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Brightness and Morphology Variations on Surface Rocks of 162173 Ryugu by Hayabusa2: Space Weathering, Impacts, and Meridional Cracks.

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Abstract

162173 Ryugu is a 900m C-type asteroid, which is explored by Hayabusa2 mission including several low altitude operations, which provide high resolution images. There are brightness and morphology variations on surface boulders/rocks of Ryugu. Surface exposure would darken the rock surface. However, the artificial impact experiment darkened the surface, which would be explained by shock darkening or darker fresh materials. Rocks smaller than a few m may have thermally-induced cracks in meridional direction.

1. Introduction

Hayabusa2 is the second sample return mission from an asteroid after Hayabusa. The target asteroid of Hayabusa2 is (162173)Ryugu (1999JU3),which is a C-type asteroid [1]. Since June 2018, Hayabusa2 observed Ryugu including several low altitude operations, where three surface rovers (MINERVA IIA, IIB, MASCOT) deployment, the first touchdown sampling, and the artifitial impact experiment, successfully [2]. ONC (Optical Navigation Camera) on board Hayabusa2 captured tantalizing features of Ryugu, which is a top-shaped dark body where visible albedo is 4.6% and photometry standard reflectance is lower than 2% [3]. Color Vis-NIR spectra are flat with little variation (close to B-Cb type, but darker). Ryugu would be composed of dark CM meteorite [3,4].

2. Brightness Variation

There are brightness (and associated color ul/v bands) variations on Ryugu. Ryugu's surface is covered with numerous boulders/rocks [5] whose number density is about twice as large as that of Itokawa. Bright, large boulders are on polar regions and smaller ones with similar brightness are scattered globally.

Ryugu's surface is covered with darker regolith materials (with various size particles >cm) that would cover and bury boulders. The distinct characteristics of brighter and darker boulders are scale-invariant on Ryugu: brighter boulders with smooth and layered surface and darker boulders with (rugged/crumbling) rough surface. High resolution images obtained by MINERVA-II and MASCOT confirmed these characteristics of bright and dark rocks; MASCOT captured also bright rugged rocks. Ryugu's low density (1190kg/m^3) [5] suggests a rubble pile body where the interior is not so coherent. Impacts could form and move surface regolith materials in a short distance, but global seismic shaking would not be prevailed; we observe the feature that surface boulders are buried by regolith with rock fragments.

3. Space Weathering

Some boulders show brightness variation within their surface, suggesting brightness/color difference may not be due to compositional variation but to the differences of space weathering maturity. Usually bright boulders are a few 10 % brighter than dark boulders and regolith materials. Sometimes they are 50% and much brighter. Figure 1 shows an example where the interior of a dark small rock is 4 times brighter in v-band (550nm). It should be noted that (bi-directional) reflectance of the bright interior is about 8% (~4 x 2%) and still in the range of CM. The darker boulders with rough (rugged/crumbling) surface have experienced longer exposure and thus more erosion and weathering. Probably the darkening timescale is so short that usual brightness difference is smaller than a few 10 %. Even brighter boulders would have been darkened from the original brightness.

On the other hand, the result of the impact experiment in April showed a darkened crater is formed at the impact point. This would be contradictory to the above idea. Newly exposed surface is darker (Fig. 3). However, there is a possibility that the result would be explained by shock darkening. In other places, we found craters with darker floor materials and darkened structure possibly caused by an impact. We need further analysis of the artificial crater using color data and direct analyses of returned sample.

4. Meridional Cracks

High resolution images (Fig. 3) show that more than 10 boulders/rocks have a crack in the meridional direction (north – south) on Ryugu. The size range of cracked rocks is from a few 10cm to 10m. Boulders with a crack in the meridional direction suggest that thermal stress would play a role in the boulder disruption. Thermal fatigue is an advocated process where difference of thermal properties among minerals should cause disintegration of rocks and it is effective in a smaller scale [6]. Actually thermal timescale of diurnal temperature change is as small as or smaller than 10cm. In the terrestrial desert area, however, meridional fractures are frequently observed on rocks [7]. Since Ryugu has a large orbital eccentricity 0.19, annual temperature change might bring about thermal stress in a longer length, a few m.

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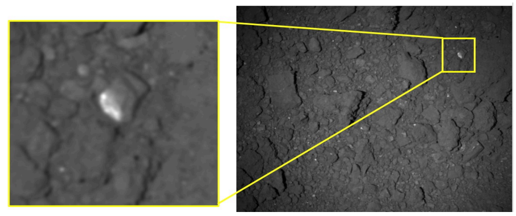

Figure 1: A small (20cm) rock which has 4 times brighter interior (hyb2_onc_20181015_134041_tvf).

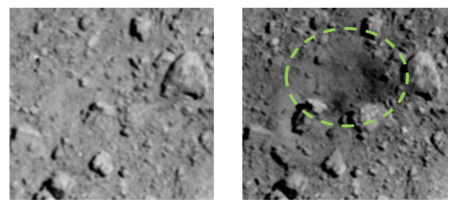

Figure 2: A darkened crater formed by SCI impact. Left: before impact (March 22). Right: after impact (April 25). http://global.jaxa.jp/press/2019/04/20190425a.html

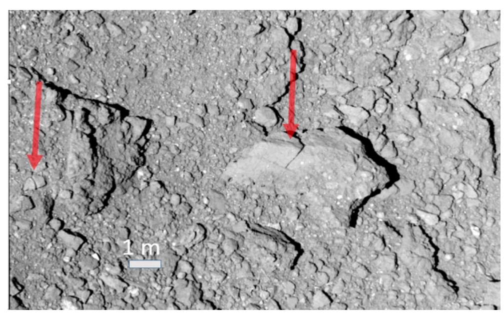

Figure 3: Rocks with a crack in the meridional direction. (hyb2_onc_20181025_021134_tvf)