MARTIAN LAVA TUBES AS POTENTIAL WATER- AND LIFE-BEARING COLONIAL HABITATS

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Introduction: Martian volcanism is very old, going back to 4 Gyr ago [1]. Two main volcanic regions can be identified: Tharsis and Elysium. These immense, elevated structures are thousands of kilometers in diameter and cover about one third of the planet's surface. The mare-like plains on Mars are roughly 3 to 3.5 Gyr old. Martian volcanism has changed over time, from intense activity hosted by the highland paterae which stopped about 3 billion years ago, until the smaller shields and cones that erupted only 2 billion years ago. The emblematic giant shield volcanoes are even younger, having formed between 1 and 2 Gyr ago. Much younger are the lava flows on Olympus Mons, about 200 to 20 Myr old. Future *in situ* studies of these volcanic plains will probably reveal even younger lava flows as shown by the evidence arrived from the study of the crystallization ages of the three main groups of Martian meteorites: Shergottites, Nakhlites and Chassignites (known as SNC achondrites) [2]. In any case, another volcanic rock provides the oldest evidence of volcanism in Mars, going back to 4.5 Gyr ago from the study of Allan Hills 84001 [2]. In fact, this ALH84001 orthopyroxenite contains ~3.9 Gyr old secondary carbonates, most likely formed as consequence of impact metamorphism and/or volcanic outgassing, probably precipitating from water from a transient lake. The recent discovery of distinctive chemical layers in the carbonate globules points towards different water floods soaking ALH 84001 [3].

As consequence of all this volcanism over the eons, most of the extruded lava ended up forming the vast volcanic plains that cover ~60% of the Martian surface. We focus here in the study of lava tubes as potential future habitats. Lava tubes, also known as pyroducts, are fairly common on planetary surfaces in the Solar System: they have already been found on Earth, the Moon and Mars. They originate when large quantities of magma flow under the surface of said bodies, followed by the drainage of the magma, leaving an empty cavity resembling a tunnel [4], [5].

These tubes, although buried, may present various, easily identifiable features visible from above. Circular holes called skylights may exist where parts of the lava tube ceilings have collapsed due to structural instability; other possible entrances, called rilles, occur when a larger area of the tube has collapsed, creating river-bed like features [6]. Another, indirect feature which indicates the presence of a lava tube, are rootless cones. These circular structures form when lava flows under H2O-rich water, which evaporates and builds up pressure on the rock, finally resulting in a phreatic eruption [7], [8].

Tunnel sizes may vary depending on the location's gravity; on Earth, they can reach 50 m. in diameter, like the "devil's throat" in Hawaii, but estimates show that Lunar and Martian tubes can be up to 3 orders of magnitude larger [6], due to the low gravity of these bodies allowing the structures to hold for longer.

Martian lava tubes are especially interesting as they may contain water or water-ice, which would have deposited there after the red planet's oceans dried up [9]. Water-containing lava tubes could prove useful for 2 things: first, they can indicate places where life might have developed or migrated into, as it is sheltered from the red planet's harsh atmospheric conditions and radiation, and, second, they can prove to be possible locations for the first human colonies to settle into, for the same reasons [10].

Experimental procedure: For the present work, we focused on using optical imaging taken by HiRise available to us from Google Earth with the Mars option, as well as elevated terrain imaging and LIDAR images. We focused on analyzing the areas surrounding the Tharsis Montes: Arsia, Pavonis and Ascraeus, as well as Olympus Mons, and Elysium planitia to the West of these, specifically Elysium Mons. With this method we were able to detect several lava tubes, both skylights and their rilles, at different distances from the volcanoes, as well as rootless cones.

We believe that methods such as GPR and Gravity Anomaly analysis should be used to follow the direction of the tubes underground. These methods should be able to show the basalt surrounding the tubes, as well as the void inside of them, and even detect the presence of water-ice. We decided that for GPR it would be best to use a frequency close to 5 MHz (Table 1), because it would give us the best depth-resolution ratio, as the depth it penetrates is half the wavelength we use. Any value of λ less than 100 m and over 15 m would be useful. Anything above or below these values, would give too bad a resolution, or too little depth, respectively.

Material	V in m/s	λ in m at 5 MHz
Basalt	0.11	22
Vacuum	0.3	60
Ice	0.16	32
Fresh Water	0.034	6.8

Table 1. The different materials that would be of interest in our study, along with the velocity (v) at which the wave sent by GPR at 5 MHz would travel when colliding with them, and the equivalent wavelenth we would obtain (λ), obtained by the formula $\lambda=v/f$.

Results and discussion: optical analysis of the areas of study led us to the conclusion that the Tharsis bulge, although it does present several skylights and rilles signaling the existence of lava tubes, isn't likely to present large amounts of water-ice, and therefore to harbor water-dependent life. The reasons that led to this conclusion were that, when the bulge formed around 3.7 billion years ago, it elevated its surrounding area (up to 10 km. in some points), which would have made the water retreat. Moreover, simulations show that the shoreline was located hundreds of kilometres from the volcanic cones, making the possibility of water seeping into the tubes really low.

On the other hand, however, we believe the plains surrounding Elysium Mons to be perfect candidates for our study: apart from skylights and rilles (albeit less than on Tharsis), we found many rootless cones scattered around the area, signaling the presence of water embedded in the bedrock at the time of the formation of lava tubes. The simulated shoreline is also quite closer to the volcano, increasing the probability of a water-lava tube encounter.

Conclusions: Future manned exploration and colonization of the red planet will require identifying habitable locations to establish first habitats on its surface. Lava tubes might be envisioned as excellent places as they can offer protection to future astronauts from the harsh surface environmental conditions. In addition, lava tubes could give direct access to liquid water embedded in the bedrock. The rootless cones and lava tubes scattered around Elysium Mons plains are excellent proxies for such study. Future missions could gain additional insight on the viability of these environments.

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