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High-resolution imaging and dynamic response observations of asteroid Ryugu

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Abstract

Touchdown operation and artificial impact experiment provided unique opportunities for high-resolution imaging and for monitoring the dynamic response of the Ryugu surface to physical contacts with prescribed amounts of forces. Results support thermally metamorphosed carbonaceous chondritic (C.C.) materials and revealed complex nature of space weathering and/or surface conditions of C.C. materials.

1. Introduction

Global observations of asteroid Ryugu by JAXA's Hayabusa2 spacecraft has revealed a number of important properties of this this asteroid. Specifically, Ryugu had a spinning top shape with a low density (1.19±0.02 g/cc) [1] and a low abundance of hydrated minerals [2]. Ryugu's average visible spectrum is very flat (Cb type) lacking a strong 0.7-μm absorption band and has a very low 0.55-μm geometric albedo of 0.045 ± 0.002 [3]. These visible spectral properties are consistent with Polana and Eulalia families, which may be the source for asteroid Bennu as well [4]. Although global remote-sensing observation data are extremely useful, their interpretation is not always straightforward because of the limited spatial resolution and lack of physical contact with the surface. This situation was greatly changed by the touchdown (TD) operation and the SCI impact experiment [5]. This study examines both high-resolution images obtained during low-altitude TD and Small Carry-on Impactor (SCI) operations and the dynamic response of the Ryugu surface to the TD and the SCI impact in order to understand the spectroscopic properties of Ryugu.

2. High-resolution observations

One of the best observation opportunities was the SCI crater search campaign with wide-angle scanning at ~1.7 km of altitude, leading to high resolution (18 cm/pix) and a wide spatial coverage (~300 m). This allowed us to find rare boulders and observe them at high resolutions. Fig. 1 shows one of the rare boulders: bright and mottled boulders (type 3) [3], revealing that it has roundish depressions on the surface. Many of these depressions have regolith deposits inside. This is probably the cause of the mottled pattern of type-3 boulders. This observation also suggests that brighter surroundings are likely its intrinsic reflectance, supporting the bright nature of type-3 boulders. The fact that the reflectance of these boulders with a distinct morphology is clearly different from other types of boulders suggest that the distinct nature of these boulders may not be due to superficial processes, such as recent solar heating or space weathering but parent-body processes, such as thermal metamorphism.

Similarly, breccia-like texture, which was observed clearly only on small boulders previously [3] is now clearly seen in large boulders at 18 cm/pix resolution covering a large area (~300×300 m). The ubiquitous presence of breccia-like structures supports impact fragmentation and subsequent cementation process on Ryugu's parent body, which may contribute to its low density.

3. Response to TD and impact

Upon Hayabusa2's TD, a curtain of powdery materials darker than the undisturbed surface emerged and

expanded for more than several minutes. The dark splotch seen in Fig. 1 is still expanding at the time of observation. The SCI impact also excavated darker material from the subsurface [5]. The fact that both surface disturbances led to the emergence of dark materials suggests that fresh materials may be darker than space weathered materials. However, the situation is more complicated; many boulders brightened upon touchdown disturbance. This is more consistent with darker dust coating on the surface than surface brightening due to space weathering. Such complicated situation indicates that understanding the exact nature of space weathering and surface condition requires further investigation, and also show that physical contact with Ryugu surface provides important constraints for surface processes on C-type asteroids.

Another important observation is the size and shape of the artificial crater [5]. It is very large (~15 m), indicating that cratering efficiency is high on Ryugu and that the youngest estimate (<< 1 Myr) by [3] is very likely. In contrast, the crater has a semi-circular shape, indicating that its cavity growth may be intervened by a large boulder(s). This observation strongly suggests that the boulders on Ryugu has high mechanical strength, consistent with thermally metamorphosed material more than pre-alternation materials similar to comets.

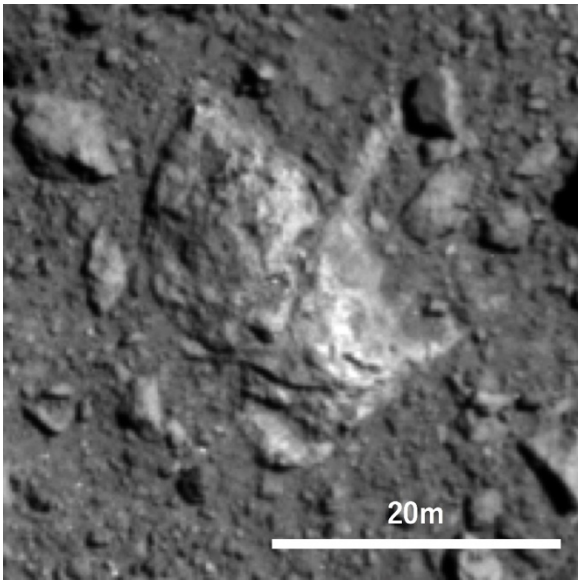

Figure 1: A type-3 (bright and mottled) boulder on Ryugu observed during the crater-search observation from ~1.7 km of altitude (~18 cm/pix).

4. Discussion and conclusion

The higher resolution observations of Ryugu boulders and the dynamic response of Ryugu surface generally strengthened the thermal metamorphism scenario proposed by [3]. However, the nature of space weathering and surface conditions of Ryugu boulders and pebbles still needs more investigation. Nevertheless, TD and impact experiment provided unique observational constraints for these processes.

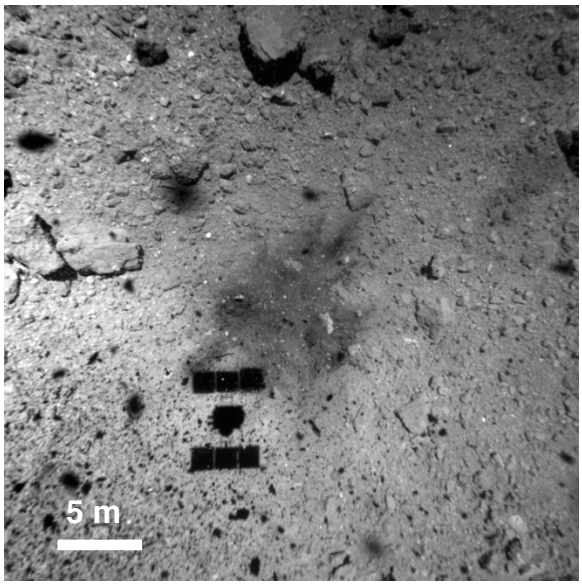

Figure 2: ONC-W1 image of the first Hayabusa2 TD site on Ryugu.

Acknowledgements

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