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Simulations of Impact Gardening on Phobos

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Abstract

The continual bombardment of Solar System bodies by meteoroids contributes to the creation and mixing of regolith. This paper investigates the impact gardening process on Mars' moon Phobos. The investigation focuses on the effects of impacts on the formation of topographical features on Phobos. Further, it calculates the formation of regolith and how the properties of regolith depend on the impact crater morphology used. The factor with largest influence on the model output is the fraction of ejecta that is emplaced in a blanket vs. launched into orbit around Mars. The thickness of the regolith is a method to distinguish between those ejecta blanket emplacement scenarios.

1. Introduction

Whether Phobos is an asteroid that was captured into Mars' orbit or if it formed in Mars' orbit is an important question. The upcoming JAXA MMX mission will study Phobos through remote sensing, then return a sample. It is well-known that surfaces of bodies exposed to space are subjected to multiple processes that "weather" the surface. One process called impact gardening creates regolith and mixes it with depth. Impact gardening has a significant effect on the surface of a body; and therefore, it must be considered when interpreting remote sensing data and samples originating on the surface. In this paper, I simulate the effects of impact gardening on the overturn of regolith for Phobos including the lateral transport of material and the time evolution of topography.

2. Model Description

A Monte Carlo technique adapted from lunar simulations to simulate the stochastic process of impact gardening [1-4] is applied to the surface of Phobos. The model uses the crater production function as a basis for generating impact craters over time [5-6]. The model explicitly follows the topography in a patch of surface of area 20 m x 20 m. However, impacts are generated over a larger area as some impacts centered outside of the box still contribute to the interior of the box. Thus the impact generation box is larger than the simulation box. The model implements impacts by calculating a bowl shape crater of the size and coordinates determined by the program. The code alters the topography within the crater by replacing the existing topography with the new bowl at an altitude centered on the previous average altitude of the area. An ejecta blanket is deposited with a distance-dependent thickness overlying the pre-existing topography outside of the rim. The program iterates through this process for the duration of the simulated time window.

The code simply tracks the current topography of the surface and the minimum topography. This combination of values provides much information about the generation of regolith and features on Phobos.

By conducting multiple runs with the same initial conditions and a different seed to the random number generator, the model calculates the probability of situations occurring. This technique will never be able to reproduce the exact impact history of a particular area. However, by repeating the simulations with varied initial conditions, we calculate the dependence of the expectation values on the inputs.

3. Results

Using nominal crater morphology, the mean altitude of the surface of Phobos slowly inflates with time. This results from the ratio of the volume of the ejecta to the volume of the excavated crater. Mass is conserved, however the density in the ejecta blanket is lower than that of the bedrock.

In addition, the thickness of the regolith and the roughness of the surface are computed. If Phobos contains phyllosilicates or other native volatiles, the calculation provides the depth where impacts have not affected the contents. In contrast, if exogenous volatiles from Mars or meteoroids are delivered to Mars, the regolith layer is the place where they would be deposited.

However, these values are dependent of the choice of crater morphology. The ratio of excavated volume to ejecta volume may change depending on the amount of escape that is expected for the ejecta. Likewise, the lateral extent of the ejecta blanket will influence the roughness and the variability in regolith thickness. The model demonstrates how the regolith thickness, once measured at Phobos, can provide constraints on the crater ejecta escape rate.

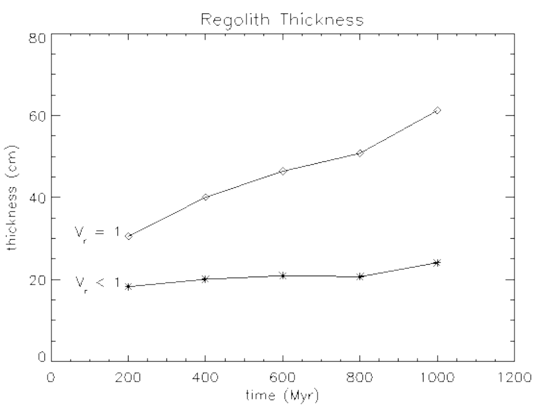

Figure 1: The time evolution of regolith thickness on Phobos is shown for two different assumptions about the escape of impact ejecta. For nominal conditions, the thickness of regolith increases over time reaching 60 cm in 1 Gyr.

4. Summary and Conclusions

The results of the impact gardening model can be used in understanding the time history of the surface of Mars' Moon Phobos in relation to remote sensing measurements from MMX or potential cubesat missions to Phobos.

Acknowledgements

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