Brightness and morphology variations on surface boulders of 162173 Ryugu: Space Weathering, Breccia, and Thermal Cracks

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Hayabusa2 is the second sample return mission from an asteroid after Hayabusa which visited an S-type asteroid Itokawa. The target asteroid of Hayabusa2 is (162173)Ryugu (1999 JU3),which is a C-type asteroid. Since June 2018, Hayabusa2 observed Ryugu including several low altitude operations, where three surface rovers (MINERVA IIA, IIB, MASCOT) have been deployed successfully.

ONC(Optical Navigation Camera) on board Hayabusa2 captured tantalizing features of 162173 Ryugu, which is a top-shaped dark body with overall visible albedo is 4.6% and photometry standard reflectance is lower than 2%. Color Vis-NIR spectra are flat with little variation (close to B-Cb type, darker). Ryugu would be composed of dark CM meteorite.

Brightness Variation: There are brightness (and associated color u/v bands) variations on the surface. Ryugu’s surface is covered with numerous boulders/rocks 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. Otohime Saxum is the largest boulder (-180m) on Ryugu; it has bright (and blue) smooth surface and darker surface. Around Otomime Saxum, there observed smooth bright boulders and dark rugged boulders.

The equatorial ridge (Ryujin Dorsum) and some of undulated crater rim zones are brighter. In high-resolution images, Ryugu‘s surface is covered with darker regolith materials (with various size particles >cm) that would cover and bury boulders. Ridge/crater brightness can be ascribed to movement of fine darker materials to potentially lower region, or to abundant brighter fragments. Bright crater rims could be explained by the former process, whereas Ryujin brightness could be also explained by the latter process.

The distinct characteristics of brighter and darker boulders are scale-invariant on Ryugu’s surface. show brighter boulders with smooth and layered surface and darker boulders with rough (rugged/crumbling) surface. High resolution images obtained by MINERVA-II and MASCOT confirmed the characteristics of bright and dark rocks; MASCOT suggested the existence of bright rugged rocks. We do not observe pond-like deposits of relatively similar size grains as we saw on Eros and Itokawa.

Space Weathering: The 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. Sometimes it is 50% and more brighter. We found the evidence that 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, which would 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 %.

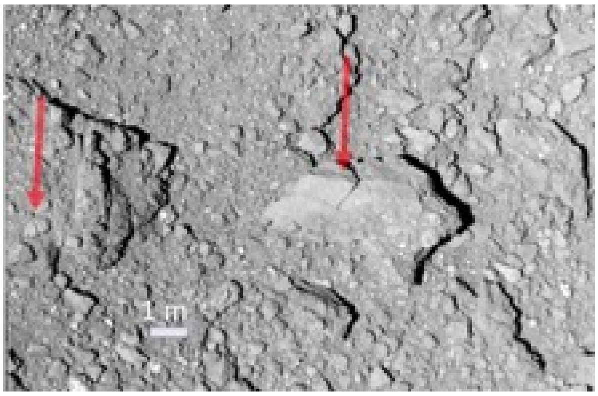
Breccia A lot of rocks on Ryugu show brecciated structure with brightness variation. The breccia formation would take place by impacts on Ryugu’s parent body, where the layered structure of boulders would be also formed.

Meridional Cracks: High resolution images 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 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. 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. Since Ryugu has a large orbital eccentricity 0.19, annual temperature change might bring about thermal stress in longer length scales.

Figure: Rocks with a crack in the meridional direction.

Keywords: Near Earth asteroids, Hayabusa 2, Space weathering, Thermal fatigue, Carbonaceous meteorites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