COMPARISON OF KNOWN LUNAR PITS USING THE LROC QUICKMAP TOOL

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Background Work and Motivation: With increased interest in building a permanent habitat on the Moon, lunar pits may provide the necessary resources used to sustain life on the Moon. These pits, which are often formed by the collapse of lava tubes [1], can provide shelter from extreme temperature variations, radiation, and micro-meteorites [2]. Additionally, water ice, a vital resource for exploration, may also be present within these pits.

Specific Question and Relationship: Since pits would be beneficial for human exploration of the Moon, the ability to locate additional pits would greatly aid lunar exploration. The goal of our research is to determine if any correlations in the LROC QuickMap data could help identify potential pit sites [3].

General Topic: Lava tubes and pits were recently discovered using orbiter images. In 2009, the first pit was confirmed through images by the Kaguya spacecraft [4]. Since then, more than 300 lunar pits have been cataloged using images from Kaguya as well as the LRO missions. Wagner et al. (2021) located 281 impact melt pits, 15 mare pits, and 5 non-impacted terrain pits. Most of wxthese pits were discovered using a computer algorithm that automatically scanned thousands of high-resolution images of the lunar surface from the LRO Narrow Angle Camera (NAC) [5]. The majority of these pits were located in either large craters with impact melt ponds, or in the lunar maria. There are several mechanisms for lunar pit formation. The large majority are skylights (i.e., holes that lead into lava tubes). Some pits formed as fractures in cooling melt ponds, or due to the collapse of a void under a dome. Collapses could be the result of vibrations generated by meteorite impacts [6].

Methods: The goal of our research is to study approximately 10% of the known pits on the Moon to become familiar with the topography and geological features shown by the QuickMap tool. Analyzing and comparing known surface features helped us narrow down our research questions and goals. After some visual inspection, we collected data. We created spreadsheets to organize the data and to find correlations in various characteristics of pits. The characteristics included: geologic location (e.g., mare, impact flow melt, and highland), pit location, scale, size, and shape, features surrounding the pit, geologic unit and age, chemical and mineral abundances (e.g., Ti, FeO, olivine, clinopyroxene, orthopyroxene, and plagioclase).

Results: We found that the size of the pits varied from 5 to 100 meters. Pits located in the mare area tended to be larger by a factor of at least two, while the highlands and flow melt pits were similar sizes (15 m to 40 m). Pits seem to occur in younger geologic periods. The oldest period is 3.92 Ga (late Imbrium period). Pits occur all the way through to the Copernican period (1.1 Ga to the present). The mineral distribution from Kaguya does not provide information past +50 or -50 degrees latitude. This coupled with the fact that the Kaguya resolution was at 50km per pixel, while our pits were 15m to 250m across. Therefore, we couldn't get an accurate mineral reading. Analyzing pit profiles is not a reliable method of identifying pits. The resolution of the LOLA data was not accurate for pits less than 100 meters. Finally, the size of the flow melt ponds did not form a trend where pits are located. They ranged from 1.7 km to 70 km in size, and all contained pits.

Conclusions: There are likely many undiscovered pits. Lighting and distortion of the lunar map near the poles, and accuracy of the various tools when dealing with small features makes finding additional pits difficult. According to Wagner et al. (2021), the LRO mission has only imaged about 40 percent of the Moon with appropriate lighting for the successful automated pit searching program. Based on our collected data, areas of interest as well as potential new pits were found. The only way to truly know the usefulness or existence of a pit is to have a physical study before humans rely on them.

[1] Wagner, R.V., et al. (2015) Update: The Search for 01Lunar Pits, *2nd International Planetary Caves Conference,* 9021.pdf [2] Leonard, D. (2019) Living Underground on the Moon: How Lava Tubes Can Aid Lunar Colonization, *Journal of Geophysical Research: Planets, Space.com* [3] LROC Quickmap, shorturl.at/biqrF [4] Possible Lunar Haruyama, J., et. al., (2019), Lava Tube Skylight Observed by SELENE Cameras, *Geophysical Research Letters, Vol.36,* shorturl.at/bgCSX. [5] Earth's Moon (2014) Lunar Pits Could Shelter Astronauts, Reveal Details of How 'Man in the Moon' Formed (2014) *NASA .gov* [6] Wagner, R.V., et al. (2021) Occurrence and Origin of Lunar Pits: Observations from a new Catalog, *52nd Lunar and Planetary Science Conference 2021 (LPI Contrib. No. 2548),* 2530.pdf