STATISTICS OF SMALL CRATERS OBSERVED ON BOULDER SURFACE OF ASTEROID RYUGU. Y. Takai[1], T. Morota[1], K. Yumoto[1], R. Honda[2], S. Kameda[3], E. Tatsumi[1,4], Y. Cho[1], K. Yoshioka[1], H. Sawada[5], Y. Yokota[2,5], N. Sakatani[3], M. Hayakawa[5], M. Matsuoka[5], M. Yamada[6], T. Kouyama[7], H. Suzuki[8], C. Honda[9], K. Ogawa[10,11], S. Sugita[1], [1]Univ. of Tokyo (takai@eps.s.u-tokyo.ac.jp), Tokyo, Japan, [2]Kochi Univ., Kochi, Japan, [3]Rikkyo Univ., Tokyo, Japan, [4]Instituto de Astrofísica de Canarias, Tenerife, Spain, [5]Japan Aerospace Exploration Agency, Kanagawa, Japan, [6]Planetary Exploration Research Center Chiba Institute of Technology, Chiba, Japan, [7]National Institute of Advanced Industrial Science and Technology, Ibaraki, Japan, [8]Meiji Univ., Kanagawa, Japan, [9]Univ. of Aizu, Fukushima, Japan, [10]Japan Aerospace Exploration Agency, JAXA Space Exploration Center, Kanagawa, Japan, [11]Kobe Univ., Hyogo, Japan

Introduction: The Hayabusa2 spacecraft had conducted its rendezvous with the asteroid Ryugu from June 2018 to November 2019. Detailed observations by Hayabusa2 have revealed a large number of boulders on Ryugu's surface and its low bulk density of 1190 kg/m^3, suggesting its "rubble-pile" structure [1, 2, 3]. Unraveling the lifetime of boulders is important for understanding the surface processes, such as thermal fatigue, impacts and surface flow, and its timescale on Ryugu's surface.

On Ryugu's surface, there are many craters larger than 10 m in diameter [4, 5, 6]. Based on the crater number densities, the surface age of Ryugu has been estimated to be ~8 Myr from the size distribution of crater larger than 100 m in diameter [4, 7]. The low number density of craters smaller than 100 m may be attributed to surface flow [4, 8]. However, statistics of small craters on the boulder surface has not been investigated yet.

During the touchdown operations on February 22, 2019 and July 11, 2019 (Japan Standard Time), the Optical Navigation Camera (ONC) onboard the Hayabusa2 spacecraft [4, 9-12] took several consecutive high-resolution images (~0.1 cm/pixel), which showed topographic features of Ryugu's surface on the scale of a few centimeters. Because the characteristic size of the Ryugu's boulder is estimated to be 3 m [4], low-altitude imaging during the touchdown allowed us to observe small craters on the boulder surface.

The purpose of this study is to constrain the survival time of the boulders on Ryugu by investigating the statistics of small craters on the boulder surface. We will discuss the disruption and resurfacing processes of boulders based on the estimated survival time of boulders and comparisons with the crater densities of large craters and mini craters on boulder surface of asteroid Bennu [13].

Method: Using the high-resolution images of the surface of Ryugu taken at the first and second touchdowns (hereafter, "TD1" and "TD2"), we investigated 841 boulders and identified 19 circular depressions on the boulder surfaces that are candidates for small craters on the scale of several centimeters to tens of centimeters (Fig. 1). The candidates for small craters were classified based on whether topographic depressions are identified or not. Out of the 19 candidates, there were 4 small craters that could be clearly identified as depressions. Figure 1 shows examples of small craters located near the TD1 and TD2 sites.

We constructed a cratering chronology model of small craters on Ryugu's boulders based on the Pi-group crater scaling law under the strength regime [14] and the size-frequency distribution model of near-Earth object population [15, 16]. In this model, we used the boulder strength of 200~280 kPa, which is estimated from the data of the thermal radiometer MARA onboard the MASCOT lander [17]. The surface age of boulders on Ryugu was estimated from the cratering chronology model and the statistics of the observed small craters.

