Origins of Bright Spots on the Surface of Boulders covering Asteroid Itokawa.

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Introduction: The Asteroid Multiband Imaging CAmera (AMICA) onboard Hayabusa spacecraft imaged the surface of near-Earth asteroid Itokawa in detail and obtained ~10 close-up images, whose resolutions are as high as several to a few tens of mm/pixel [1]. Numerous boulders are found on these high-resolution images, whose geological implications were reported by [2, 3]. Among the most enigmatic, unidentifiable features observed on the surface of boulders are centimeter-scale, high-albedo dots and scratches [2, 4], referred to here as "bright spots" (Fig.1). Bright spots are not observed in the high-resolution images of asteroid Eros obtained by NEAR Shoemaker. Origins of bright spots are not known and the detailed studies of them have not been attempted. The formations of bright spots may be explained as: (1) remnants of micrometeoroid impacts, (2) scratches due to the frictions of between rocks, and (3) concentrations of chemically different components. In this study, we report morphological characteristics, spatial distributions and size distributions of bright spots, as a first step to understand the formational origin and real identity of bright spots.

Method: We examine the close-up images (such as ST_2539444467, ST_2539451609, ST_2539437177, ST_2539429953, ST_2539423137, ST_2563511720, ST_2563537820, and ST_25630607030), whose resolutions are better than 22mm/pixel (Fig.1A to F). We carefully map the outlines of bright dots (Fig.1H and I) as well as all of the boulders found on these images using image processing software (Fig.1A and B) and compile the information of bright spots in a database.

Observation: ~400 bright spots on the surfaces of more than 100 boulders and ~3000 rocks and boulders are identified using the high-resolution images. In order to understand the formational origin of bright spots, we examine the cumulative size frequency dis-

