LAVA TUBE CAVES ON MARS – SEEKING SIGNS OF PAST LIFE. Richard J. Léveillé[1] and Saugata Datta[2], [1]Canadian Space Agency (6767 route de l'Aéroport, Saint-Hubert, QC, J3Y 8Y9, richard.leveille@asc-csa.gc.ca), [2]Department of Geology, Kansas State University, Manhattan, KS 66506; sdatta@ksu.edu.

Lava Tubes and Caves on Mars: Lava tubes and subsurface cave-like features have been identified near a number of volcanic edifices on Mars based on orbital imagery and remote-sensing data [1]. These appear as linear to sinuous elongated depressions, chains of pits or craters, or skylight-like openings (Figs. 1-2). To date, none of these have been explored from the surface and we know little of their subsurface spatial extent, age or geological properties. That being said, their apparent diversity may be related to their different ages, geological history, or emplacement processes and subsequent environmental change. On Earth, lava tube caves may exist for up to a few millions of years before they typically collapse due to active tectonics, erosion, and weathering processes [2]. On Mars, they may presumably exist for much longer periods due to lesser tectonic activity, and lower rates of erosion and weathering in more recent times when compared to Earth. It remains to be shown whether the existence of any such caves on Mars coincided with periods of increased aqueous activity suspected to have occurred at various times throughout Martian history.

Astrobiological Interest in Caves: Subsurface environments on Mars, such as caves, are widely viewed as high priority locations to search for active life, or evidence of past life on Mars [1-4]. Caves on Mars can potentially provide protection from the elements suspected of being detrimental to life and preservation of biosignatures: ionizing radiation, high winds and dust storms, temperature extremes, and possibly highly oxidizing conditions (especially if the latter are intimately linked to soil composition). On Earth, stable environmental conditions in caves also favor microbial growth, and extensive cave biofilms and microbial mats are common [2, 5]. The conditions in caves also favor continued mineral precipitation, in some cases influenced by the presence or activity of the microbial communities themselves [2, 6, 7]. Studies of terrestrial lava caves have revealed diverse secondary mineral assemblages and textures [7, 8] and various biosignature suites [7, 9]. The latter provide evidence of microbial presence (e.g., microfossils, organic biomarkers) or activity (e.g., isotopic signatures, biominerals). The minimal diagenesis that occurs in caves compared to surface depositional environments also makes them excellent for the preservation of environmental and biological information in mineral deposits over long periods of time. Recently, evidence for microbial life in cave-like synsedimentary cavities from 2.75 Ga terrestrial environments has been reported [3]. Cave-like habitats have thus been important throughout most of life history on Earth and may also have been important on Mars.

By analogy with Earth, lava tube caves on Mars would provide more habitable environments, and would potentially offer increased preservation potential for both inorganic and organic biosignatures than at the surface. In addition, caves may have served as refugia for microbial communities as global climate change led to deleterious conditions across most of the planet's surface. Based on these considerations, lava tube caves should be a high priority target for future life detection and sample return missions.

Future Exploration of Caves on Mars: The exploration of lava tube caves on Mars presents several important hurdles. Because they are associated with volcanoes, lava tubes tend to be found at relatively higher elevations than many other sedimentary or hydrothermal environments. In addition, they may be located on relatively steep slopes. Thus, landing a spacecraft near the mouth of a cave presents engineering challenges. Nevertheless, new precision landing technologies (e.g. MSL EDL) may alleviate these issues by decreasing landing ellipse size, as well as topographic and atmospheric constraints for spacecraft descent to the surface.

Lava tubes also typically present very rough terrain at their entrances and within them. On Earth, a vertical descent from the entrance is often required to access deeper parts of lava tube caves. Large boulders known as "breakdown" could also severely hinder the access to, and movement within a lava tube by a typically planetary rover. However, numerous novel technologies, many of which are currently being developed, may provide solutions to these problems. Examples include tethered rovers, or "cliffbots", microbots, inflatable/spherical rovers, deep drills and penetrators. Abundant wind-blown dust accumulations may also alleviate these issues somewhat by providing a smoother surface. Terrestrial examples of old lava tubes in desert-like environments and recent images from Mars of putative lava tubes (Fig. 2), as well as those of craters, lend support to this hypothesis.

Even if we could access a lava tube cave with a robotic system, other important issues need to be overcome. Solar power will not be possible at a distance of more than a few meters from cave entrances. Any rover or probe will thus need alternative power sources or highly efficient batteries that will need to be fully charged before entering the cave. Vision (or imaging) in reduced light conditions will also require any robotic system to have an adequate illumination system and (or) an active vision system (e.g. TriDAR), along with intelligent navigation for automated hazard avoidance and target localization. Line-of-sight communications will not be possible in deeper parts of caves and novel communications and data transmission systems will be required. Finally, an advanced science payload will be required for remote analyses (e.g. IR absorption, thermal emission, Raman/LIBS/LIF), in situ sample processing and analysis, or sample collection and return. Although these are all important technical challenges, solutions currently exist or are being developed.

Before even considering sending a spacecraft to explore a Martian lava tube cave, we must advance our knowledge of the diversity, distribution and origin of such caves by more detailed and systematic remote sensing surveys using existing and future orbital assets and novel search techniques [10].

Presentation Summary: This presentation will cover some of the issues highlighted above, summarize recent developments in relevant science and technology, and present results from our ongoing research on the geochemistry and geomicrobiology of terrestrial lava tube caves, with examples from Hawaii and New Mexico.

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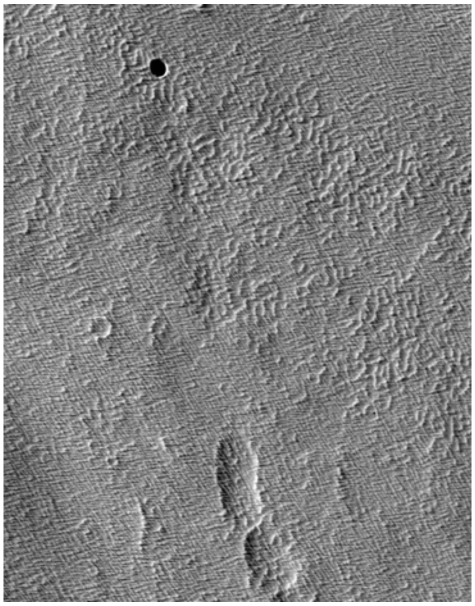

Figure 1. Possible skylight opening (upper left) to putative lava tube with collapsed tube channel (lower center), near Arsia Mons (HiRISE image: PSP_009765_1780, detail). Image: NASA/JPL/ University of Arizona.

Figure 2. Chain of collapsed pits on Arsia Mons volcano with putative lava tube skylight (center) or pit crater (HiRISE image: PSP_005414_1735, detail). Note the wind-blown sediment creating a relatively smooth slope with a relatively low gradient. Image: NASA/JPL/University of Arizona.