Effects of surface topography on ejecta growth and crater formation process

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Impact craters are a typical geological feature found on solid bodies such as asteroids and satellites. The crater shape was observed to change depending on an impact angle and surface topographies. The crater formed on a plane surface usually looks like a circle except for craters formed by an oblique impact. Then, most impact craters are observed to be circular, but the crater found on a slope is usually elliptical. In addition, recent spacecrafts such as Hayabusa2 and OSIRIS-REx have revealed that Ryugu and Bennu have a bulge terrain at the equatorial region and large impact craters with a unique shape are found on the bulge. However, the effects of the bulge topography on the crater formation process have not been well understood. In this study, we performed crater formation experiments on targets simulating a bulge and a ridge made of regolith and investigated the effects of the topography on crater shape, ejecta growth and its sedimentation process.

We have prepared a mountain range and a cone shape target in order to simulate a bulge and a ridge. The target is composed of quartz sand with a diameter of 100 mm and the angle of repose for quartz sand is about 30 degrees. The slope was controlled to be 20 degrees and 30 degrees for the mountain range type and 30 degrees for the cone shape type. The impact experiments were conducted by using a vertical gas gun, and the mountain range target was set in a glass container to observe the crater formation from the side. The cone type target was set in a stainless container, and was placed in a vacuum chamber. The chamber was evacuated below 1000 Pa or less. The projectile was an alumina sphere with the diameter of 3 mm and an aluminum sphere with the dimeter of 2 mm, and it was impacted on the target surface vertically at the speed from 69 m/s to 202 m/s for the mountain range type target and from 1.19 km/s to 4.19 km/s for the cone type target. For the mountain range type target, the horizontal distance from the summit to the impact point, d, was changed from 1 mm to 19 mm, and for the cone type target, the width of the cone shape was changed from 85 mm to 280 mm.

As a result, the crater shape was found to strongly depend on d in the mountain range type target, and the craters formed near the summit were observed to be elliptical. The major axis of the ellipse appeared to be along the ridge direction, and the minor axis appeared to be along the slope direction. The aspect ratio of the major axis to the minor axis decreased with the increase of d, and at the same d, it increased with increasing the impact velocity. In the cone type target, the depth-to-diameter ratio was always smaller than that of the crater formed on the plane surface, and it was found that the ratio became smaller as the impact velocity increased. Furthermore, the smaller the width of the cone shape is, the greater the excavation efficiency is. In addition, it was found that the ejecta curtain formed on the slope had a smaller curtain angle on the side of the impact point, and that the asymmetry of the ejecta curtain increased when the d was smaller (figure).

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