

Resurfacing processes on small asteroids constrained by crater size distributions on Ryugu, Itokawa, and Eros

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Recent ion irradiation experiments in laboratories suggest that space weathering may take place very rapidly [1], but telescopic observations of asteroids support much slower space weathering [2]. The spectral rejuvenation process on asteroid surfaces may hold a key for bridging the gap between the two opposite conclusions [3]. However, the nature of the spectral rejuvenation process has not been understood well yet. One approach for understanding the spectral rejuvenation process is to constrain the depth-age relation of surface layers on asteroids. In fact, imaging observations by Hayabusa2 revealed that smaller craters are highly depleted on the surface of the asteroid Ryugu [4], strongly suggesting that resurfacing is acting efficiently on near-surface layers. This depletion was already observed on Eros and Itokawa [5]. In this study, we analyze this depletion in small craters to constrain the resurfacing mechanism on small asteroids, such as Ryugu, Itokawa, and Eros. More specifically, we estimate the resurfacing age of Ryugu, Itokawa and Eros based on crater counting and crater production functions. Then we compare the analysis results with theoretical models for resurfacing mechanisms on such small asteroids.

Crater retention age can be estimated by using both the crater size frequency distribution (CSFD) and the crater production function (CPF). The CSFD on Ryugu shows that the large craters distribution ($\geq 100\text{m}$ in diameter) is close to saturation level, but the number density of small craters ($\sim 10\text{ m}$) is reduced by a factor of 100 [4]. Similar depletion in small craters is also observed on Itokawa [5]. We calculated crater retention ages for different size craters and derived the relation between crater retention ages and excavation depth of craters.

The CPFs on Ryugu, Itokawa, and Eros are estimated based on a classical main belt collisional evolution model and a scaling relation for crater formation. We used a scaling relation including armoring effect [6] for Ryugu and Itokawa to account for the high abundance of boulders on them. In this analysis, we used larger craters than $\sim 10\text{m}$ in diameter. Finally, we derived the relation between crater retention age, t , and depth, d , of crater, $t \sim d^a$, where a is found to be 1.8 ± 0.4 on Ryugu, 1.1 ± 0.3 on Itokawa, and 1.9 ± 0.3 on Eros, respectively. If crater degradation is controlled by a diffusion process, the relation between crater retention age t is proportional to the square of crater depth d , i.e., $t \sim d^2$. Ryugu's and Eros's power-law indices ($a \sim 1.8-1.9$) are consistent with diffusion ($a = 2$), which is not the case of Itokawa's power-law index. However, Itokawa's power-law index a increase to 1.9 if we include smaller craters than $\sim 10\text{m}$ in

diameter in this analysis. This value is consistent with diffusion ($a = 2$). Actually, Michel et al. 2009 suggests that the depletion of small craters on Itokawa is reproduced by a seismic shaking model without taking an armoring effect into account [7]. The efficiency of an armoring effect for small craters on asteroids is uncertain, but an armoring effect may change the interpretation of CSFDs. In order to understand crater scaling for smaller craters, Small Carry-on Impactor (SCI) experiment on Hayabusa2 is important.

[1] Lantz+2018, Icarus, **302**, 10–17

[2] Lazzarin+2009 AA, **498**, 307-311

[3] Shestopalov+2013, Icarus, **225**, 781-798

[4] Sugita+2019, Science in revision

[5] Hirata+2009, Icarus, **200**, 486-502

[6] Tatsumi & Sugita 2018, Icarus, **300**, 227-248

[7] Michel+2009, Icarus, **200**, 503-513

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