BRIGHTNESS AND MORPHOLOGY VARIATIONS ON SURFACE ROCKS OF 162173 RYUGU: SPACE WEATHERING, BRECCIA STRUCTURE, AND MERIDIONAL CRACKS. S. Sasaki[1], S. Sugita[2], E. Tatsumi[2], H. Miyamoto[2], C. Honda[3], T. Morota[4], O. S. Barnouin[5], M. Hirabayashi[6], S. Kanda[1], M. Kanamaru[1], N. Hirata[3], T. Hiroi[7], T. Nakamura[8], T. Noguchi[9],R. Honda[10], T. Michikami[11], S. Watanabe[4], N. Namiki[12], P. Michel[13], S. Kameda[14], T. Kouyama[15], H. Suzuki[16], M. Yamada[17], H. Kikuchi[2], D. L. Domingue[18], Y. Cho[2], K. Yoshioka[2], M. Hayakawa[19], M. Matsuoka[19], R. Noguchi[19], N. Sakatani[19], H. Sawada[19], Y. Yokota[19] , and M. Yoshikawa[19], [1]Osaka Univ. (Dept. Earth & Space Sci., Toyonaka 560-0043, Japan, sasakisho@ess.sci.osaka-u.ac.jp), [2]Univ. Tokyo, [3]Univ. Aizu, [4]Nagoya Univ., [5]Johns Hopkins Univ., Applied Physics Lab, [6]Auburn Univ., [7]Brown Univ., [8]Tohoku Univ., [9]Kyushu Univ., [10]Kochi Univ., [11]Kinki Univ., [12]NAOJ, [13]Observatoire de la Cote d'Azur, [14]Rikkyo Univ., [15]AIST, [16]Meiji Univ., [17]Chiba Inst. Tech., PERC, [18]Planetary Sci. Inst., [19]ISAS/JAXA

Introduction: 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 (1999JU$_3$),which is a C-type asteroid [1,2]. Since June 2018, Hayabusa2 observed Ryugu including several low altitude operations, where three surface rovers (MINERVA IIA, IIB, MASCOT) have been deployed successfully.

ONC on board Hayabusa2 captured tantalizing features of Ryugu, which is a top-shaped dark body with overall 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].

Brightness Variation: There are brightness (and associated color ul/v bands) variations on the surface. 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. Otohime Saxum is the largest boulder (-150m) on Ryugu; it has bright (and blue [4]) smooth surface and darker surface (Fig.1). Around Otomime Saxum, smooth bright boulders and dark rugged boulders are observed.

Regionally, the equatorial ridge (Ryujin Dorsum) and some of undulated crater rim zones are brighter [3]. 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. Figures 2 (and Fig.5) 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 captured also bright rugged rocks. No pond-like deposits of relatively similar size grains (on Eros and Itokawa) are observed.

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 (Fig.2).

Space Weathering: Some boulders shows 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 more brighter. Figure 3 shows an example where the interior of a dark small rock is 4 times brighter in v-band (550nm). It should be noted that (bidirectional) 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.

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 [3], where the layered structure of boulders would be also formed.

Meridional Cracks: High resolution images (Figs. 4 and 5) 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 scale.

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References:

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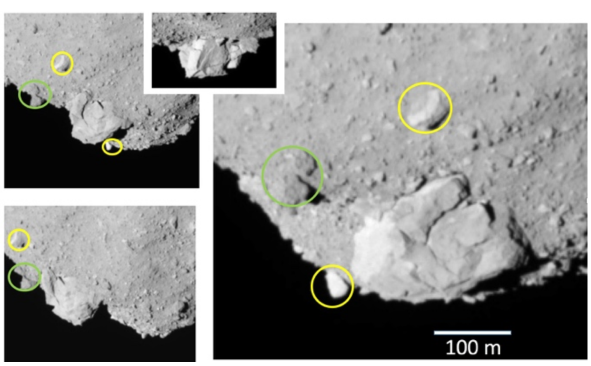

Fig.1 Otohime Saxum and surrounding bright (yellow circles) and dark rugged (green circles) boulders.

