Resurfacing rate based on the crater distribution on Ryugu: Implication for Ryugu’ s sample ages

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The depletion of small craters on Ryugu, which is observed by the Optical Navigation Camera Telescope (ONC-T) onboard the Hayabusa2 spacecraft, suggests the presence of resurfacing processes [1,2]. The cratering process which leads to excavation and crater obliteration, mixes surface materials with subsurface materials vertically over the entire crater depths. The timescale of such a mixing process sets a limit to the residence time of surface grains, which will be recorded as a cosmic-ray exposure (CRE) age. Thus, the timescale of resurfacing on Ryugu is a good basis of comparison with the CRE ages of Ryugu's returned samples. However, the resurfacing rate for various depths on Ryugu have not been estimated.
In this study, we estimated the resurfacing rate on Ryugu as a crater retention age by using crater production functions (CPFs). The CPFs consist of impactor size-frequency distribution models and a crater scaling relation, which links the impactor's size to a crater's size, and can reproduce crater size-frequency distributions (CSFDs) on the fresh surface of an asteroid. If no crater obliteration is present, the CSFD on an asteroid follows a single CPF. The time *t(D)* required to produce the observed crater number density on an asteroid is obtained by calculating the intersections between the CPFs and the observed CSFDs. The time *t(D)* is the retention age of craters of diameter *D*. We calculated the CPFs of different ages to estimate the retention ages for craters of different size on the CSFDs. To assess the uncertainty due to impactor distribution models, we used two main-belt impactor models and three near-Earth impactor models [3,4,5]. To address the boulder-rich surface of Ryugu, we used a scaling relation including the armoring effect [6].
Craters on Ryugu can be classified into two groups based on the color of crater floors: red craters and blue craters [2,7]. Most of craters smaller than 30 m (~70 %) have bluer spectra than their surroundings [2]. The blue craters on Ryugu are considered to be formed while Ryugu evolved on a near-Earth orbit based on the Ryugu's stratigraphy of surface colors [7]. Thus, we applied the main-belt impactor models to craters larger than 30 m and the near-Earth impactors models to craters equal to or smaller than 30 m.
The retention ages of 10-m craters are estimated to be 10^3–10^5yr. Assuming a crater depth-to-diameter ratio of 0.1, we can interpret the retention age as the consequence of the mixing of 1-m surface materials on Ryugu on a timescale of 10^3–10^5yr. When we compared the resurfacing timescale with the CRE ages of returned samples, we used the resurfacing timescale at a depth deeper than the penetration depth of cosmic rays (~1 m). This is because the mixing of materials within the top 1 m of surface allows the CRE ages to accumulate. In fact, we should compare the CRE ages of returned samples with the resurfacing timescale at a depth of 2–4 m, where cosmic rays cannot reach. The 2–4 m layer on Ryugu has been mixed on a timescale ranging from 10^4yr to a few Myrs. Although the timescale depends on the near-Earth impactor models, the upper value (a few Myr) is comparable to the CRE age (5-6 Myr) based on the cosmogenic ^{21}N concentrations (Fig.1) [8]. This result suggests that the vertical mixing of materials by

cratering is the surface geological process explaining the CRE ages.

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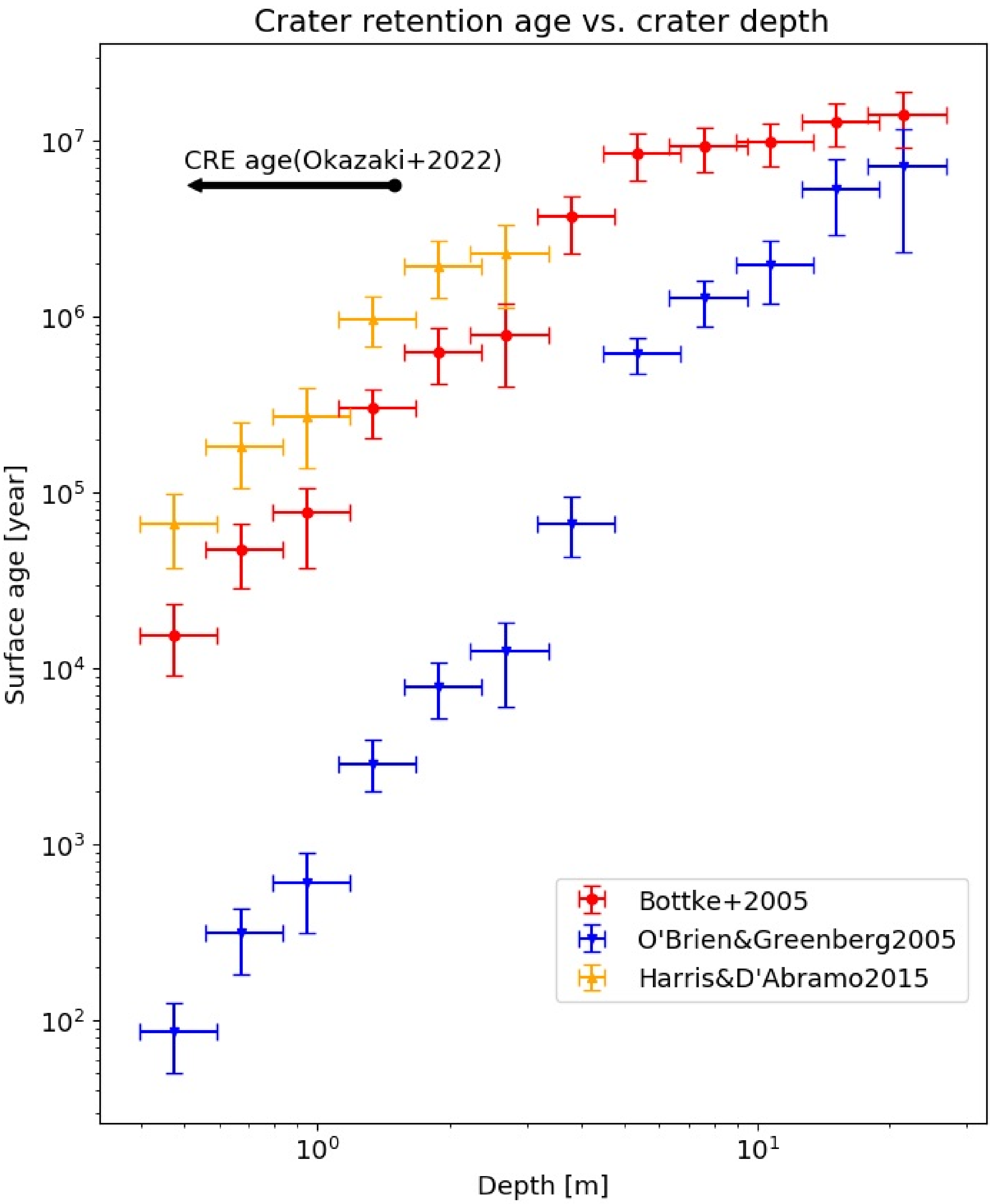
Fig. 1. Relation between a crater retention age and crater depth. We used three impactor models. The black circle indicates the CRE age of returned samples, which is comparable to the timescale of mixing to 2-4 m derived from the impactor model calculated by Harris and D'Abramo (2015).

Keywords: Asteroid, Craters, Resurfacing processes


Crater retention age vs. crater depth
CRE age(Okazaki+2022)
Surface age [year]
Depth [m]
Bottke+2005
O'Brien&Greenberg2005
Harris&D'Abramo2015