Artificial impact crater formed by Small Carry-on Impactor on the asteroid 162173 Ryugu in the gravity-dominated regime

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The Japanese asteroid explorer Hayabusa2 conducted an impact experiment by using a Small Carry-on Impactor (SCI) on the surface of Ryugu, which constituted the first impact experiment on an asteroid, on April 5th, 2019, and successfully formed an artificial impact crater larger than 10 m in size. The SCI crater has a semicircular shape and an elevated rim around the crater. We found a large boulder named as Iijima-boulder with the size of 5m on the crater floor and it could be moved about 3m northeast during the crater formation. There was another large boulder named as Okamoto-boulder at the south edge of the SCI crater, but we could not detect finite displacement of this boulder after the SCI impact. The Okamoto boulder might have a deep root below the surface and this boulder could stop the ejecta excavation flow toward the south region so that the SCI crater did not grow southward to became a semicircular shape. The size-frequency distribution of the boulders on the SCI crater wall was found to be different from that outside of the SCI crater: the sub-meter sized boulders were deficient on the crater wall. Moreover, a circular depression like a pit was recognized at the center of the SCI crater and it might indicate a cohesive subsurface layer.

The ejecta curtain was observed by a Deployable CAMera3 (DCAM3) from the beginning of the crater formation for more than 10 min. We found that the ejecta curtain continued to grow more than 200 s and the ejecta curtain growth was asymmetric and heterogeneous. We never observed the ejecta curtain growth toward the south, and this feature is consistent with the fact that the crater growth was prohibited by Okamoto-boulder placed at the south region. The observed ejecta curtain growing northward were separated into several rays and this heterogeneity could be due to large boulders covering the surface. The detachment of the ejecta curtain from the ground was never observed during the crater growth and beyond the duration of the crater formation time of 300 s. The ejecta was then confirmed to be deposit on the surface by the gravity of Ryugu.

Our observations of the SCI crater and the ejecta curtain showed that the artificial impact crater was formed in the gravity dominated regime although the surface gravity was as small as 10^{-5}G and the surface was covered with large boulders. Thus, the crater scaling laws in the gravity dominated regime are appropriate for Ryugu and the crater chronology on Ryugu should be revised according to crater size scaling laws that are suitable for the non-cohesive surfaces. This new finding on the suitable scaling laws for a small C-type asteroid could feed collisional evolution models of asteroid populations and their migration within the solar system.

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