Detection of Lava Tubes Using Ground Penetrating Radar. S. Jazayeri[1], S. Esmaeili[1], S. Kruse[1], E. Bell[2], P. Whelley[2], J. Richardson[2], K. Young[3], W. B. Garry[3]. [1]University of South Florida, [2]University of Maryland, [3]NASA Goddard Space Flight Center (sjazayeri@usf.edu).

Introduction: The existence of lava tubes on the Moon or Mars promises potential safe places for human crews and their instruments, plus unprecedented science investigations. These tunnel-like volcanic features offer protection from harmful radiation, thermal extremes and micrometeorite impacts. Therefore, developing exploration methods to evaluate and map lava tubes from the surface is important in order to identify and locate tubes suitable for habitation. Geophysical methods including Ground Penetrating Radar (GPR) are promising tools for quickly and non-destructively detecting such features from the surface without endangering the astronaut explorer [1]. GPR systems emit high frequency (~10-1000 MHz) electromagnetic waves into the subsurface and record the returned signal. In this study we present the analysis of real and synthetic GPR profiles over terrestrial lava tubes. Our results indicate that GPR surveys are generally successful in resolving the ceilings of lava tubes, and in some cases, detecting the floor of the tubes.

Field Site: Lava Beds National Monument (LBNM) in Northern California, USA, contains a variety of lava tubes with different sizes, shapes, and depths that serve as analogs for planetary lava tubes. We surveyed 7 tubes with various instruments during two field campaigns in 2017 and 2018 [1].

Field Measurements: Data were collected using 100 MHz GPR antennas. An RTK GPS was used to record the location of each measurement. Light Detection and Ranging (LiDAR) surveys produced point clouds of the surface and tube interiors [1].

Selected Results: The tube geometry models (Figs.1b, 2b) were used to assess the GPR results and also to create synthetic GPR models that help us better understand the challenges associated with resolving different tube details. We show a sample GPR profile from Valentine Cave, which has a relatively smooth flat floor. This example profile crosses the tube perpendicularly at a bifurcation around a pillar (red line in Figure 1b).

Signatures of the ceilings of both segments of the tube are clearly observed in the recorded data (Fig. 2a). Creating synthetic data based on the geometry models derived from LiDAR data (Fig. 2b,c) helps us understand the complexities associated with the real data. Differences between recorded and synthetic data are presumed to be products of rock heterogeneity, fractures and moisture in the fractures, out-of-plane reflections, and other unmapped voids (Fig 1a show the tube opening and ceiling complexities).

Conclusions: Tube dimensions can typically be obtained from the data (assuming ceiling rock velocity can be inferred from the data). Reflections from the floor are weak and harder to identify and are shifted upward in raw data due to increased radar wave velocity in the void. Further processing is required to correctly project the floor to its actual depth. Additionally, these simulations are useful to predict the signature of lava tubes and voids on other planets.

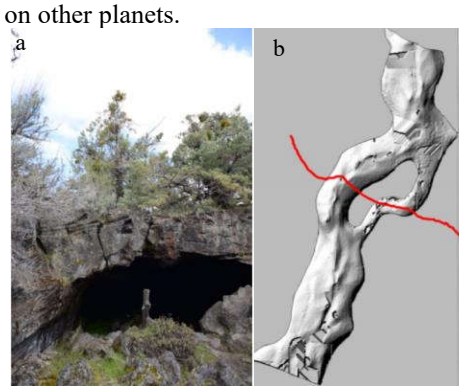

Figure 1. a) Entrance of Valentine Cave at LBNM. b) The shaded relief map of the tube ceiling from LiDAR data. Red line represents the location of the GPR profile in Fig.2a [2].

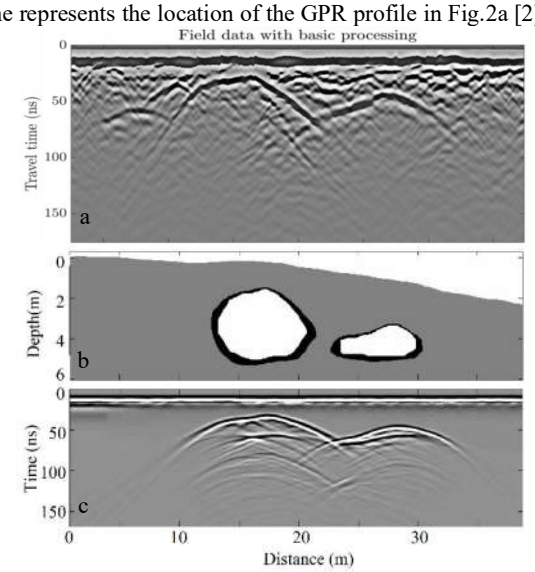

Figure 2. a) Collected GPR data. b) Geometry model cross section from LiDAR data. c) Simulated GPR data based on the geometry model.

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References: [1] Esmaeili, S., et al. (2020) *JGR: Planets*, doi: 10.1029/2019JE006138. [2] Esmaeili S. et al. (2019) AGU Fall Meeting, abstract #NS43D-0865.