

Cratering experiments on boulders surrounded by regolith: Armoring effect on cratering processes

*Tadakatsu Utsunomiya¹, Minami Yasui¹, Masahiko Arakawa¹, Yusaku Yokota¹

1. Kobe university

The Hayabusa spacecraft observed that the surface of the asteroid Itokawa is covered with pebbles and boulders with a diameter of several centimeters to several meters, making it the first example of direct observation of a rubble-pile object. In addition, compared to the Moon, Itokawa has very few small craters, and holes and fractures can be seen on the boulder surface, suggesting that an armoring effect is working in the crater formation process on Itokawa. Previous laboratory experiments using boulder-covered asteroid surface simulants showed that the crater size was significantly reduced when the diameter ratio of projectile to target particle was less than 1. It has been shown that the crater size follows a scaling including the target particle strength when the impact energy is smaller than the strength of the target particle. However, all previous experiments using coarse-grained targets had the same particle size. Focusing on a single boulder, the behavior of the boulder when colliding with it and the crater formation process are still unclear. In this study, we investigated the effect of burial depth and strength of boulder on the armoring effect in order to clarify the effect of boulder exposed on the ground surface on the crater formation process. Specifically, we changed the burial depth of a sample simulating a boulder, and investigated the amount of ejecta, the crater morphology, and the degree of boulder disruption.

To simulate a boulder, a mixed sphere with a diameter of 40 mm was prepared by mixing gypsum and quartz sand with a diameter of 100 microns at a mass ratio of 8 to 1, and placed in the center of a tub covered with 100-micron quartz sand. The depth of the mixing sphere was defined as the height from the bottom of the sphere to the target sand surface, and was varied from 0 mm to 40 mm in 10 mm increments. Cratering experiments were conducted using a vertical single-stage light gas gun at Kobe University. A nylon ball with a diameter of 10 mm was used as the projectile. The impact velocity ranged from 76 to 212 m/s. Collisional phenomena were photographed by a high-speed camera to confirm the position of the impact point and to observe the shape of the ejecta curtain and the disruption of the mixing sphere.

For quartz sand without a mixing sphere (homogeneous target), a cone-shaped crater was formed and the projectile remained in the center of the crater. This is a typical crater shape in the gravity-dominated regime. On the other hand, when a mixing sphere was placed, a large difference was observed in the crater formation process depending on the depth. At a depth of 0 mm, no crater was formed, and the sphere's fragments were disrupted catastrophically and scattered radially, forming radial traces on the sand surface centered on the impact point. No ejecta curtain was observed. At a depth of 20 mm, a crater was formed, but an irregular crater shape with radial traces was observed. And the largest fragment of the mixing sphere was buried in the center of the crater, and many small fragments were scattered inside the crater. The ejecta curtain was very thin. At a depth of 40 mm, a cone-shaped crater was formed, similar to the case of homogeneous target, and the degree of disruption of the mixing sphere was smaller than that at a depth of 0 mm, and the largest fragment remained buried. The ejecta curtain had an inverted conical shape, similar to that of homogeneous target.

Comparing the crater rim diameters at each depth, two distinct trends were found. At depths of 0 to 10 mm, no craters were formed and the diameter was almost 0 mm. On the other hand, at depths of 20 to 40 mm, the crater diameter was larger than that at a depth of 0 to 10 mm, but there was no significant difference in the data between these depths, and the crater diameter was 80 to 90% of that for

homogeneous target. This suggests that the armoring effect was hardly effective when the boulder was more than half buried from the target surface.

Keywords: asteroids, crater formation processes, armoring effect, boulders, buried depth