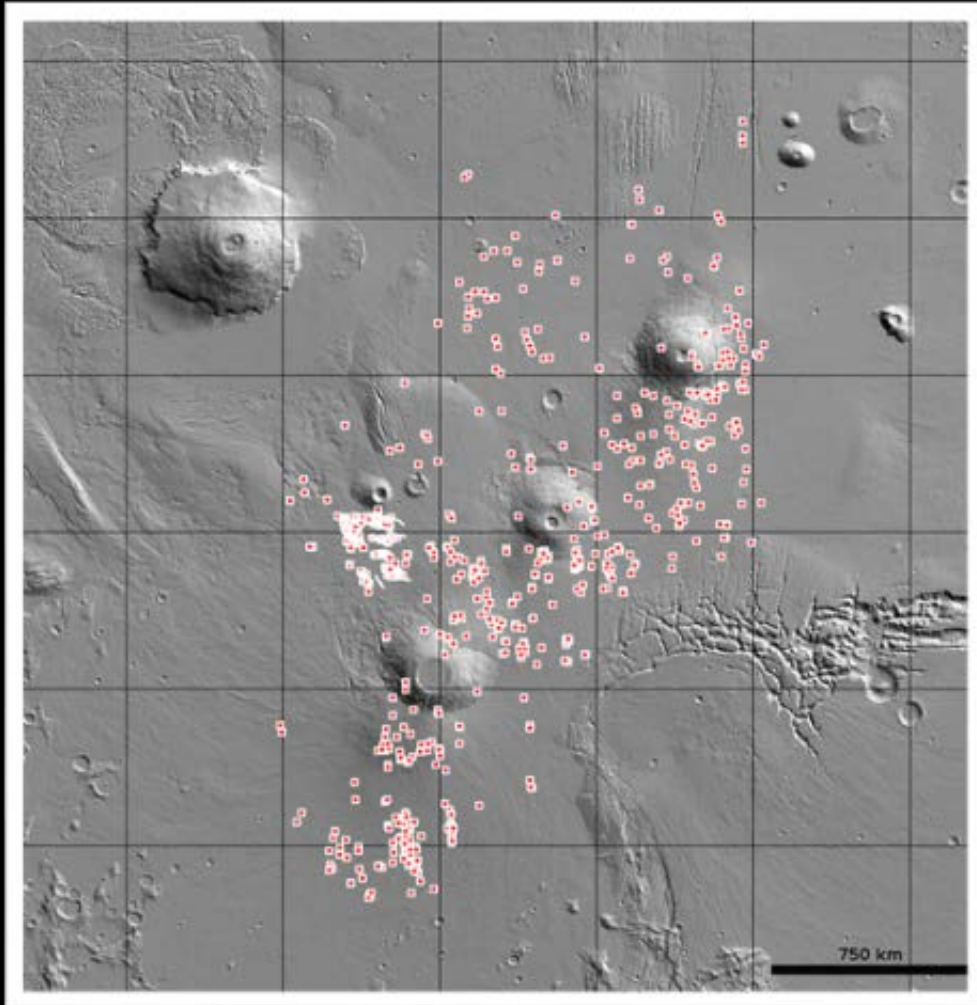
Legend

- Mars Global Cave Candidate Catalog (Cushing et al., 2017)
- Mission Landing Sites

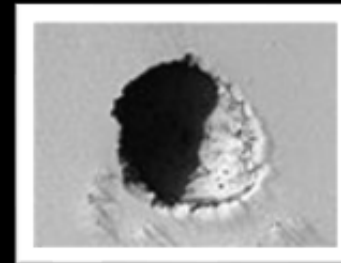


Mars Reconnaissance Orbiter (MRO) HiRISE Camera data have been used to identify more than 1200 skylights and "candidate caves" (Daga et al, 2013; Cushing, 2017).