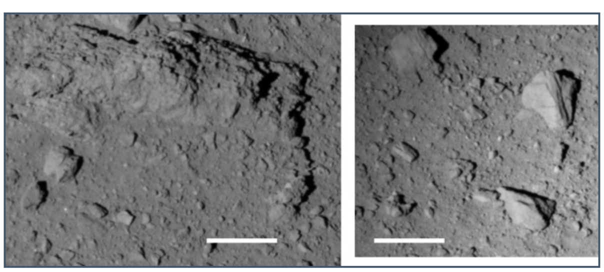

Fig.2 Left: a large dark (probably layered) boulder with rugged surface, half being covered with regolith. Right: bright layered boulders, partly covered with dark regolith. The white scale is 10m in each figure.

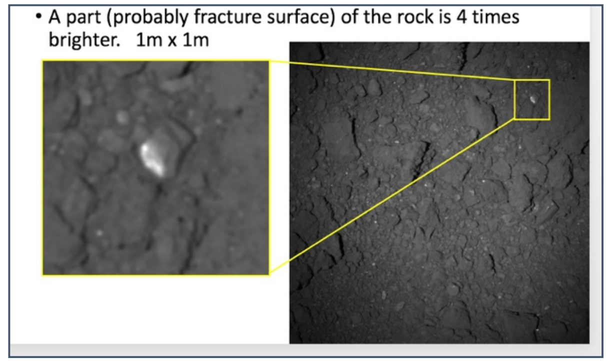

Fig. 3 A small (20cm) rock which has 4 times brighter interior (hyb2_onc_20181015_134041_tvf).

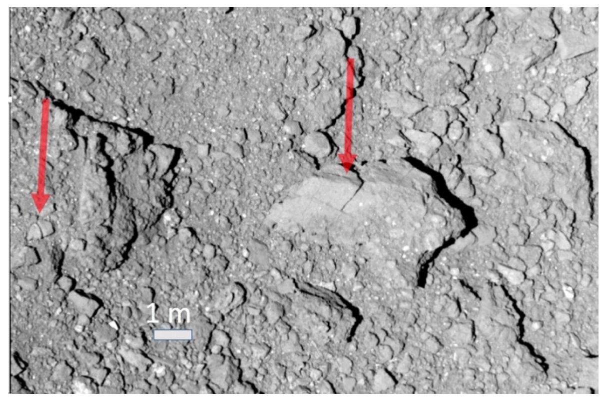

Fig. 4(a) Rocks with a crack in the meridional direction. (hyb2_onc_20181025_021134_tvf)

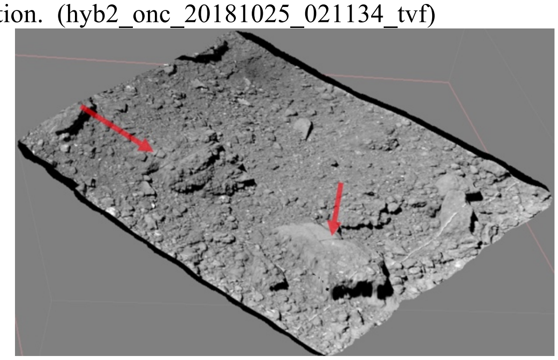

Fig. 4(b) 3D image of the area of Fig.4(a).

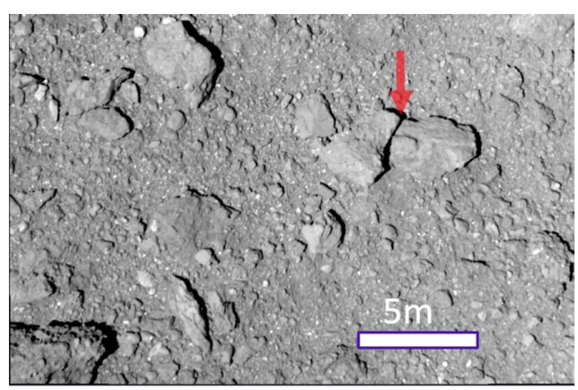

Fig. 5 A cracked boulder close to the candidate touch down site. (hyb2_onc_20181015_135015_tpf)