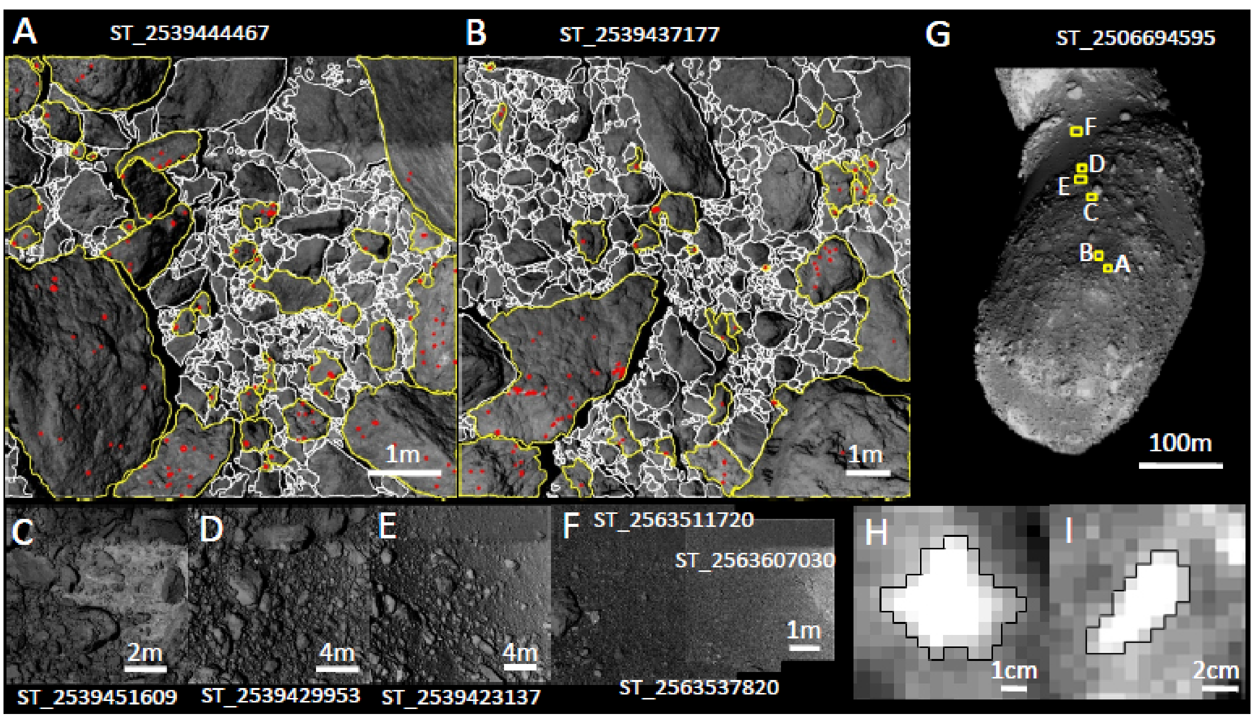

Fig.1 (A) Numerous number of rock materials are observed. Fine-grained materials are generally idstributed between larger particles, whose diameters range from centimeters to meters. Red-colored dots indicate the locations of bright spots. Rocks with bright spots are outlined in yellow, while rocks without bright spots are in white. **(B)** Rough terrain around the Komaba crater. **(C), (D), (E), and (F)** Close-up images used in this study. **(G)** The eastern hemisphere of Itokawa with locations of individual close-up images used in this study shown [2]. **(H) and (I)** Close-up of the bright spots. Generally bright spots are quasi-circular, while bright spots show elongated shape (I).

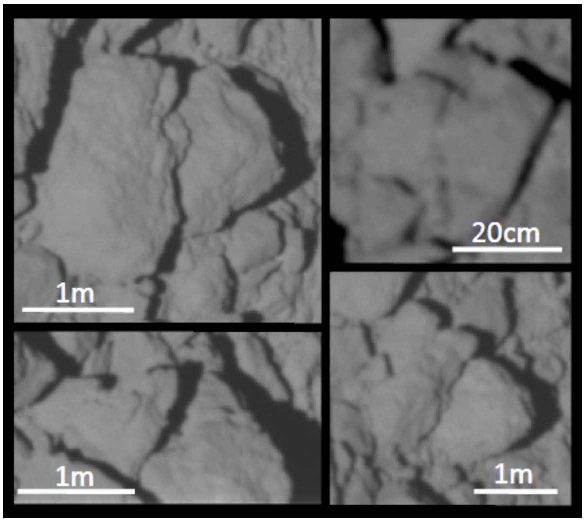

Fig.2 Fractured rock materials are observed in the close-up images. The fractured rock materials may be further evidence of resurfacing of Itokawa by millimeters to centimeters scale micrometeoroid impacts. If impact origin, the size limit of the bright spot (~20cm) may be indicative of a certain size threshold of the micrometeoroid. A micrometeoroid of sufficient size will rupture the boulder rather than forming a bright spot.

tribution (SFD) of bright spots. The cumulative SFD plots indicate the number of bright spots with diameters greater than some value D, generally fitted to a power law in the form $N (\geqq D) = kD^{-b}$, where the exponent $-b$ is the slope on a log–log plot. The slopes of cumulative SFD curves of the close-up images (ST_2539444467, ST_2539451609, ST_2539437177, ST_2539429953 and ST_2539423137) (Fig.1A to E) and the composite image of Muses-C terrain (ST_2563511720, ST_2563537820, and ST_25630607030) (Fig.1F) are –2.7, –2.1, –2.3, –2.2, –2.0 and -2.6 respectively. Consequently, the slopes of cumulative SFD curves of bright spots determined from this investigation range from –3 to –2. These values are approximately similar to the power-index of cumulative SFDs of impact craters with diameters > 1m on the lunar surface. Crater Analysis Techniques Working Group (1978) shows that most of the crater cumulative SFDs generally have slope indices within the range of ±1 of the slope –3 [5]. Furthremore, the power-indexes of the cumulative SFDs of micro-craters on lunar rocks obtained by Appolo17 are also within a range of –3 to –2 [6]. Because about 25% of bright spots have major axes with lengths greater than 5 centimeters, chemical concretions such as chondrules are difficult to be attributed to the bright spots.

Conclusions: For all of these reasons, we conclude that bright spots are micro-craters formed by impacts of micrometeoroids and/or interplanetary dust particles on the surfaces of boulders. Whereas less than 10 percent of the total bright spot population are elongated in shape (Fig.1I) which may be indicative of friction of the overlapping boulders, more than 90 percent of bright spots are quasi-circular in shape, and their cumulative SFDs and physical attributes point to an impact origin related to the bombardment of micrometeorites.

Because of the mass of Itokawa is significantly small ($(3.58 \pm 0.18) \times 10^{10}$ kg) [7], Itokawa is an asteroid that lacks atmosphere, and thus is resurfaced by a relatively higher frequency of the micrometeoroid collisions [e.g., 8-10]. As a crucial evidence implicating such activity, a few fractured boulders are observed (Fig.2). This may indicate that a small boulder of tens of centimeters to several meters in size may be modified or destroyed rather than forming a bright spot by a impact event. Hörz. F. et al (1971) have shown that long ages under the influence of meteoroid impacts permit the formation of craters so large that the impacts finally fracture into smaller rock materials [11].

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