

Orientation of Boulders and Relationship with Gravitational Slope on Asteroid Ryugu: Implications for Surface Evolution.

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Hayabusa2 spacecraft conducted close investigation at asteroid 162173 Ryugu from June 2018 to November 2019. Detailed observations by Hayabusa2 revealed numerous boulders on Ryugu's surface [1, 2] and its low bulk density (1190 kg/m³), suggesting that Ryugu has a rubble pile structure [3, 4]. The distribution of visible spectral slope on Ryugu's surface and stratigraphic relationship suggest that surface mass movement might have occurred from the equator and polar regions to the mid-latitude regions [1, 5]. In addition, morphological evidences for mass movement, such as imbricated boulders and asymmetric regolith deposits along boulders, have been reported [1]. However, the surface flows toward the mid-latitude regions on Ryugu has not been quantitatively characterized.

The spatial arrangement and orientation of clasts have been used for analyses of past flow directions [e.g., 6]. On the surface of rubble-pile asteroid Itokawa, the organized orientations of gravels were found in the boundary regions between the smooth and rough terrains, indicating gravel migration in the direction of local gravitational slopes [7]. To understand the direction and spatial scale of the mass movement, we measured the shape of boulders and investigated the relationship between their orientations (azimuth of major axis) and direction of gravitational slope on Ryugu. Based on these results, we discuss the mode of surface mass movement and the thickness of surface flow layer.

In order to measure the shape of boulders, we analyzed the images taken by Optical Navigation Camera Telescope (ONC-T) onboard Hayabusa2 [1, 8-11] during the MASCOT deployment operation (resolutions ~0.3 m/pixel), and created the catalog of boulders larger than 1 m in mean diameter near the equator (from 20°N to 30°S). This catalog includes size, axial ratio, azimuth angle of major axis of boulders.

Considering the accuracy of shape measurement and identification of major axis of boulders, we used nearly 500 boulders larger than 4 m in the mean diameter and the minor axis/major axis ratio less than 0.7 and observed in emission angle less than 30°. We also measured the shape of 792 small boulders and pebbles with diameters of 0.1 m to 7 m using close-up images obtained in the low-altitude operations (resolutions 0.013 m/pix and 0.033 m/pix). We calculated the angle between local gravitational slopes and major axes of boulders. To calculate local gravitational slopes, we used the SPC shape model of Ryugu [3] and took centrifugal force at the current rotation period (7.63 hours; [3]) into account.

The small boulders and pebbles exhibit its major axis tend to be preferentially perpendicular to the local slope direction than parallel ones, while boulders larger than 4 m do not show clearly such trend. Mass movement such as rolling of boulders can result in such transverse orientation to the local slope [e.g., 12]. The stronger arrangement of small boulders and pebbles suggest that they have more frequently experienced mass movement than larger boulders. This means that small boulders are relatively easy to move on Ryugu, which leads to segregation of small particles similar to asteroid Itokawa [7].

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