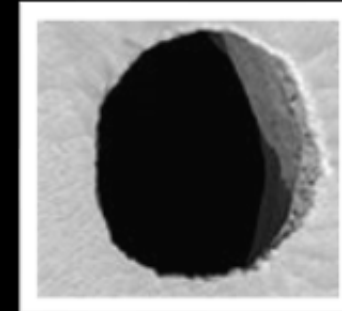
MARS



- Tharsis region



d= 180m

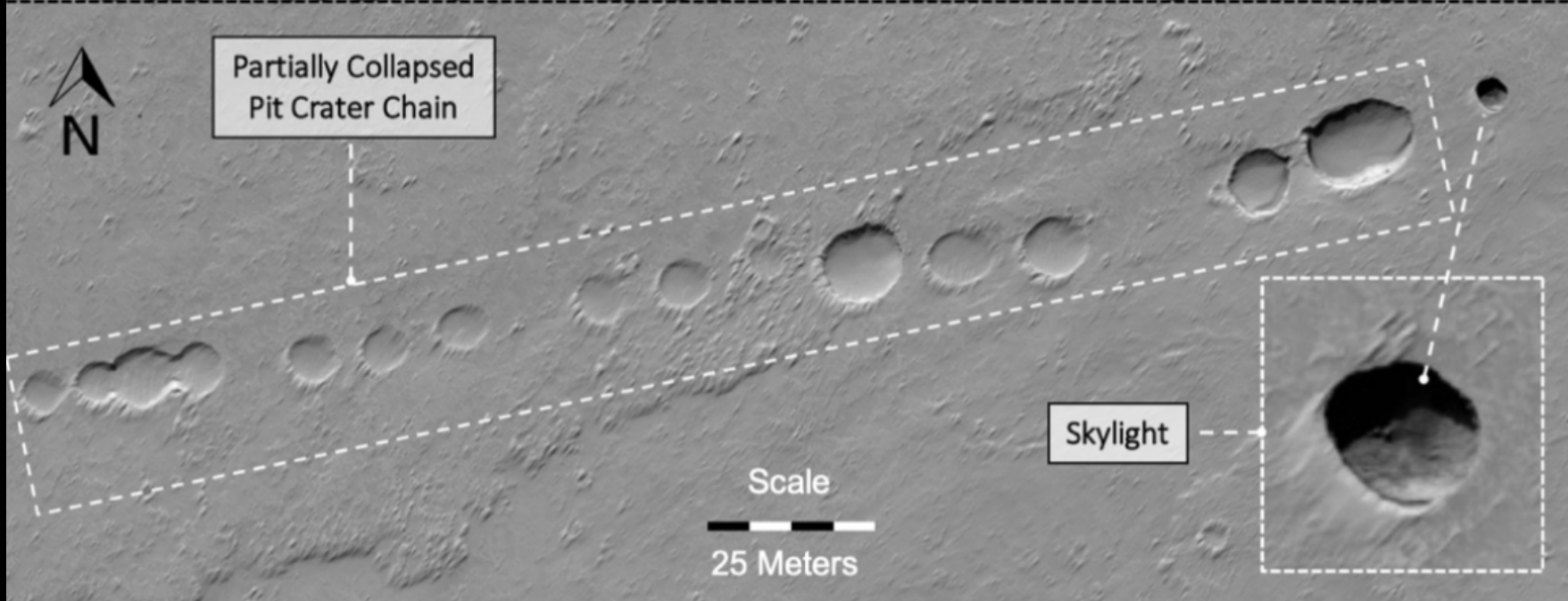
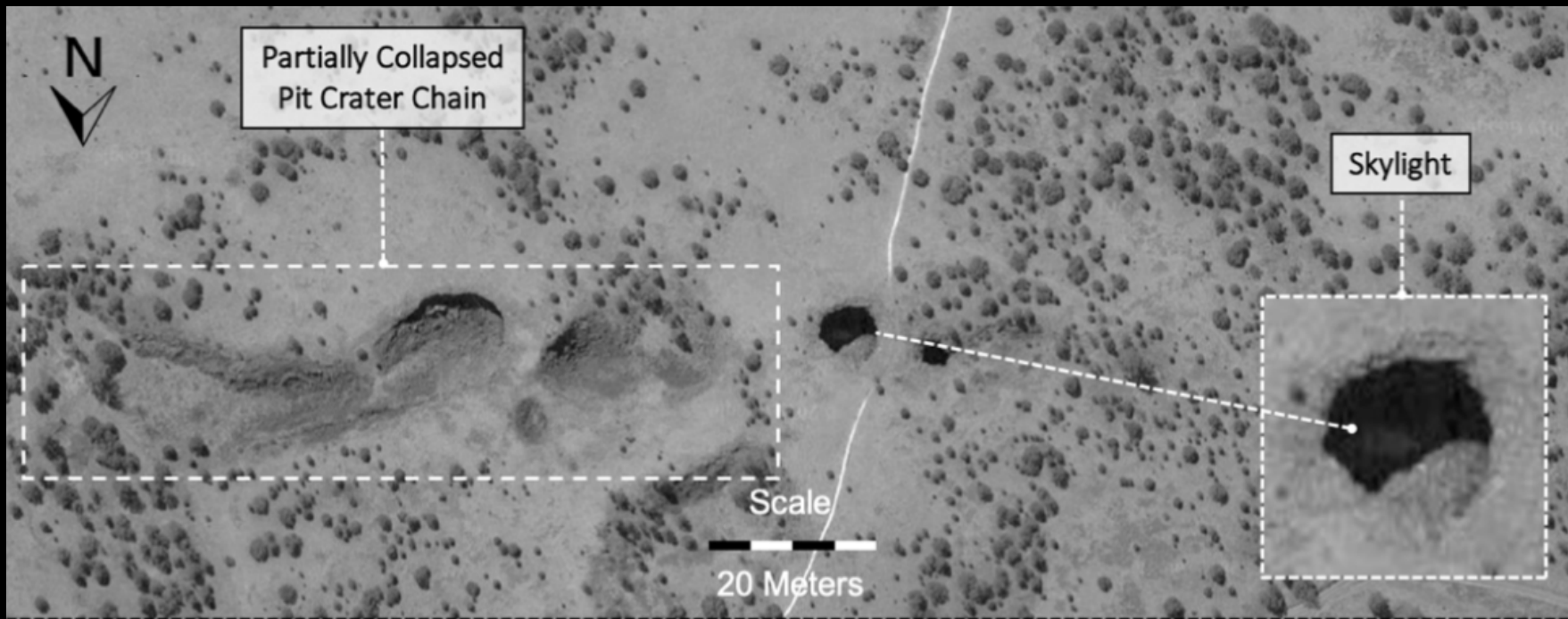


