CORRELATING MAGNETIC ANOMALIES AND GEOMORPHOLOGY OF TERRESTRIAL LAVA TUBES AS AN ANALOG FOR LUNAR PROSPECTING E. Bell[1], N. Schmerr[1], K. Young[2], J. Bleacher[2], S. Esmaeili[3], W. Brent Garry[2], S. Jazayeri[3], S. Kruse[3], J. Richardson[4], P. Whelley[4]. [1]University of Maryland, Department of Geology, 8000 Regents Dr., College Park, MD 20742 ebell1@umd.edu, nschmerr@umd.edu; [2]NASA Goddard Space Flight Center; [3]University of South Florida; [4]University of Maryland.

Introduction: Terrestrial volcanic fields provide excellent analogs for studying lava tubes, and can be used for the refinement of geophysical prospecting techniques and data analysis methods for application to future lunar prospecting of similar features. Geophysical techniques, such as magnetometry, will be able to help identify the presence, scale, and extent of caves or tubes connected to mare pits. [1] Lunar lava tubes can provide shelter from radiation, micrometeoroids, and large thermal extremes; simplifying the various engineering requirements for both human and robotic systems. [2, 3]

In this study, we analyze terrestrial surveys and model magnetic signatures of lava tubes to show that it is possible to use ground-level magnetic surveys to obtain initial first order geometric characterization of lava tubes within basaltic lava flows.

Field Sites: Our field site, Lava Beds National Monument, California, USA, encompasses a multitude of lava tubes, lava flows, and cinder cone volcanos associated with the Medicine Lake shield volcano. [4, 5] This study examines three intact sections of the Modoc Crater lava tube system; Incline, Skull, and Ship Caves.

Field Measurements: For this study, ground level magnetic surveys of the total magnetic field strength, were obtained by walking parallel lines, at 3 to 5-meter intervals. These lines run perpendicular to the length of the lava tubes. Additionally, Light Detection and Ranging (LiDAR) 3-D surveys of both the interior and ground level topography over the lava caves were conducted. [6, 7] These data capture surface details, and provide location and geometry of the lava tubes. Example of these types of surveys is shown in Figure 1.

Analysis and Modeling: Our analysis consists of correlating the magnetic anomalies produced by the lava tube to the cross-sectional area and depth of the tube for 1-meter thick cross-tube profiles along the length of the tube. The relationship between these is then used to calculated the best-fit equivalent magnetic susceptibility for these lava tubes. This equivalent magnetic susceptibility is then used to calculate a forward model of the ground level magnetic signature produced by a 3-dimensional model of each lava tube, constructed from the LiDAR mapping of the tube structure, for comparison to the observed data. [8]

Operational Implications: For lunar surface exploration, a number of prospecting, science, and hardware related elements will need to be balanced to successfully achieve mission objectives. Elements such as data density, location, and resolution, as well as terrain accessibility can be simulated by modifying terrestrial

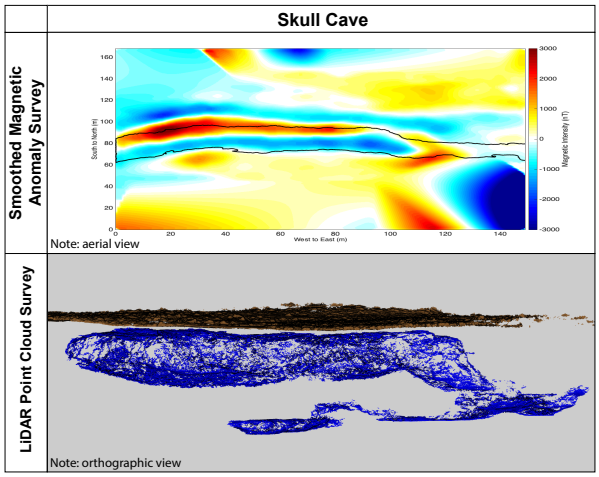

Figure 1: Example data. Top: Aerial view of smoothed interpolated magnetic anomalies (black = tube outline). Bottom: 3-D point cloud model (black = ground level, blue = lava tube)

data sets to mimic operational conditions of the lunar surface. The ability of the resulting analysis to resolve the required geologic detail can then be assessed.

Conclusions: We have collected ground level magnetic and 3-dimensional LiDAR survey data sets on three lava tubes within the Modoc Crater lava tube system. We show that the strongest negative magnetic anomaly readings can be proportionally correlated to the cross-sectional area and depth of the lava tube. By combining this information with other geophysical data (e.g. ground penetrating radar, seismic, gravity, EM), additional geomorphic understanding of a lava tube's structure is likely possible. [9]

Additionally, the LiDAR surveys can enable forward modeling to evaluate the possible remanent magnetic signatures produced by large scale lava tubes that are thought to exist on the Moon. [10, 11]

Finally, our terrestrial data sets can be modified to simulate the analytical impacts from various lunar surface exploration operational constraints.

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References: [1] Wagner, R., Robinson (2014), Icarus, 237, 52-60. [2] Horz, F. (1985) *Lunar Bases and Space Activities of the 21st Century*, 405-412. [3] Young, K. et al. (2018) *LPSC 49*, Abstract # *2504*. [4] Larson, C. & Larson J. (1990) *Lava Beds Caves*. [5] NPS Lava Beds (2017) https://www.nps.gov/labe/ planyourvisit/upload/GEOLOGY.pdf. [6] Whelley, P. et al. (2018, November). *GSA Annual Meeting, USA-2018*. [7] Garry, W.B. et al. (2017) *GSA Cordilleran Section Meeting*, Abstract 25-3. [8] Bell, E. et al. (2018) *LPSC 49*, Abstract # *2412*. [9] Esmaeili, S., et al. (2020) *JGR: Planets*, doi: 10.1029/2019JE006138. [10] Blair, D. et al. (2017) *Icarus*, *282*, 47–55. [11] Hemingway, D., & Tikoo, S. (2018) *JGR: Planets*, *123*(8), 2223–2241.