

RAPID SPACE WEATHERING PROCESS ON RYUGU INFERRED FROM THE ARTIFICIAL CRATER.

E. Tatsumi^{1,2,3}, M. Matsuoka⁴, S. Sugita³, K. Yumoto³, N. Takaki³, Y. Cho³, R. Honda⁵, M. Yamada⁶, T. Morota³, N. Sakatani⁷, S. Kameda⁷, T. Kouyama⁸, Y. Yokota^{4,5}, C. Honda⁹, M. Hayakawa⁴, H. Suzuki¹⁰, K. Yoshioka³, H. Sawada⁴, K. Ogawa^{4,11}, N. Hirata⁹, N. Hirata¹¹, T. Saiki⁴, H. Imamura⁴, Y. Takagi¹², H. Yano⁴, K. Shirai¹¹, C. Okamoto[†], Y. Tsuda⁴, S. Nakazawa⁴, Y. Iijima[†], K. Kitazato⁹, T. Kadono¹³, K. Wada⁵, M. Arakawa¹¹, M. Hirabayashi¹⁴, S. Watanabe¹⁵, ¹Instituto de Astrofísica de Canarias, Tenerife, Spain (etatsumi@iac.es), ²Dept. of Astrophysics, Univ. of La Laguna, Tenerife, Spain, ³Univ. of Tokyo, Tokyo, Japan, ⁴Japan Aerospace Exploration Agency, Kanagawa, Japan, ⁵Kochi Univ., Kochi, Japan, ⁶Planetary Exploration Research Center, Chiba Inst. of Tech., ⁷Rikkyo Univ., Tokyo, Japan, ⁸National Inst. of Adv. Ind. Sci. and Tech., Ibaragi, Japan, ⁹Univ. of Aizu, Fukushima, Japan, ¹⁰Meiji Univ., Kanagawa Japan, ¹¹Kobe Univ., Hyogo, Japan, ¹²Aichi Toho University, Aichi, Japan, ¹³Univ. of Occupational and Environmental Health, Kitakyusyu, Japan, ¹⁴Auburn Univ., Alabama, USA. ¹⁵Nagoya Univ., Aichi, Japan, [†]Deceased

Introduction: The Japanese spacecraft Hayabusa2 investigated the Cb-type asteroid Ryugu from June 2018 to November 2019 [1]. After the global mapping and the first touch-down operation, Small Carry-on Impactor (SCI) operation was successfully conducted on 5 April 2019 to make an artificial crater (SCI crater) [2]. This operation aimed to reveal cratering mechanism on asteroids with very small gravity. Mass of the impactor is ~2 kg and the impact speed was estimated as ~2 km/s. Moreover, this operation gave us a precious opportunity to uncover a substrate layer of Ryugu, observe it by the remote-sensing instruments, and explore unweathered materials. The observation of SCI crater might give us the insights of space weathering, heating, and layering on Ryugu. Hayabusa2 is equipped with a telescopic multiband camera, ONC-T [3]. ONC-T has seven color filters in near-ultraviolet to near-infrared wavelength; ul: 0.40 μm , b: 0.48 μm , v: 0.55 μm , Na: 0.59 μm , w: 0.70 μm , x: 0.86 μm , p: 0.95 μm .

We investigate spectral slope, UV down/up-turn, and 0.7- μm band absorption around the SCI crater. For global observations, the spectral slope was the most prominent variation in visible spectra [3]. The bluer regions of Ryugu, such as the equatorial ridge and the pole regions, correspond to higher gravitational potential regions, suggesting mass wasting from higher to lower potential regions and leading to the bluer subsurface material to be the fresher region on Ryugu [3]. Recently, more detailed mapping in the pole regions were conducted and possible 0.7- μm band absorption, indicative of Fe-bearing hydrated minerals, was suggested [4]. This observational result led to a scenario of space weathering by solar wind in the past [4]. The observational facts from the SCI crater could also be strong constraints on the space weathering effect on Ryugu. In this study, we report the visible color observation results of the SCI crater and discuss the processes occurred on the surface of Ryugu in the context of both the global observation and the SCI crater observation.

Data Processing: Before (8 March 2019) and after (30 May 2019) the SCI operation, ONC-T observations at the SCI target site with multi-band filters were conducted. The spatial resolutions before and after the SCI observations are 13 and 5 cm/pixel, and the phase angles are 17° and 32°, respectively. After the conversion to radiance factor (I/F) [5,6] and co-registration to v-band images, we measured the spectral indexes, such as spectral slope, 0.7- μm band depth, and UV-index. The spectral slope from b band to x band is measured by the same method as in [3], but in this study we used 6 bands (ul, b, v, w, x, and p).