d= 150m

Skylight examples



d= 35m

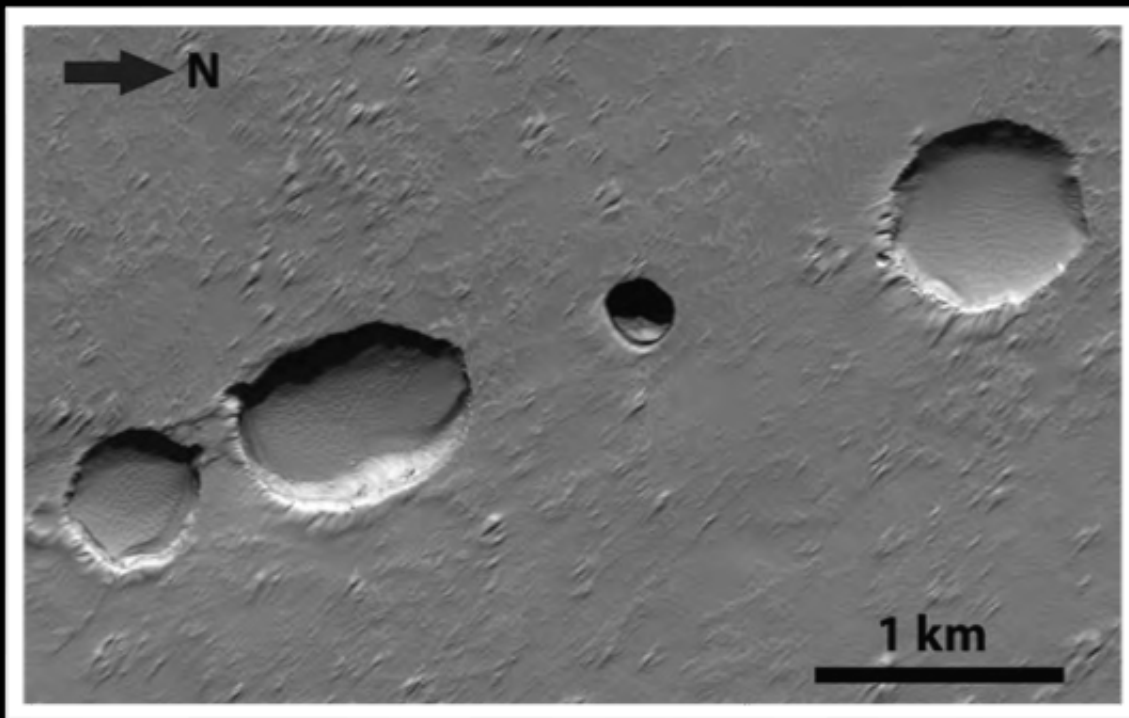


Pit Crater Chains & Skylights

El Malpais, NM

~Arsia Mons, Mars

Credit: Paris et al. (2019)



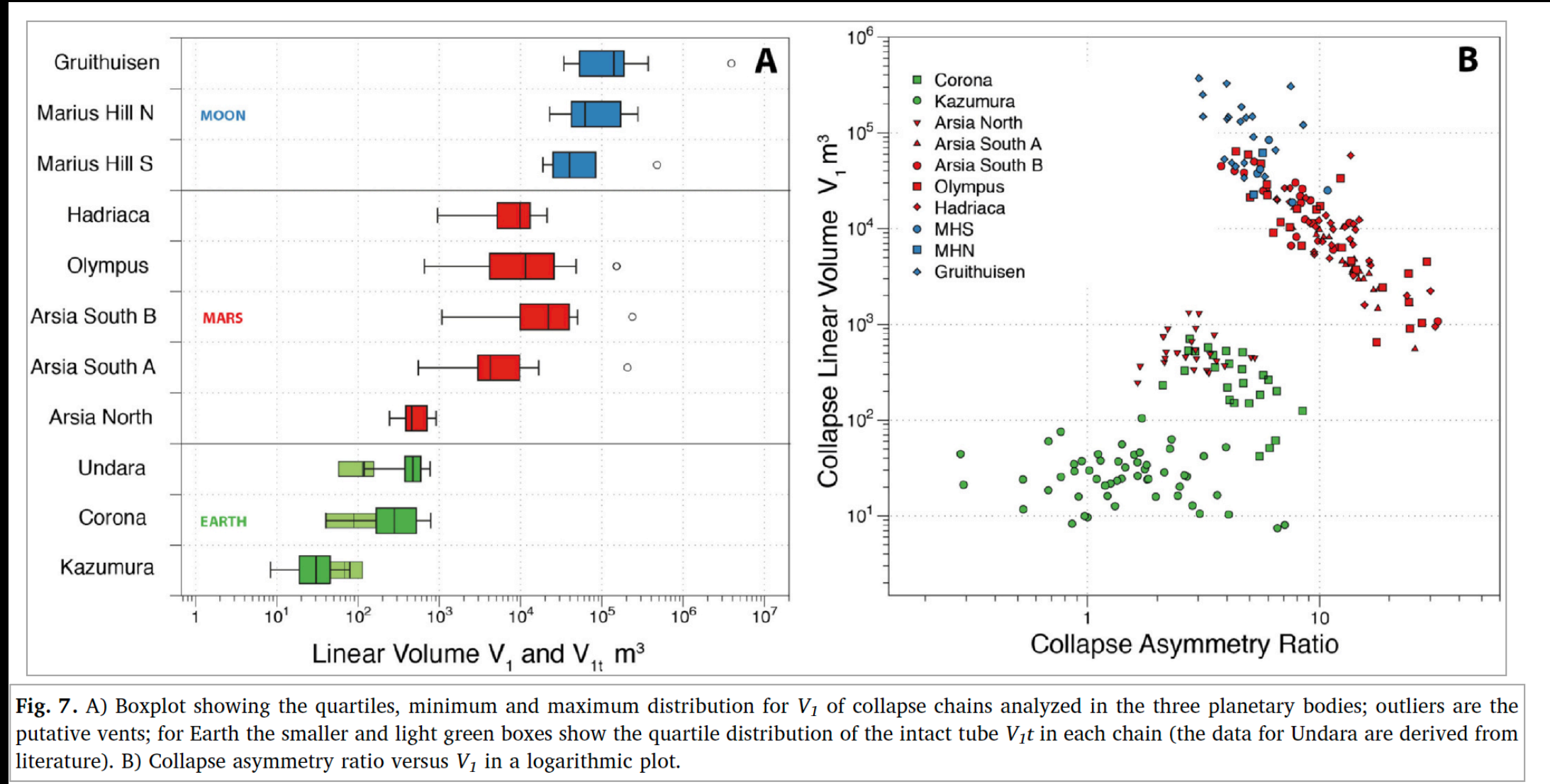
Arsia Mons, Mars (image: NASA/U of Az)

