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Analysis of Lava Tubes and Skylights in the Lunar Exploration Context

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Abstract

The past and current scientific activities related to the future robotic and human exploration of the Moon have stressed the importance of lava tubes as convenient settlements in an inhospitable planet, providing a natural shielding to a variety of natural hazards with minimizing costs of the construction of manned bases. The detection of lava tubes could be favoured by the presence of skylights, which also represent a way to access to these underground structures. In this context, we analyze one of the proposed mechanism of skylights formation, that is random impacts craters, by comparing crater-geometry argumentations ([11]) with numerical modelling outcomes.

1. Introduction

The Moon holds a leading role in the understanding the histories and evolution of more complex worlds and hence the broad implications the lunar science holds in many planetary topics. Among these geologic processes, volcanism provides undoubtfully information into the thermal evolution of the Moon.

1.1 Lava Tubes

The most prominent feature of effusive volcanism are lava tubes. They form when a lava channel flow develops by radiative cooling a solid crust whereas the lava stream beneath is still liquid and flowing away from the feding vent (e.g., [8]). At the end of the extrusion period, if the lava flow conditions were ideal in terms of viscosity, temperature, supply rate and velocity, an empty flow channel now free from molten magma is left ([11]).

1.2 Skylights

Lava tubes could be identified mainly from the occurrence of leeved channels or the presence of collapsed sections of roofs ([6]). Skylights could originate as enlargement of pre-existing fractures, for instance following a moonquake ([8]), or as incompleting crusting over the melted lava flow (e.g., [4]), or as collapse of the lava tubes ceiling caused by random meteoroids impacts (e.g., [6]).

2. Observations

In our analysis, we consider two skylights candidates detected by the Terrain Camera onboard the Japanese orbiter SELenological and Engineering Explorer (SELENE) ([9], [10]), and then observed at higher resolution by Lunar Reconnaissance Orbiter Camera (LROC) onboard the NASA spacecraft Lunar Reconnaissance Orbiter (LRO) ([2]).

A first pit is located on the Marius Hills region within Oceanus Procellarum, at 14.2°N, 303.3°E, and a second one was found in Mare Tranquillitatis, at 8.3°N, 33.2°E ([9]). The Marius Hills pit has diameters ranging from 48 to 57 m, and mean diameter of 52.5 m, whereas the Mare Tranquillitatis pit has diameters ranging from 84 to 99 m, and mean diameter of 91.5 m ([2]).

3. Method

3.1 Crater Geometry

[11] sustained that the roof of any lava tube should be at least two times larger than the larger crater depth to not collapse.

3.2 Numerical modelling

Numerical modeling was performed through iSALE shock physics code (e.g., [1], [5], [13]), that is well tested against laboratory experiments at low and high strain-rates ([13]) and other hydrocodes ([12]).

We hypothesize a rock projectile striking the surface at 18 km/s. The target is made up by a basaltic layer of 280 m and 470 m, respectively for the Marius Hills and Mare Serenitatis pits. The thermodynamic behavior of each material is described by tables generated using the Analytic equation of state (ANEOS). In addition, a constitutive model is necessary to account for changes in material shear strength resulting from changes in pressure, temperature and both shear and tensile damage ([5]).

4. Summary and Conclusions

In this work, we have investigated if random impacts could be a reliable origin for skylights. We verified if the minimum thickness foreseen by [11] is sustained by the outcomes of the modelling of two skylights pits observed on SELENE and LRO images. We found that the relation is not stringent enough to have uncollapsed roofs on lava tubes.

This is important in the view of a future use of lava tubes as convenient habitats for future human settlements in an inhospitable planet, providing a natural shielding to a variety of natural hazards with minimizing cost of construction of manned bases (e.g., [3]; [6]; [11]).

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