BRIGHTNESS/COLOR VARIATION ON ITOKAWA: SPACE WEATHERING AND SEISMIC SHAKING. S. Sasaki1, M. Ishiguro2, H. Demura3, N. Hirata3, T. Hiroi2, M. Abe2, S. Abe2, H. Miyamoto2, J. Saito2, A. Yamamoto2, K. Kitazato5, R. Nakamura6, 1RISE Project Office, National Astronomical Observatory of Japan, Oshu, Iwate 023-0861, Japan, 2School of Earth and Environmental Sciences, Seoul National University, Seoul 151-742, Korea, 3The University of Aizu, Fukushima 965-8580, Japan, 4Department of Geological Science, Brown University, Providence, RI 02912, U.S.A., 5The Institute of Space and Astronautical Science, JAXA, Kanagawa 229-8510, Japan, 6Graduate School of Science and Technology, Kobe University, Nada, Kobe 657-8501, Japan, 7Department of Geomaterial Engineering, The University of Tokyo, Tokyo 113-8656, Japan, 8Remote Sensing Technology Center of Japan, Roppongi, Tokyo 106-0032, Japan, 9National Institute of Advanced Industrial Science and Technology, Ibaraki 305-8568, Japan.

Introduction: Hayabusa is a Japanese engineering spacecraft by ISAS/JAXA aiming at sample return from S-type asteroid (25143) Itokawa [1]. Itokawa is a small near Earth asteroid (550m x 300m x 240m). Between September and November 2005, Hayabusa observed Itokawa’s surface by Asteroid Multiband Imaging CAmera (AMICA) and Near Infrared Spectrometer (NIRS). AMICA has a wide bandpass filter and seven ECAS-compatible narrowband filters: 380 (ul), 430 (b), 550 (v), 700 (w), 860 (x), 960 (p), and 1010 nm (zs) [2]. Spectral range of NIRS is between 760nm and 2100nm. From 7km, AMICA observed the whole surface of Itokawa with resolution 70 cm at solar phase angle around 10 degree. The highest resolution during close approaches was less than 1cm [3].

Brightness/color variations on Itokawa: Itokawa is heterogeneous in both color and brightness (Fig. 1) [3]. The brightness difference is approximately 10-20% on distant images and as high as 30% on close-up images. Brighter areas usually correspond to at locally elevated zones and at gravitationally steep zones, although some steep zones are not bright. Brighter areas are bluer and darker areas are redder in color [4, 5]. No previously observed asteroids show such large variations in both of these characteristics. These variations may be due to the space weathering process [6].

Muses Sea area on Itokawa is displayed in Fig. 2. Muses Sea (the landing site) is composed of cm-sized pebbles which should have transported from other areas. Shirakami is one of the distinctly brightest regions on Itokawa. In this region, the brightest area (a) has very steep slope, which is steeper than a typical angle of repose of granular materials. The elevated zone with moderate slope angle (b) consists of boulder-covered dark areas (10m-scale patch areas) and boulder-poor bright areas. Typical boulder size on the dark patch area is about 1m. The neighbouring darker area (c) is covered continuously with numerous boulders. The morphology here suggests that the bright surface of Shirakami was formed by removal of the superposed dark boulder rich layer. The area (a) is a totally excavated whereas the area (b) is partially excavated due to boulder movements. In Fig. 2, brightness of of Yatsutagake (d) might be also explained by excavation of a darker superposed layer. At the foot of Shirakami and Yatsutagake extends a darker and boulder-rich zone (denoted by e). Figure 3 is a close-up image of the elevated area to the north of the Muses Sea. Here are observed bright patch surfaces of a few meter scale. Some boulders on brighter surface are dark, which would suggest darker materials should superpose on brighter materials.

Space weathering and seismic shaking: In comparison with color observation [4, 5] and experimental data [7, 8], we consider that the darker materials experienced more space weathering than the brighter materials. High resolution images suggest that boulders’ surface was optically weathered. After the emplacement of boulders, Itokawa’s surface was weathered by micrometeorite impacts (and irradiation by high-energy particles). Then, dark weathered boulder-rich surfaces were removed, leading to the exposure of underlying relatively fresh bright area (Fig. 4). Probably Itokawa shows brightness/color heterogeneity because it is too small to be covered with regolith.

Although there are a couple of apparent bright craters which would be explained by direct excavation, most of bright areas might not be related to local impact events. Seismic shaking or tidal distortion during planetary encounter would be possible cause of surface movements of dark boulder layer. Since clear brightness difference prevail on all over Itokawa, the seismic shaking may have been a single event. The observed morphology that locally elevated regions are bright could be explained by the seismic shaking (E. Asphaug, personal comm.), since surface motion at elevated region would be stronger though concentration of internally propagating waves. The fact that the brighter areas are striking at both ends of Itokawa could be explained by the shaking process, since the both ends have relatively low escape velocity and concentration of propagating waves could be expected.
Figure 1 Composite color images of Itokawa constructed from b-, v-, and w-band data. Top: Eastern hemisphere including the Muses Sea. Bottom: Western hemisphere. The contrast adjustment was done in each image to enhance the color variation [3].

Figure 2 The Muses Sea area on Itokawa where detailed feature of Yatsugatake-Shirakami region is involved. The smooth area is the Muses Sea which includes possible landing spot of Hayabusa (denoted by a white stellar mark). Yatsugatake is a bright rough ridge to the west of the Muses Sea. A white rectangle is the area of Fig. 3. (ST_2474731509)

Figure 3 Close-up v-band image of a region to the north of the Muses Sea (just to the east of Usuda boulder). Scale in the figure is 10 m. The brightness contrast is enhanced in this image for clarity. (ST_2530292409).

Figure 4 A model of brightness heterogeneity on Itokawa’s surface. After the boulder emplacement, the surface layer with boulders are weathered. Then, seismic shaking or planetary encounter would move the surface dark layer, leading to excavate underlying fresh bright materials.