Lava Beds National Monument, USA
(image: Google Earth)

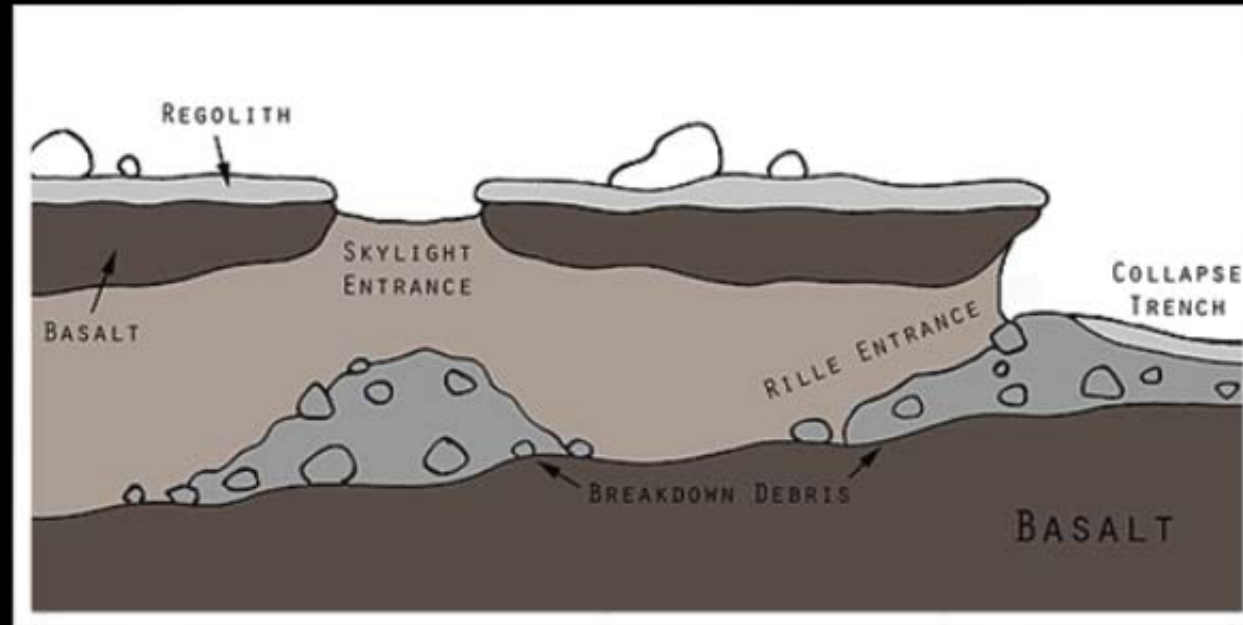


200m

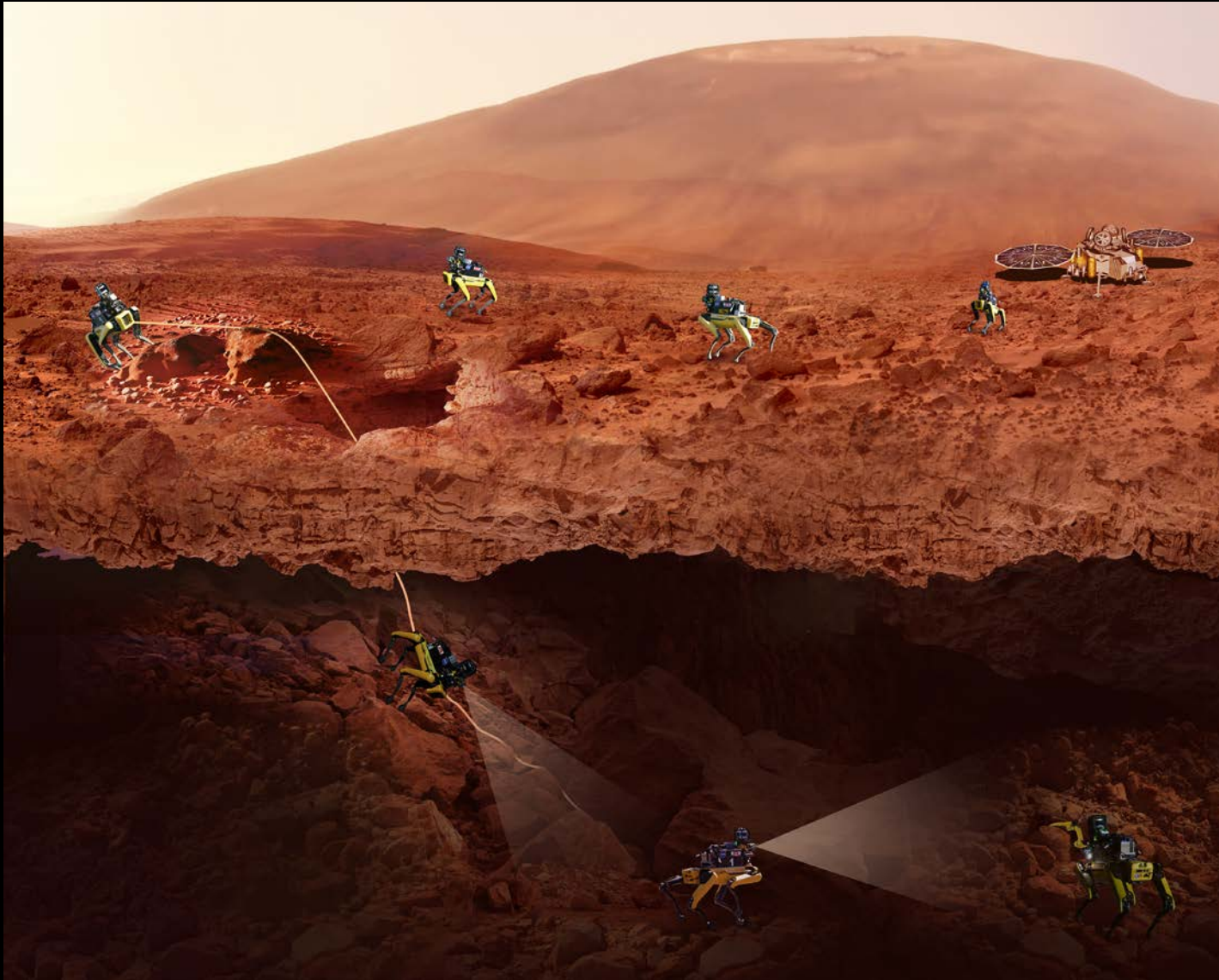
Comparative planetology: Detailed analysis of aspect ratios of lengths and widths of lava tube collapse pit chains have been used to estimate subsurface void spaces on Mars and the moon. However, we will need to explore in situ to characterize these features accurately.



For Mars caves, little is known about the volume of the void space or the thickness of the crust above it. A mission to a Martian cave would likely require a surface-based characterization of higher resolution than seen from orbit.



A preliminary Mars Lava Tube mission concept involves multiple, low mass, biomimetic robots.



- Mobile
- Autonomous
- Collaborative
- Legged
- Low Mass (<70 kg, with payload)

Touma et al. (2020)

Autonomous collaboration would facilitate ingress and subsurface operations...



Fig 1: Concept for tether-brace behaviour (left); Concept for cave-ingress (middle); Concept for lava tube mission (right). [1]

-From Touma et al. (2020)

Preparing for a Mars Cave Mission through Analog studies...

