TIMESCALE OF REDDENING PROCESS OF THE RYUGU SURFACE BASED ON THE CRATER SIZE-FREQUENCY DISTRIBUTION.
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Introduction: The Hayabusa2 spacecraft arrived at the C-type asteroid (162173) Ryugu on June 27, 2018, and has acquired the high-resolution images and spectra of the Ryugu surface [1-3]. Although Ryugu's surface has almost homogeneous reflectance and color at the macro scale [3], the regional variation in the spectral slope from b- to x-band (b-x slope, 0.48 - 0.86 μm slope) is observed by the telescopic optical navigation cameras (ONC-T) [1, 2, 4]. The redder materials of the Ryugu surface seem to cover blue materials. Some small craters excavate the red materials on the surface and penetrate the underlying blue materials (Figure 1), suggesting that the craters are younger than the reddening of the surface (space weathering or deposition of red materials). In this study, we performed the crater size-frequency measurements on the Ryugu surface using the ONC image data to constrain the surface age of the Ryugu and the age of reddening event or the timescale of reddening process of the Ryugu surface.

Identification of Craters: We used images obtained from Box-A (20 km altitude) and Box-C (5–7 km altitude), and in the Mid-altitude operation (~5 km altitude) to identify craters. The spatial resolutions of the images are 2 m/pixel, 0.5–0.7 m/pixel, and 0.5 m/pixel, respectively. We identified 68 craters larger than 20 m in diameter on the whole surface of Ryugu. These craters were categorized into 4 classes based on the confidence level (CL) [5], CL1: circular depression with rim, CL2: circular depression, CL3: quasi-circular depression, CL4: Quasi-circular feature.

To identify the craters excavating the red materials we used the b-x slope images [4] calculated from multi-band images obtained in the Mid-altitude operation. We identified 15 craters excavating the red materials. These craters have diameters from 10 to 50 m, suggesting that the thickness of the red material layer is less than 1 m.

Cratering Chronology Model of Ryugu: The cratering chronology models of asteroids have been numerically calculated from the collision rate with other asteroids and scaling laws for crater formation [6–8]. In this study, we used the intrinsic collision probabilities Pi for the main belt and the NEAs [9, 10], the population models of the main belt asteroids and NEAs [11, 12], the mean impact velocities for the main belt (5.3 km/s) and the NEAs (18 km/s) [9, 10], and the new Pi–scaling law developed by Tatsumi and Sugita [13] to develop the cratering chronology model of Ryugu. Because little is known about the bulk strength of materials on Ryugu, we examined two cases (i) the strengthless target (Y = 0 MPa) and (ii) the strength for dry soil (Y = 0.18 MPa) [14].

Crater Size-frequency Distribution and Model Ages: The density of large craters (D>100 m) on Ryugu is lower than the empirical saturation level and its slope is steeper than that of the saturated distribution, suggesting that craters larger than 100 m are not saturated and the size distribution reflects the crater production function. However, craters smaller than 100 m are significantly under-saturated, suggesting that some crater erasure processes such as seismic shaking [15] and armoring effect [13, 16] are active on the Ryugu surface. Based on cratering chronology model for the main belt, the surface age of Ryugu is estimated to be 5–200 Ma from the size–frequency distribution of craters larger than 100 m [1].

The observed frequency of craters penetrating the underlying blue materials is ~1/50 of that of craters found on the whole Ryugu. The model age of the reddening is estimated to be 0.1–4 Ma based on the main-belt chronology model and 4–160 Ma based on the NEA chronology model. The NEA model age is roughly close to the median dynamical lifetime of NEAs (~10 Ma) [17, 18], suggesting that the reddening of the Ryugu surface may have some connect with the orbital transition from the main belt to near Earth orbit.