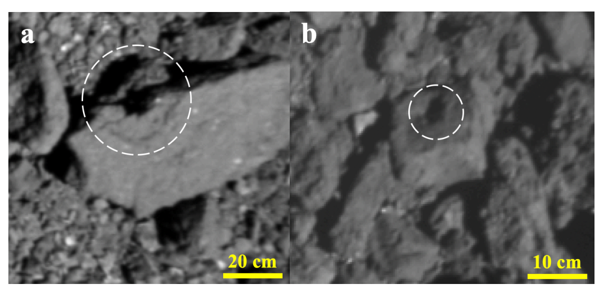

Fig. 1. Small craters observed on Ryugu's boulders. **(a)** A small semicircular crater approximately 30 cm in diameter on a 1-m boulder with a flat surface, located near the first touchdown site (4.3˚N, 206.5˚E). **(b)** A small crater approximately 3 cm in diameter on a 20-cm boulder with a flat surface, located near the second touchdown site. (10˚N, 300˚E)

Results: Figure 2 shows the size-frequency distributions (SFDs) of small craters. Based on the isochrones and plots of small craters, the surface age of boulders on Ryugu can be estimated to be 10^4 to 10^6 years. This is younger than the global surface age of Ryugu (~8 Myr) [4, 6, 7]. Moreover, Ryugu's boulders have lower crater density than that of Bennu's boulders, whose surface age is estimated to be 1.75 ± 0.75 Myr [13] based on the same size frequency distribution of near-Earth object population [15].

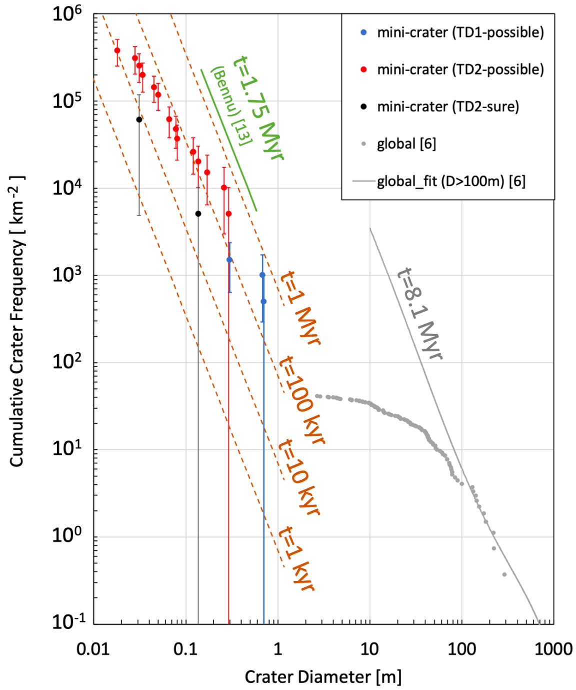

Fig. 2. Crater size-frequency distributions on Ryugu and Bennu. Blue, red and black circles indicate the SFDs of small craters near the TD1 and TD2 sites. Gray circles indicate the SFD of global large craters [6]. Dashed lines show isochrones of 1 kyr to 1 Myr calculated from the cratering chronology model for Ryugu's small craters. Gray curve indicates a model SFD fitted to the global crater data. The model SFD was calculated based on the crater scaling law for coarse-grain target [18] and the main-belt asteroid population model [19]. Green solid line indicates a fitting line of small craters on boulders of Bennu [13].

Discussion: The result that the boulder surfaces are younger than the Ryugu's crater retention age suggests that the boulders have been disrupted or resurfaced on Ryugu's surface by some surface processes such as thermal fatigue and micrometeoroid impacts. Laboratory experiments and numerical simulations for thermal fatigue and micrometeoroid impacts suggest that the survival time of cm-sized carbonaceous chondrites at 1AU is ~10^4 to 10^7 years [20, 21], consistent with the surface age of Ryugu's boulders. Therefore, it is suggested that one of the main factors contributed to determine the timescale of disruption or resurfacing process of Ryugu's boulder is exfoliation of rock surface on the scale of a few centimeters due to thermal fatigue and micrometeoroid impacts.

The lower crater density on Ryugu's boulders compared with Bennu's boulders [13] suggests that Ryugu's boulder surface suffered more rapid disruption or resurfacing process. The difference of resurfacing rate between Ryugu's and Bennu's boulders may be attributed to differences in the environment of micro-object bombardment and orbital distance from the sun [7, 22], which controls the crack growth speed by thermal fatigue, in the past.

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