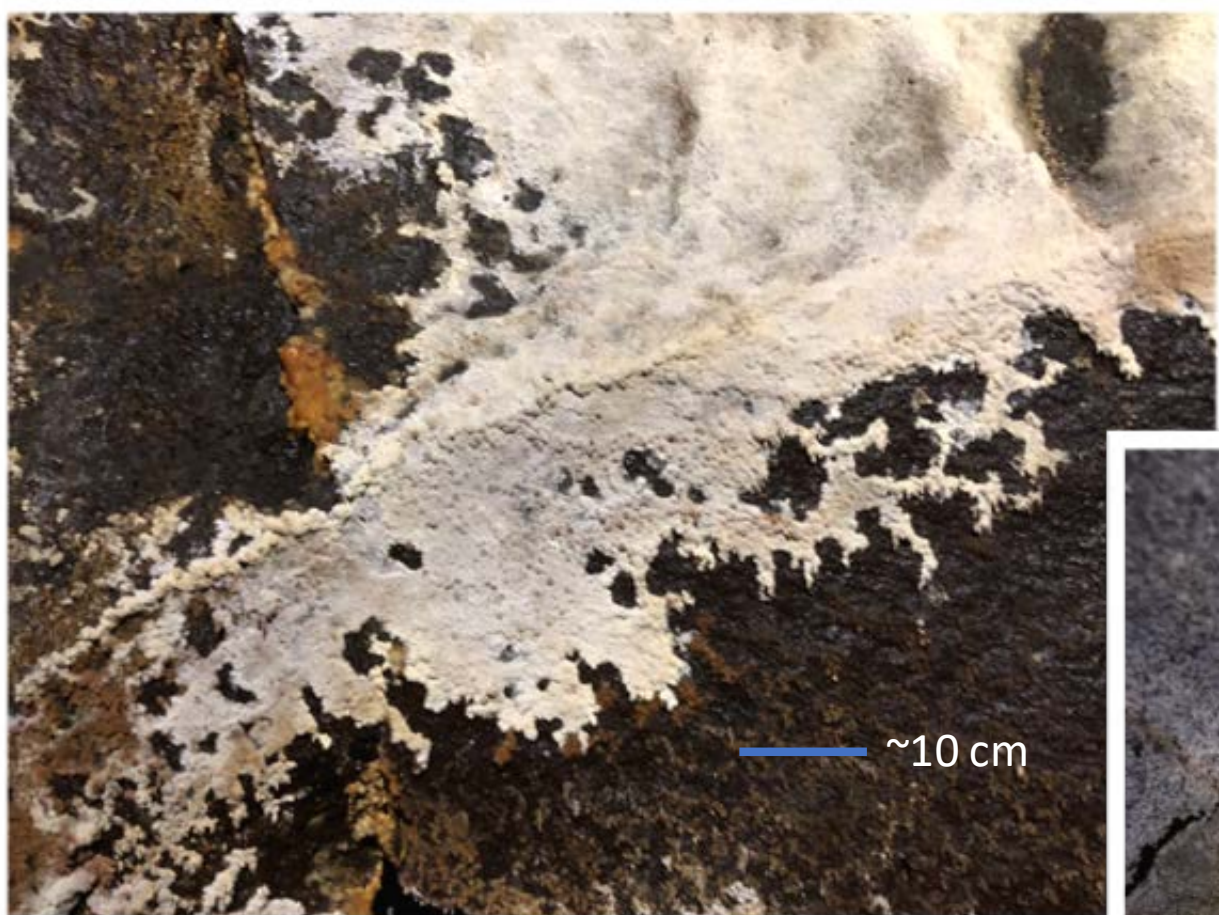


BRAILLE

Biologic And Resource Investigations in Low Light Environments



A NASA Planetary Science & Technology through Analog Research (PSTAR) Project

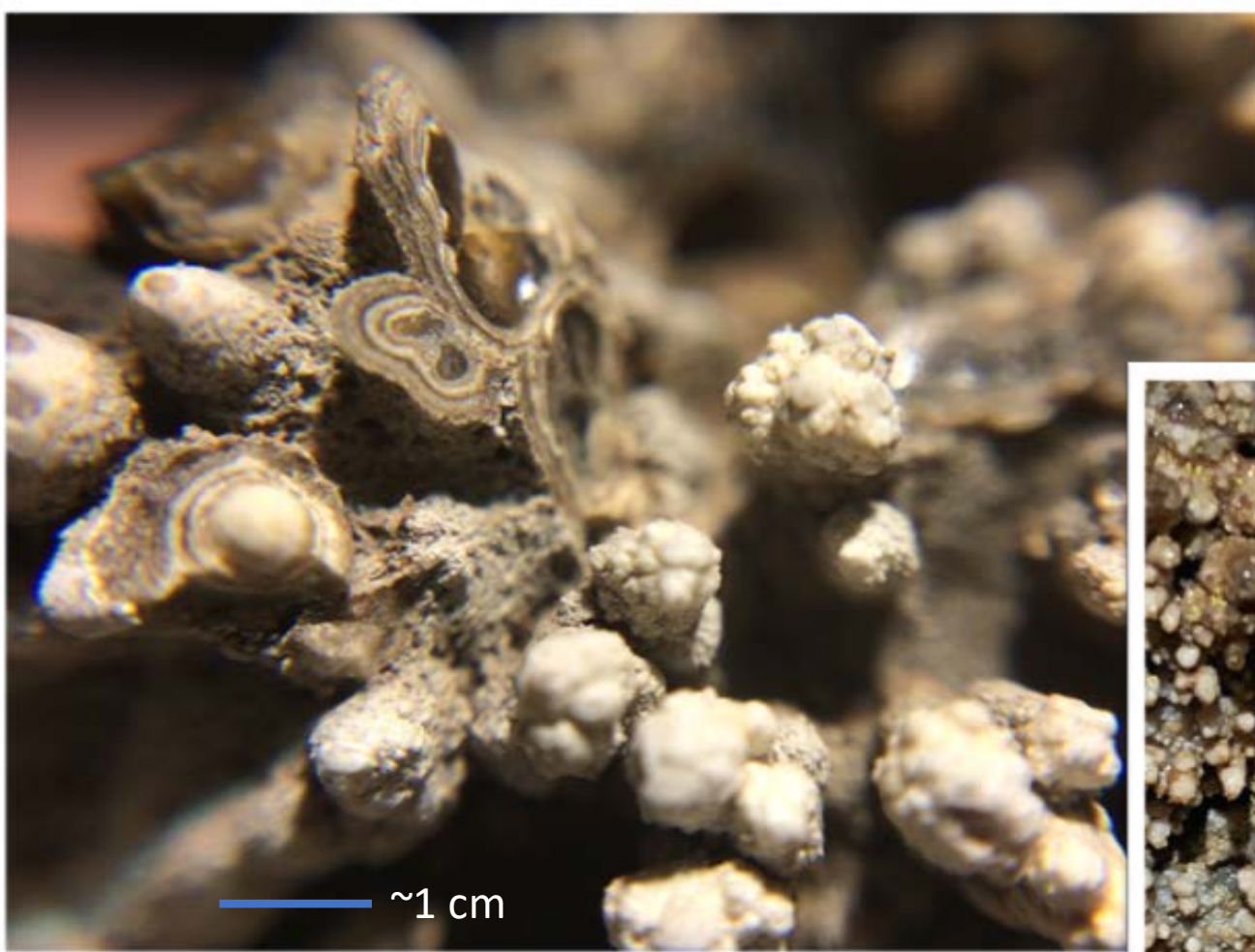


Silica-dominant mineral crusts could persist over geologic timescales.





