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Surface modifications in a changing tidal environment: the case of Phobos

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Abstract

Due to their weak gravity field, small bodies in the solar system are more susceptible to external perturbations. For the same reason, it is often difficult to interpret surface processes on these bodies using theories developed for large planets. In this work, we investigate processes on the surface of Phobos, the irregularly shaped moon of Mars, and its unique dynamical environment. We show that visible displacement of surface materials can happen under the long-term evolution of Phobos' tidal environment. Results might provide new constraints on the formation and evolution history of Phobos' surface features.

1. Introduction

The airless surfaces of small bodies in the solar system are usually observed with a layer of granular materials. The microgravity environment has made this unconsolidated layer subject to different kinds of transport and migration. Resurfacing processes can thus be easily triggered by external perturbations. For example, a variety of surface features formed by regolith sorting and migration have been observed on near-Earth asteroid Itokawa and Eros, showing regolith motion on both global and local scales [3, 4, 6].

As early as the first batch of images of Phobos were obtained by Mariner 9 and Viking spacecrafts, scientists have found Phobos being covered by a layer of regolith with an estimated thickness varying from a few to a few hundreds of meters [5, 7]. The regolith layer is believed to have contributed to the development of various surface features, including the distinctive network of grooves [7, 8]. To understand the dynamic working of these granular materials, it is necessary to model first the dynamical environment on Phobos' surface. Due to drag of the tidal bulge on Mars, the orbit of Phobos decays on secular time scales. Therefore, objects on its surface are facing increasingly stronger tidal and rotational forces, which could be among the major factors of regolith migration.

2. Data and Methods

The dynamic slope is defined as the angle between surface acceleration and surface normal. We transform the 100m-resolution digital terrain model (DTM) of Phobos [9] to a polyhedron with same resolution, and calculated the value of dynamic slope on each surface facet. Surface acceleration incorporates gravitational acceleration assuming a homogenous dense body, tidal acceleration resulting from a circular orbit around a point-mass Mars, and rotational acceleration from a uniform spin [9]. Maps of surface dynamic slope are then produced for Phobos at different distances to Mars. Assuming the orbit of Phobos has only been evolving under the influence of tidal dissipation, the age of Phobos can be connected with its orbital distance by a simple analytical expression [2].

3. Results

We investigated craters in different areas of Phobos. Detailed morphological characteristics revealed in Mars Express (MEx) High Resolution Stereo Camera images (HRSC) are examined against changes in local dynamic slope. Crater Stickney and Todd have similar asymmetric morphology with traces of regolith downslope displacements on some areas of their walls [1]. We find that dynamic topography of these two craters has been profoundly altered in long-term tidal evolution (Figure 1). The pattern of mass wasting features shows better correlation with current-day slopes than with slopes when they were formed, indicating a relatively young age of these regolith processes.

4. Summary and Conclusions

We find a causal relationship between long-term evolution of tidal environment and regolith displacement

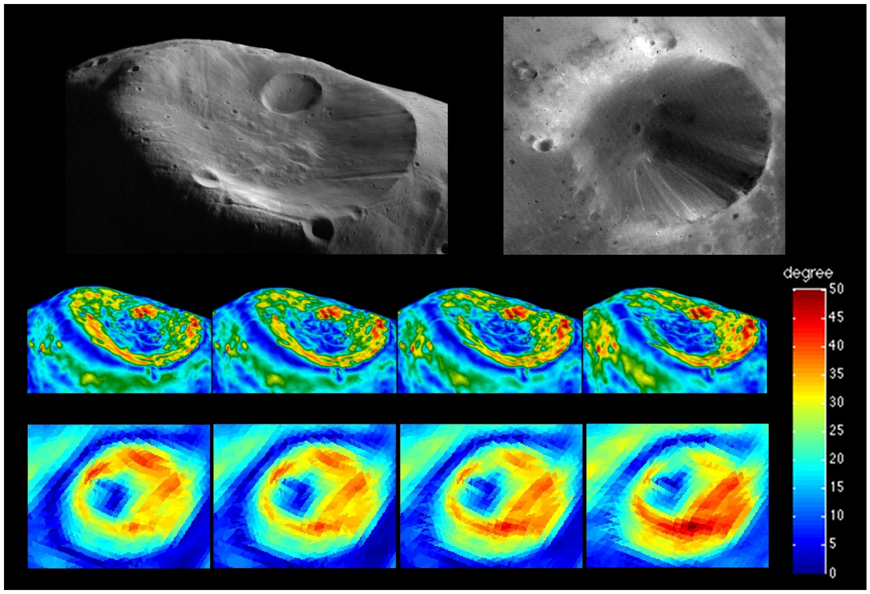

Figure 1: First row: MEx images of crater Stickney (left) and Todd; Second and third row: the evolution of dynamic slopes in these two craters. From left to right, the color-coded values are showing dynamic slopes modeled at 1.2 Byr, 500 Myr, 20 Myr ago, and present.

in craters of Phobos. Results can help understand dynamics of granular material in a highly perturbed microgravity environment. Insights of regolith features on Phobos are also useful for future mission planning.

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References

[1] Basilevsky, A., Lorenz, C., Shingareva, T., Head, J., Ramsley, K. and Zubarev, A.: The surface geology and geomorphology of Phobos, Planetary and Space Science, in press, 2014.

[2] Dermott, S. F., Malhotra, R. and Murray, C. D.: Dynamics of the Uranian and Saturnian satellite systems: A chaotic route to melting Miranda? Icarus, 76, 295-334, 1988.

[3] Mantz, A., Sullivan, R. and Veverka, J.: Regolith transport in craters on Eros, Icarus, 167, 197-203, 2004.

[4] Miyamoto, H., Yano, H., Scheeres, D. J., Abe, S., Barnouin-Jha, O., Cheng, A. F., Demura, H., Gaskell, R. W., Hirata, N., Ishiguro, M., Michikami, T., Nakamura, A. M., Nakamura, R., Saito, J. and Sasaki, S.: Regolith Migration and Sorting on Asteroid Itokawa, Science, 316, 1011-1014, 2007.

[5] Noland, M., Veverka, J. and Pollack, J.: Mariner 9 polarimetry of Phobos and Deimos, Icarus, 20, 490-502, 1973.

[6] Richardson, J. E., Melosh, H. J. and Greenberg, R.: Impact-induced seismic activity on asteroid 433 Eros: A surface modification process, Science, 306, 1526-1529, 2004.

[7] Thomas, P., Veverka, J., Bloom, A. and Duxbury, T.: Grooves on Phobos: Their distribution, morphology and possible origin, Journal of Geophysical Research: Solid Earth, 84, 8457-8477, 1979.

[8] Thomas, P. C., Veverka, J., Sullivan, R., Simonelli, D. P., Malin, M. C., Caplinger, M., Hartmann, W. K. and James, P. B.: Phobos: Regolith and ejecta blocks investigated with Mars Orbiter Camera images, Journal of Geophysical Research, 105, 15091-15106, 2000.

[9] Willner, K., Shi, X. and Oberst, J.: Phobos' shape and topography models, Planetary and Space Science, http://dx.doi.org/10.1016/j.pss.2013.12.006, 2013.