STEREOSCOPIC SHAPE MEASUREMENTS OF RYUGU SAMPLES FOR CURATION CATALOG. Yuna Yabe[1], Koki Yumoto,[1] Yuichiro Cho[1], Shoki Mori[1], Akinojo Ogura[1], Akiko Miyazaki[2], Toru Yada[2], Kentaro Hatakeda[2], Kasumi Yogata[2], Masanao Abe[2], Tatsuaki Okada[1,2], Masahiro Nishimura[2], Tomohiro Usui[1,2], Seiji Sugita[1]. [1]Dept. Earth and Planet. Sci., Univ. of Tokyo, 7-3-1 Hongo, Tokyo, Japan (yyabe@eps.s.u-tokyo.ac.jp), [2] JAXA/ISAS

Introduction: Boulders on asteroid Ryugu have been classified into several types based on surface textures and reflectance spectra, and different types of boulders may have experienced different parent body processes [1]. It has been confirmed that particles with these different shape types exist in the returned samples of several hundred micrometers [2].

In addition, bright boulders have been found on the surface of Ryugu, which are composed of material that is brighter than the surrounding materials and appear as bright spots [3-5]. A large number of bright boulders were also observed in the optical images of the returned samples, but it has also been pointed out that the apparent brightness of many of these boulders is strongly dependent on the geometrical conditions of observations (illumination and the angle at which the image is taken) [6,7]. The bright spots in the sample are expected to be affected by specular reflection on the surface of the sample particles. To compensate for this geometric effect (i.e., photometric correction), precise measurement of the sample geometry is necessary. In this study, as a part of the return sample curation, we measured the three-dimensional shape of individual particles by stereo imaging.

Measured Ryugu Samples: The samples were kept in the clean chamber of JAXA's curation facility to maintain its cleanliness, and could not be taken out. We developed a measurement system that can take images from different angles by rotating a small CMOS camera around a rotation axis tilted by 15 degrees (Figure 1)[7] and took images of a total of 69 particles of the Ryugu samples.

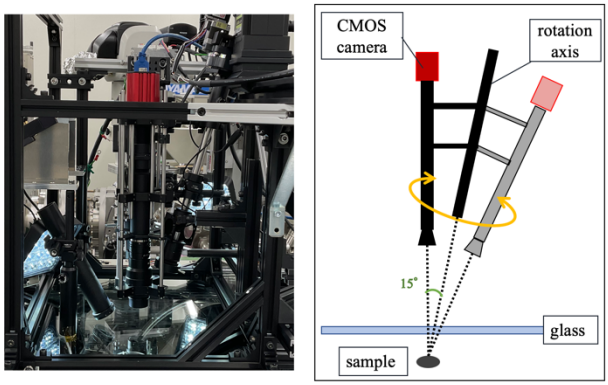

Figure 1: The equipment developed in this study. By tilting the camera's rotation axis by 15 degrees, it is possible to take pictures from various angles.

New Measurement System and Analysis: For each particle, the camera orientation angle was changed by 6-degree increments over full angular range of 180-210 degrees. A narrow band-pass filter centered at 0.55 µm was used to suppress chromatic aberrations. The pixel resolution of the camera was 1.9 µm/pix. A group of about 30 images per particle was analyzed using the shape-from-motion package (Metashape), and a high-resolution digital elevation model (DEM) was obtained. In this study, we created DEM with a face element diameter of about 15 pix (about 30 µm). For the same particle, DEMs were obtained from measurements with 3-degree and 6-degree increments, and the volumes agreed with each other with a difference of about 10%.

Measurement and Analysis Results: Some of the returned samples showed smooth surfaces, while others had rough volcanic rock-like surfaces (Figs. 2A, 2B). Of the total 69 particles, six particles had no smooth surface, which is about 9% of the total. In addition, there were four particles whose top surface appeared to be composed of two large surfaces, which accounted for about 6% of the total. In the future, we plan to evaluate the surface microstructure of these particles to correlate their shape characteristics with other detailed measurements.