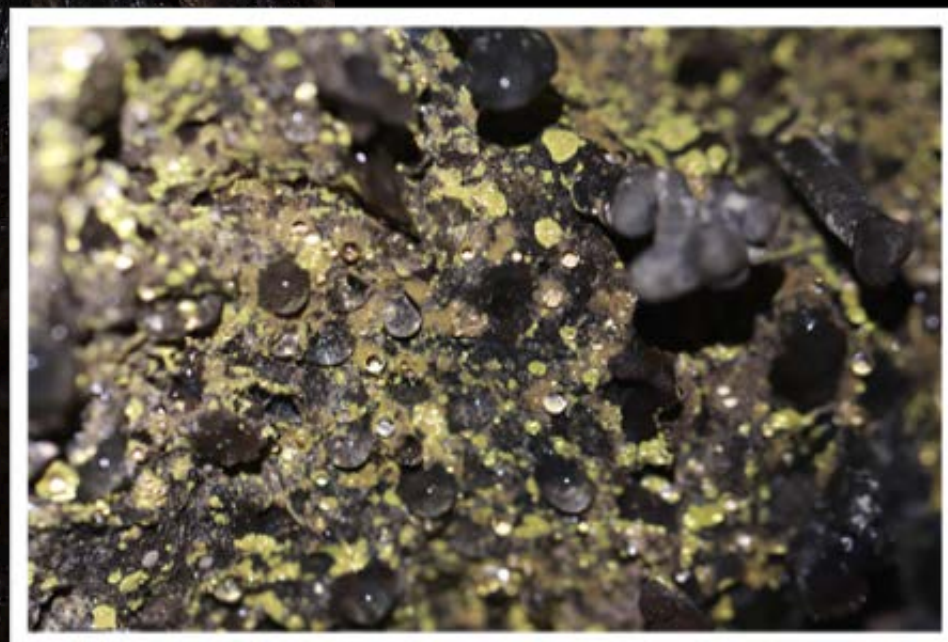
Cave Polyps



cave polyps & coralloids

Silica-rich secondary “biominerals” would be more resistant to erosion than similar carbonate structures.





Much of the biomass and biomineral features are concentrated along cave walls and ceilings.



