Topography of large craters and equatorial bulge of 162173 Ryugu

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In LIDAR topography data, 3 circular depressions are recognized near the equatorial bulge. All of these circular depressions are identified as craters and have been given names approved by IAU, namely Urashima, Kolobok, and Brabo craters. After careful calibration for different passes, consistent and precise cross sections of the craters are derived.

For Urashima crater, topography data of 4 passes are merged. Because these passes are taken in different days of operation, altitude of the spacecraft and sampling rate vary widely from 6 to 21 km and from 1/32 Hz to 1 Hz, respectively. Nonetheless, the cross sections show a good match. Similarly, three passes are merged for Kolobok and Brabo craters, and the match among different passes is very good for these craters, too, except for topography over large boulders.

Depth-to-diameter ratios (d/D) of Urashima, Kolobok, and Brabo craters are 0.2, 0.14, and 0.155, respectively, and are consistent with previous in situ observations of asteroid topography, while there seems marked difference from craters on Itokawa and Bennu. Both Itokawa and Bennu are comparable in size and surface gravity to Ryugu, and these 3 asteroids are regarded as rubble pile bodies. On the contrary, the d/D of Itokawa craters, 0.08 +- 0.03, is significantly shallower than that of Ryugu and other asteroids. The d/D of Bennu is apparently shallower, too. In addition, craters on Ryugu have topographically distinctive raised rim while those on Itokawa do not.

The low d/D of Itokawa is regarded as a result of either an influence of curvature of small body, a lack of raised rim, or fine grains infilling the craters, but has been unsolved. On the other hand, craters of Mathilde have characteristics much alike to those on Ryugu; the d/D ranging from 0.12 to 0.25, prominent raised rim, and a lack of ejecta blanket. While Mathilde is 50 times larger than Ryugu, the bulk density of Mathilde is only 1.34 +- 0.2 g cm^{-3}. Such low density is likely suggesting that Mathilde is as porous as 50 %.

The shapes of the four craters are neither bowl-shaped like 951 Gaspra and Eros nor flat like Itokawa. It is notable that slopes of inner wall of Ryugu craters are linear rather than paraboloidal, and that Kolobok and Brabo craters are flat-bottomed. 3D topography model of Urashima crater shows a central cavity on Urashima crater indicating an agreement with impact cratering experiments into porous targets, while the d/D of Ryugu crates is lower than experimental results which is between 0.2 and 0.5. It is interesting that slopes of the 3 craters are almost identical. Such nearly identical conical shape indicates that either the crater shape is well relaxed, or in the contrary, is holding initial shape.

The slopes of inner walls are measured with respect to local gravity estimated by taking GM of 30.0 $m^3 s^{-2}$ and assuming a constant density inside of Ryugu. The mode of the slopes of inner wall of Urahisma, Kolobok, and Breabo craters are between 16 and 20 degrees, 7 and 15 degrees, 16 and 18 degrees, respectively. The mode of slopes is shallower than the repose angle of regolith which is between 30 and 35 degrees. The shallow slopes and flat bottom may indicate that morphology of Ryugu craters is sufficiently relaxed. However, preservation of entire conical shape as well as central cavity of Urashima crater instead suggest that modification of crater topography on Ryugu is limited volumetrically and is less effective than Itokawa.

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