LAVA TUBES AS ANALOGUE REPOSITORIES FOR LIFE, GEOCHEMISTRY, AND CLIMATE RECORDS ON MARS. P.J. Boston[1], J.G Blank[2], D.E. Northup[3], M. Deans[4].

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Introduction: Lava tubes are a terrestrial analogue for a key prospective astrobiological target on Mars, namely, the cave, subsurface, and rock fracture environment. Caves exhibit stable physical and geochemical conditions, are sheltered from physical weathering and especially ultraviolet and cosmic ray bombardment, and may be one of the best ways to access the relatively near to mid-range subsurface of the Martian landscape. Lava tube caves have been identified on the Moon and Mars using satellite imagery [1,2]. They may be present on other Solar System bodies [3]. The restricted connection of many lava tubes to the atmosphere could increase the possibility for the retention of water [4], a requirement for living systems. These subterranean settings could serve as a protected habitat for lifeforms, enhance the preservation of recognizable biosignatures from past life and preserve evidence of past climates [5-8].

Although premature for consideration for very near-term missions (e.g. MSL or MSR/Mars 2018), Mars lava tubes offer much scientific value for future robotic and eventually human missions [9]. Identifying such features on the Martian surface or elsewhere in the Solar System and developing methodologies for studying their numerous analogues on Earth will set the stage for future capabilities to actually access such potential treasure troves of unusually well preserved materials on future missions.

Mission Description: A mission that aims to access a lava tube could be framed in one of two ways, either a direct entry into a natural opening, or a shallow drilling effort into a sealed tube. To enter a lava tube directly, a mission must be capable of advanced robotic entry, possibly by small independent and numerous units that use a variety of novel techniques not currently employed on conventional large-scale robotic rovers [10, 11, 12] or to access an open lava tube with a smooth floor (Figure 1) a rover like the current K-10 could be employed [13, 14]. The second alternative is to employ drilling technology to bore down through the parent rock into the lava tube chamber below. Ground penetrating radar (GPR) is being used on Earth to find subsurface cavities [15] and has been suggested for use on Mars [16, 17].

Science Merit Related to Mission Objectives: Science objectives of future landed missions will include broad aspects of the potential presence of extant life and traces of past life. We note that microbial/mineral materials on lava tube walls produce distinguishable and distinctive textures that persist after the organisms themselves no longer inhabit the surfaces [18]. In terrestrial lava tubes, allochthonous deposits of sediments are frequently preserved unaltered for geologically significant periods of time, thus enabling a glimpse of past climate and hydrology [18]. These lava tubes often have collapsed segments that could be excellent time capsules for trapped volatiles, particles, possibly organics, and build up of high concentrations of gases from deeper geological sources [19, 20]. On Earth, tectonic and weathering processes limit the lifetime of lava tubes to perhaps a few million years (e.g., Saudi tubes are considered to be very old, at ~3-4 Ma). On a more geologically quiescent body such as Mars, the duration of a lava tube feature is likely to be much longer.

Most Important Question Answered by Site: Lava tubes provide a window into the subsurface that allows access to major void space that may contain: 1) volatiles (frozen or gaseous; 2) mineral and geochemical biosignatures and climate signals, 3) live or dead Martian life. As in many Earth lava tubes, we anticipate similar exquisite preservation of mineral, sedimentary, and geochemical materials.

Logistic and Environmental Constraints: The dozens of lava tube sites around the world that our team is studying range from a few feet off a parking lot to many km hiking over rough terrain. The temperatures within the caves vary greatly with latitude, altitude, and whether a particular tube is acting as a cold trap.

Figure 1: Hibashi Cave, Saudi Arabia. This lava tube has a smooth floor courtesy of blown in sand. Frequent dust storms on Mars probably have deposited a similar blanket of material on the floors of open lava tubes. Such a flat floor would be accessible even to some wheeled or legged robots. Microbial/mineral white coating is visible on the walls. Image courtesy of J. Pint.

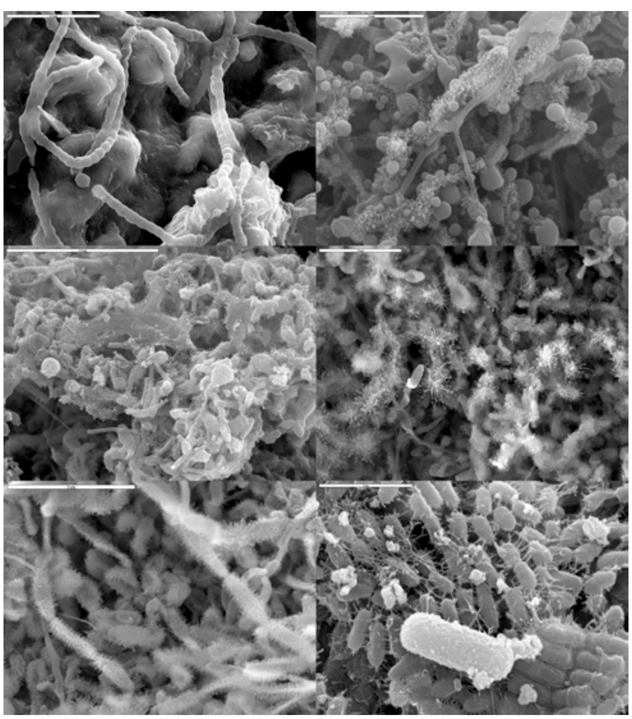

Figure 2: Selection of SEM images of microbial colonies on lava tube surfaces around the world. In some cases microbial colonies are visible to the naked eye, in many cases the rock appears to be bear, but at microscopic resolution numerous organisms, biofilm, and associated minerals appear.

Table 1: Lava Tube Analog Overview

Feature	Description
Lava tubes on Earth are liberally distributed around the planet	Lava tubes studied by our team: New Mexico, Arizona, Oregon, California, Hawaii, Azorean Islands, Saudi Arabia, Oman, Chile (Atacama)
Elevation	Sea level to 4 km
Areal Extent	Lava tube containing flows of 1 – 100 km^2
Prime Science Questions	e.g., What textural, microscopic, and geochemical signals of biology, climate, and sedimentological histories are contained within the lava tubes?
Distance of Science Targets from nearest road or airstrip	From 20 m to 10 km
Environmental characteristics	Max temp: 45°C Min temp: -10°C Precipitation: <1 mm/decade to 4 m/year Vegetation coverage: Bare (new Hawaiian lava tubes <50 yrs old; old Saudi sand desert lava tubes) to heavily vegetated temperate or tropical forest.
Previous studies at analogue site	Complete bibliography at http://www.caveslime.org/ & http://www.ees.nmt.edu/boston/pubs.html
Primary Landing Site Target	e.g., Mars lava tubes have been identified so far at: Arsia Mons, Olympus Mons, Pavonis Mons, East of Jovus Tholus, & Elysium Mons

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