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Statistical Study on the Distributions of Boulders Covering Asteroid Itokawa : Inverse Grading of Boulders

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One of the biggest surprises through the Hayabusa mission is that Itokawa, a small ~300m-sized S-type asteroid, is covered with a considerable number of boulders. Because such a small asteroid was previously expected to exist without regolith, the distributions of the boulders, which may hold information on their origins and evolutionary processes, should be carefully examined. Earlier studies on the distributions of boulders have focused on the boulders larger than a few meters, though much smaller boulders could be observed in high resolution images. Thus, we carefully map the distributions of boulders, whose sizes are down to a few millimeters.
Eros and Itokawa are the only two asteroids, which were rendezvoused by a spacecraft and imaged at high-enough resolutions to identify boulders. For the case of Eros, the total amount of boulders was, surprisingly, comparable to the crater volume, which has been interpreted as the evidence of the crater-excavation origin for these boulders. Spatial distribution of boulders is consistent with modeled trajectories of fragments excavated from a cratering event, which supports the above view. However, the same process does not work for the boulders on Itokawa because (1) The total amount of boulders is much larger than the total volume of ejecta excavated from craters; (2) The spatial distributions of boulders have no correlation with the distribution of craters.
In order to critically understand the distributional characteristics of boulders, we mapped out the outlines of all rock materials found in high-resolution images of Itokawan, and Eros for comparison. Automatically extracting the outline of a boulder by comparing the luminance value with the surrounding under a single criterion is difficult, because (1) the complex features on the surface of the boulders lead to variance in luminance values, (2) the outlines of boulders are often obscure. Thus, we manually mapped the rock materials. The results are summarized into a database, which contain data sets of the shapes of boulders, such as the long axis and short axis of each boulder.
In total we observed ~20,000 particles of rock materials on Eros and Itokawa, with size-ranges from sub-cm to ~10 m. Cumulative Size Frequency Distribution (CSFD) plots for boulders on Eros have a log-log slope of -2.0 $_{+}$0.2, for all the images. The log-log plot of CSFDs of boulders on Itokawa also have similar slope-values as observed on Eros, though slight variations is found in some regions. For example, in the rough terrain, the slope value of boulders larger than 10cm is relatively steep, while that of smaller boulders is small. This may reflect actual distributional characteristics of boulders, but can be simply due to embayment of smaller particles by larger particles.
In order to estimate the cause of the depletion of gravels in the rough terrain, we focus on an interesting feature: only a few gravels lay upon boulders in the rough terrain. Thus, larger boulders may be embaying gravels, eventually decreasing the observable-number of gravels. We introduce modification and plot new CSFDs. These new CSFD-plots show a consistent value for all rock materials regardless of their sizes. Therefore, a considerable number of gravels mainly ranging from mm-size to cm-size is likely hidden beneath the rough terrain. Interestingly, the smooth terrain also consists of gravels with the same size range, and is located in gravitational-

lows.
Thus, a gravel layer is likely spread beneath the rough terrain, which is partially exposed as smooth terrain at gravitational-lows. The transition region between the rough and smooth terrain may be an exposure of the inverse-graded stratigraphic architecture. A long period of repetitious seismic shakings may explain the formation of this stratigraphic architecture.

Keywords: asteroid, boulder, exploration