Color of the SCI crater: Figure 1 shows the spectral slope map for the SCI crater. The floor of the SCI crater is found to be bluer than the surrounding region. The clear color difference is observed between the inside and outside of the SCI crater. The floor material might be excavated from the sublayer of the impact site. It should also be noted that the possible impact site between two boulders, Mobile boulder and Stable boulder, is redder in comparison with the global average. We also see the relatively red part on the eastern wall of the crater. Moreover, after the SCI operation, Mobile boulder was excavated, and we see the bluer color for the part which had been lied underground. The UV-index value of inside the SCI crater is slightly smaller than surrounding area. However, the 0.7- μm band depth is similar for inside and outside of the SCI crater.

Discussions: Based on the global observation, we had expected to see bluer material inside of the SCI crater. While we see the relatively bluer material inside of the SCI crater than its vicinity, the degree of blueness of the SCI crater is similar to the equatorial ridge and far redder than the material around both north and south poles, which have negative values of spectral slope. Relatively bluer materials inside of the SCI crater support the hypothesis of the fresh bluer material under the red surface material as suggested by [3,7]. However, the darker and bluer SCI crater floor cannot be on the main trend of Ryugu, which is brighter and bluer to

darker and redder [3,8]. Since the SCI crater is the freshest feature on Ryugu, the space weathering on Ryugu might brighten the material in a very short time scale. This brightening time scale should be much shorter than the crater retention age of 10-m sized craters, which is estimated $10^3 - 10^5$ yr [9]. This short time scale of space weathering may correspond to the ion irradiation induced space weathering with the time scale of $10^3 - 10^4$ yr [10] rather than micrometeorite bombardment induced space weathering with time scale of $10^6 - 10^7$ yr [11].

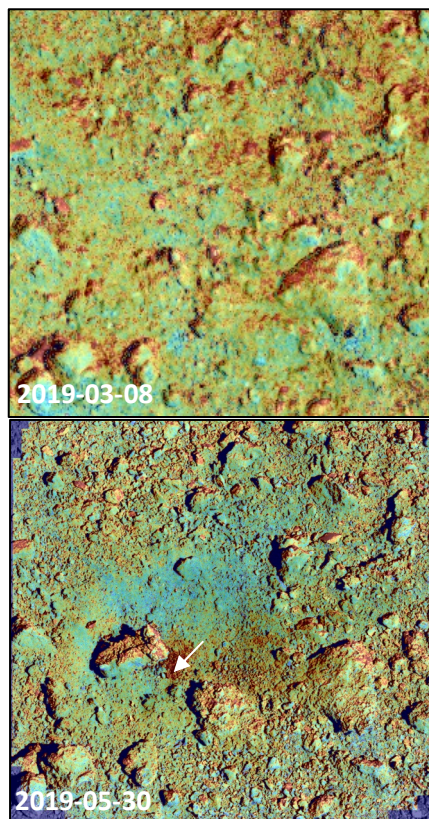


Figure 1. The b-to-x spectral slope maps around the SCI crater: before (top) and after (bottom) the SCI operation. White arrow indicates the impact point of SCI. The floor of SCI crater shows bluer spectra, and the possible impact site shows redder spectra.

Another interesting color feature is the redder material in the middle of the SCI crater, at the impact point. We can see the similar feature for some of the natural craters (Fig. 2). This feature can be observed in more than 10% of craters > 20 m found in [12]. This could be explained by the metamorphism by high pressure and temperature process [13], breaking up of material just at the impact site which can be sometimes observed by the impact experiments, or excavating another layer underneath. Some of these red materials

have very high porosity observed by the thermal imager, while the red material in the SCI crater shows the porosity similar to the average [14].

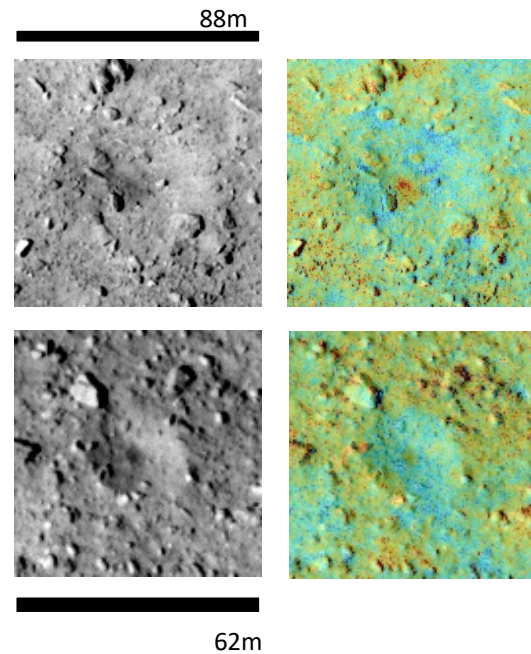


Figure 2. The I/F (left column) and b-to-x spectral slope (right column) images of two natural craters (top row: #21 and bottom row: #46 in [12]). These craters show a bluer floor and a dark and reddish central region similar to the SCI crater.

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