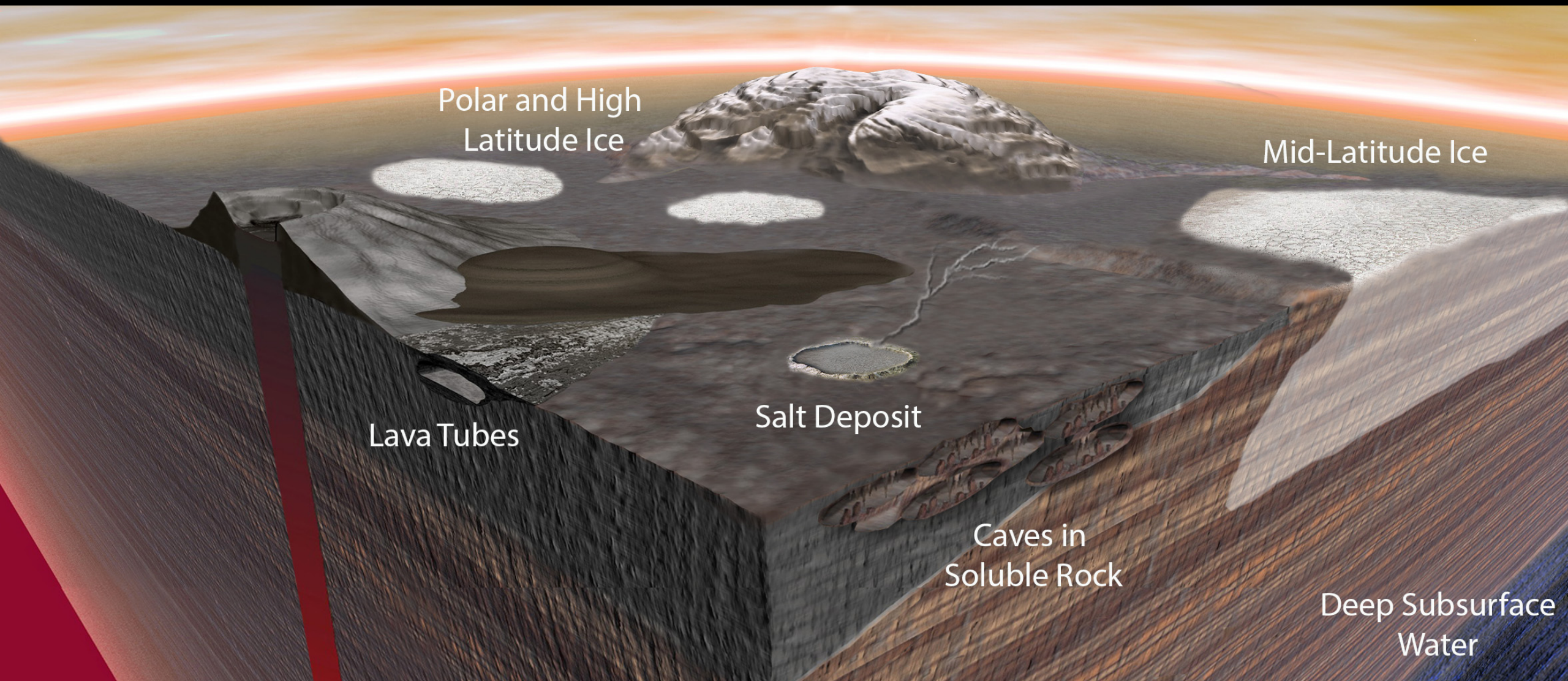
2020-2021 Activities

- BRAILLE–JPL CoSTAR Team collaboration
- Boston Dynamics Spot Robot tests in Volcanic Caves
- Autonomous Mission SLAM Operations
- Autonomous life detection mission simulation exercises



Testing in Valentine Cave,
Lava Beds National Monument
5 May 2021

Volcanic caves – a primary target in the search for Signs of Life on Mars



Carrier et al. (2020); Sketch – Julie Fletcher (NASA), from Stoker et al. (2020)

Volcanic caves on Mars are commonly invoked sites for potential human habitats on Mars due to the protection they offer from surface radiation, dust, and temperature fluctuations.



Credit: Sefrina Arifin (2018)

FOOD

MARTIAN GREENHOUSES

Ecologists have tested 14 plants in soil produced to match the chemical composition of Martian soil, which contains all essential nutrients for plants to grow, including phosphorus, nitrogen, potassium, and iron. But for plants on Mars to maintain the kind of growth shown at right, agronomists would need to engineer soil that is more water efficient and nitrogen rich.

Crops grown in soil simulants
Percentage alive after 50 days



Some scenarios depict modular units, transported in sections to the subsurface environment.

SHELTER

LIVING IN LAVA TUBES

Lava tubes are cave-like conduits formed underground by cooled, hardened lava after molten rock has flowed through. Scientists say the ones on Mars may be significantly larger than those on Earth. The interiors of the Martian tubes, hidden under dozens of feet of solid rock, are protected from cosmic and solar radiation and fluctuating temperatures on the harsh, dusty surface.

WATER

HIDDEN GLACIERS

Ground-penetrating radar from NASA's Mars Reconnaissance Orbiter has revealed massive glaciers of frozen water preserved beneath rocky debris at much lower latitudes than where ice had been previously identified. These glaciers extend for dozens of miles.

Thoughts Relevant to CoPP Concerns & Interests

- Martian caves are MSRs, by definition, as a feature in the Martian subsurface.
- Volcanic caves would have shallow depths relative to dissolution caves and / or deep aqueous reservoirs.
- The temperature in volcanic caves would be cold (likely $< 25^{\circ}\text{C}$) and fluctuate little; water in volcanic caves would persist as water ice due to stable temperature in caves.
- Microbial life and life signatures (biominerals) in terrestrial caves persist to a greater degree on cave walls and ceilings.
- Exploration using low-mass, biomimetic robots could reduce a possible “contamination footprint”.
- A initial robotic mission to a Martian cave would likely involve landing elsewhere and traveling to a cave entrance; this would avoid contamination issues associated with landing maneuvers.
- Volcanic caves may have interconnected fracture networks; a remote (relatively isolated) target could limit aerial extent of contamination risk.
- The subsurface, linear void spaces of Martian volcanic caves are estimated to have significantly (~80 times) larger volumes than those on Earth.
- Volcanic caves on Mars could be desirable locations for future human habitats.



Acknowledgements



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Lunar & Planetary Laboratory, University of Arizona

NASA BRAILLE Team

NASA/JPL CoSTAR Team



NASA PSTAR Program

