The origin of Itokawa dimples and a comparison with the surface structure of Phobos

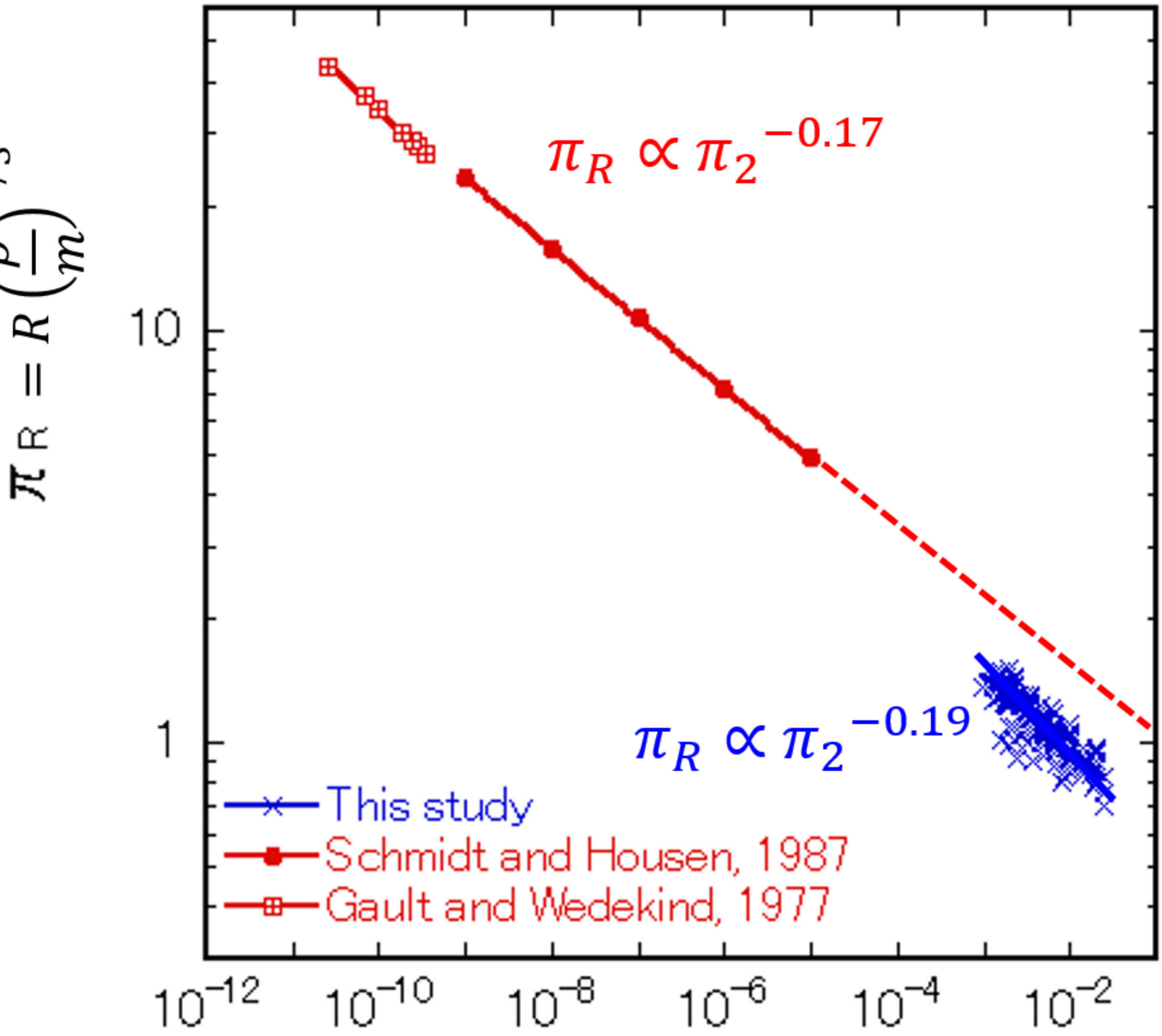
*Masato Kiuchi[1], Akiko Nakamura[1]

1.Graduate School of Science, Kobe University

High-resolution images of asteroid 25143 Itokawa obtained by Hayabusa mission revealed that the surface of Itokawa has unique feature compared to other asteroids. The surface of Itokawa can be divided into two regions, one is rough terrain composed by many boulders and the other is smooth terrain composed by fine materials. On the smooth terrains small dimples associated with boulders are observed. This structure was considered as results of low-velocity impacts of boulders (Nakamura et al., 2008) or seismic shaking beneath boulders (Hirata et al., 2009), however, the origin of dimples have not been understood.
Although widely used successfully for craters on planetary surfaces, whether the scaling law about crater size (Holsapple, 1993) can be applied to low-velocity impacts is not obvious. This scaling law was originally derived based on point source approximation which can be applied when the crater size is sufficiently large as compared with impactor size. Moreover, the gravity dependence of crater diameter has not been fully understood. Hypervelocity impact experiments were conducted under increased gravities (Schmidt and Housen, 1987) and under low gravities (Gault and Wedekind, 1977). In these experiments crater diameter was proportional to about -0.17 power of gravitational acceleration. However, there are few impact experiments under different gravity condition except above experiments.
We developed a drop mechanism which can simulate gravities smaller than 1 G. A target container was suspended by springs of constant force, or fallen freely to archive simulated gravity range between 0.01 and 1 G. We used silica sand of average diameter 140 μm as the target material. Stainless steel sphere of 8 mm diameter was impacted onto the target and the impact velocity was between 1 and 5 ms^{-1}. As a result, the crater diameter was proportional to -0.19 ±0.01 power of the gravitational acceleration. This value is roughly in agreement with previous studies at hypervelocity (Kiuchi and Nakamura, 2015 JPGU meeting).
However, the crater diameter obtained by our experiments is not on the line expected from the scaling law (Holsapple, 1993) as shown in the Figure. This difference is caused by a difference of the power-law exponents of π_2; the exponent is -0.19 for low-velocity impacts and -0.17 for hyper-velocity impacts. A steeper exponent, -0.25, was obtained for our new impact experiments with glass bead projectiles conducted in the similar setup. These results suggest that the impact energy is consumed for crater formation more efficiently at low-velocity impacts compared to hypervelocity impacts.
We estimated the crater diameter formed by re-impacts of boulders ejected from primary crater on Itokawa based on results of our experiments. We assumed that these boulders impact onto smooth terrain at escape velocity of Itokawa, 0.17 ms^{-1}. By combining with these conditions of Itokawa surface and the scaling law obtained by our low-velocity impact experiments, the crater diameter formed by the impact of a boulder of diameter 2 m would be 7 -8 m. Note that the impact velocity assumed was the maximum value and the effect of porosity difference between the laboratory and Itokawa surface was not considered here, however, the estimated crater diameter was consistent with observational data in which the diameter of dimple associated with a boulder of diameter 2m is about 7 m. This result supports the possible low-velocity boulder-impact origin of dimples.
We applied similar estimate to boulders derived from Stickney crater of Phobos. As a result, craters which have about 2 to 3 times diameter of boulders would be formed. However, we have not identified dimples associated with boulders on surface images of Phobos. This may be due to a

difference of the surface structure of Itokawa and Phobos and/or due to a difference of surface evolution processes of two bodies.

Keywords: dimple, Itokawa, impact experiments, Phobos



g: gravitational acceleration

a: impactor radius

v: impact velocity, R: crater radius

ρ: target density, m: impactor mass

$$\pi_2 = \frac{ga}{v^2}$$