Surface processes of asteroids: A Review

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A wide array of surface processes influence the evolution of asteroids. In preparation for the arrival of the Hayabusa2 and OSIRIS-REx spacecrafts to the asteroids Ryugu and Bennu, respectively, we review the global- and local-scale surface processes that act upon small bodies. Insights are obtained from non-spherical asteroids that have been well characterized by spacecraft, from large Vesta to small Itokawa.

The mechanisms that drive change on the surfaces of asteroids encompass impact cratering, tidal interactions, disruption of a parent body and subsequent re-accumultion, YORP spin-up, and thermal fracturing. Impact craters dominate the surface geology of most asteroids greater than a few km in scale. They are the source of many blocks, and spectrally distinct ejecta units. Impacts also form widespread surface lineaments and have been implicated in the seismic destruction and modification of pre-existing small craters; these features can all be used to make inferences about the interiors of asteroids.

Surface displacements on asteroids can also result from tidal forcing, re-aggregation processes, or YORP-related spin up. These processes lead to surface disturbances which mobilize intermediate size blocks (<0.2 m) and fines that can move along geopotential slopes where alignments of surface blocks, changes in regional block size—frequency distributions, and block rounding have all been seen. In the extreme, YORP spin-up may produce an equatorial ridge, where the slopes towards the equator of an asteroid are significantly enhanced. Surface displacements could also drive the Brazil Nut effect, although the consequences of this process are difficult to separate from simple surface flow.

Recent studies demonstrate that thermal fracturing can be an effective process for generating fine regolith. It provides one remedy to the challenge of forming fines on the surface of asteroids via cratering alone, especially in low-gravity environments. Re-accumulation of fines provides another viable means for producing regolith when these fines possess similar relative velocities to the other components of an asteroid after its parent body was disrupted.

Most of the moderate- to small-sized asteroids visited to date are S-types. Although the insights we have obtained on surface process from these bodies will help predictions and interpretations of what we will see on Ryugu (C-type) and Bennu (B-type), experience with Mathilde, the only C-type asteroid visited by spacecraft, indicate that asteroid geology and the effects of surface processes might be significantly influenced by composition. In the case of Mathilde, its composition has contributed to its high porosity, making it much less sensitive to the forces that lead to surface disturbances that contribute to the observed geology seen on many asteroids.

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