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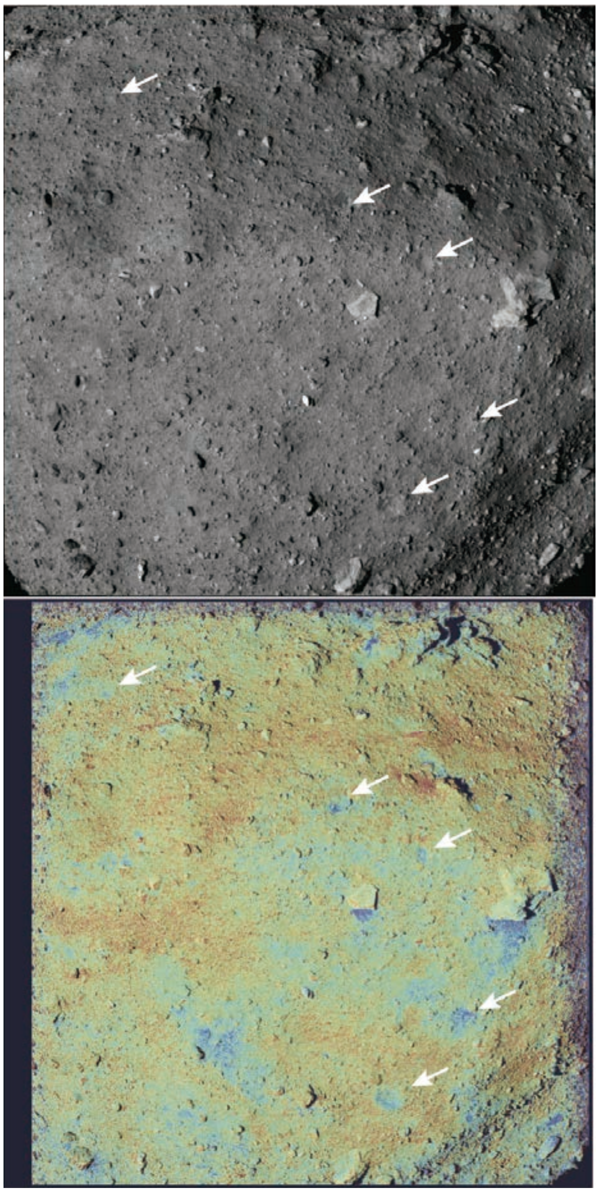

Figure 1. ONC-T image obtained in the Mid-altitude operation (hyb2_onc_20180801_203445_tvf_l2d) and the b-x slope image [4]. Arrows show the craters excavating the surface red materials.

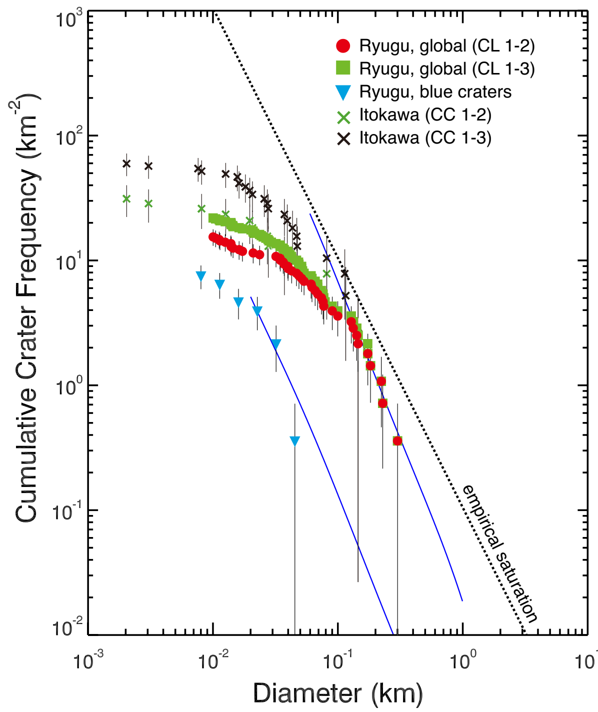

Figure 2. Cumulative crater size-frequency distribution. Blue curves indicates the crater production function (the MBA chronology model) fitted to the observed size distributions. Dashed line indicates the empirical saturation level. Error basrs are calculated by $\log(N \pm N^{1/2})/A$, where N is the cumulative number of craters and A is the counted area. Data of Itokawa craters are from Hirata et al. [19]. CL: Confidence level [1, 5]. CC: Confidence class [19]