POTENTIAL DETECTION OF MARTIAN LAVA TUBES FROM MARS GLOBAL CAVE CANDIDATE CATALOG SKYLIGHT LOCATIONS USING SHARAD.

N. M. Bardabelias[1], J. W. Holt[2], and M.S. Christoffersen[3], [1]University of Arizona Department of Geosciences (nmb23@email.arizona.edu), [2]University of Arizona Lunar and Planetary Laboratory (jwholt@email.arizona.edu), [3]University of Arizona Lunar and Planetary Laboratory (mchristo@email.arizona.edu).

Introduction: Lava tubes are tunnel-like structures formed when exposed sections of effusive flows cool while material continues moving internally [1, 2]. These tubes thermally insulate the material flowing through it, allowing subsequent flows to travel long distances before beginning to crystallize [3]. As eruption rate slows, the lava level within the tube decreases, eventually creating a partially or fully hollow tunnel.

Motivation. For bodies with thin or no atmospheres, lava tubes provide shelter from harsh surface radiation environments, diurnal temperature swings, and micrometeorite bombardment [6]. This is of geologic and astrobiological significance for studies of past habitability or future human exploration: subsurface caverns may preserve biosignatures and/or volatiles which would make lava tubes an ideal exploration candidate for terrestrial bodies.

Lava tubes are difficult to identify in visual remote sensing data as their surface expressions are often the result of collapse - without this collapse, lava tubes are generally indistinct at the surface [1]. Skylights, large pits, and pit chains identified on Mars can indicate varying levels of possible lava tube collapse breaching the surface, while sinuous rilles observed on the Moon have also been suggested as an expression of tube collapse [4]. For terrestrial lava tubes, additional methods of detection include thermal infrared remote sensing, seismicity, magnetic field perturbations, and measuring low-frequency sounds; however, these methods only apply to active lava tubes and can yield ambiguous results [1, 2]. Ground penetrating radar (GPR) presents a unique solution to this problem, as it detects subsurface reflectors through differences in material permittivity and is thus capable of detecting inactive lava tubes [5]. This work hypothesizes that the difference in permittivity between a sufficiently large, evacuated lava tube and its surroundings could lead to a characteristic power echo in radar data. If so, analysis of radargrams can reveal the shape and extent of a single tube or tube network.

SHARAD radar system. The Mars Reconnaissance Orbiter (MRO) Shallow Radar (SHARAD) probes the subsurface using a frequency-modulated ('chirped') signal downswept from 25 MHz to 15 MHz. This 10 MHz bandwidth yields a 15-m resolution in free-space, reduced to 5 m in basaltic terrains [7]. Prior work from the SHARAD science team suggests that, for models of lava tubes under Martian conditions, their instrument may be able to detect these features in the shallow subsurface [7].

Methods: This work uses skylights, a known indicator of lava tube collapse on terrestrial bodies, to identify potential Martian lava tubes in SHARAD data. By correlating these skylight locations with radar ground tracks from SHARAD, this work aims to characterize radargrams in these areas and determine if Martian lava tubes exhibit a distinctive radar signal.

Martian skylights observed in both the Mars Odyssey Thermal Emission Imaging System (THEMIS) [8] Visual Imaging System (VIS) and the Mars Reconnaissance Orbiter (MRO) HiRISE and CTX data [9, 10] are mapped to the USGS Mars Global Cave Candidate Catalog (MGC[3]). Of the 1062 candidate cave targets, this work examines only the 354 targets identified in the MGC[3] as potential skylight entrances into lava tubes. Using the Java Mission-Planning and Analysis for Remote Sensing program (JMARS) [11], this work identifies SHARAD ground tracks that cross over or within 5 km adjacent to skylight locations. All but three of these skylights are within the Tharsis region, with one each in Acidalia Planitia, Elysium Planitia, and Margaritifer Terra.

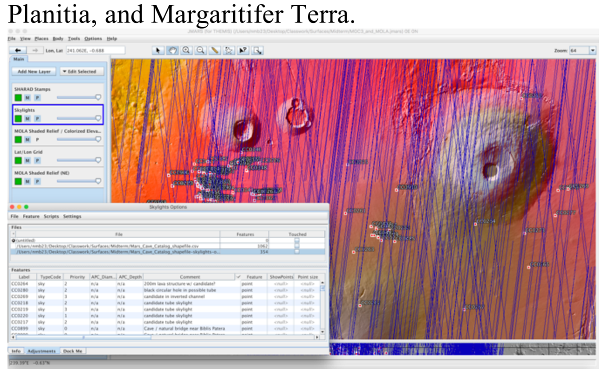

Figure 1: JMARS software showing a Mars Orbital Laser Altimeter (MOLA) elevation basemap for the Tharsis region, points and labels representing skylight candidates from MGC[3] (red), and SHARAD ground tracks (dark blue). The bottom left table displays additional MGC[3] data for candidate skylight locations.

SHARAD radargrams are then compared to MOLA-derived clutter simulations for identification of unique subsurface reflectors using the Geology by Seisware visualization software.

Discussion: Expected results from this work include the shape and depth of subsurface reflectors coinciding with MGC^3 skylight locations. Through further analysis of the geologic context around reflector locations and comparison of observed lava tube depths with available digital terrain models of collapse features, this work aims to ultimately determine whether lava tube detection is plausible with current orbital radar systems at Mars. These results may have implications for RIMFAX operations on the Mars 2020 rover [12], as well as for future orbital GPR at Mars and other terrestrial bodies.

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