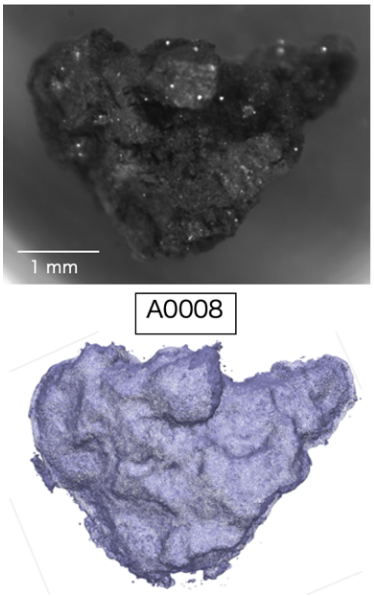

Figure 2-A: Top) Optical image and Bottom) DEM of A0008 particle. The obtained DEMs reproduce the detailed surface structure.

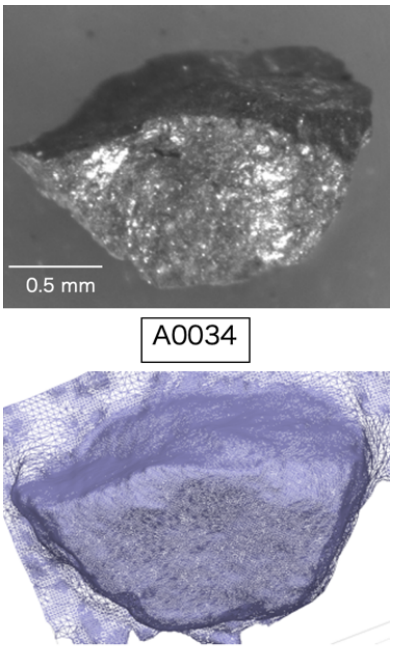

Figure 2-B: Top) Optical image and Bottom) DEM of A0034 particle

Shape analysis using a high-precision DEM is advantageous for calculating volumes that reflect the three-dimensional shape of actual particles. Since the lower part of the sample could not be seen clearly due to the angle of the camera, the accuracy of the DEM was lower than the upper part. Thus, in this study, the upper part of the particle was used to estimate the overall volume of the grains. The density of each grain was obtained with its weight data(Figure 3)[6].

Discussions and Conclusions: In the previous study, the volume of the particles was estimated by approximating the grain with an ellipsoid. Its dimension was determined using the thickness of the sample, major and minor diameters observed from the top, with a correction coefficient assuming an unevenness equivalent to that of volcanic rocks [6]. As a result, the average density of the 10 particles was 2.3 g/cc, which was larger than the estimates by the previous study(1.8 g/cc) (Figure 4)[6]. For the individual particles, there were both larger and smaller particles than [6]. For example, because the grain A0008 has a rough shape and the volume calculated based on its DEM is much smaller than that of the ellipsoid, its calculated density was larger than that in the previous study. In contrast, A0034 has a smooth surface with no major irregularities. The volume calculated in this study is larger than the previous study. Therefore, its density was smaller.

We made further improvements to the measurement system and increased the observation angle of the camera. We plan to start measuring smaller samples (sizes < 2 mm) with the improved instrument from Jan. 2022. Spectroscopic data acquired by the same instrument are presented by [8]. These DEMs will be cataloged and made available to the public by JAXA.

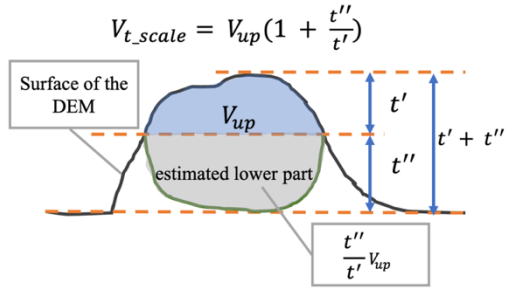

Figure 3: Height-based approximation of volume. Thickness *t'* was determined based on the confidence level of the face element; the facets showing sufficient accuracy were used for our volume assessments.

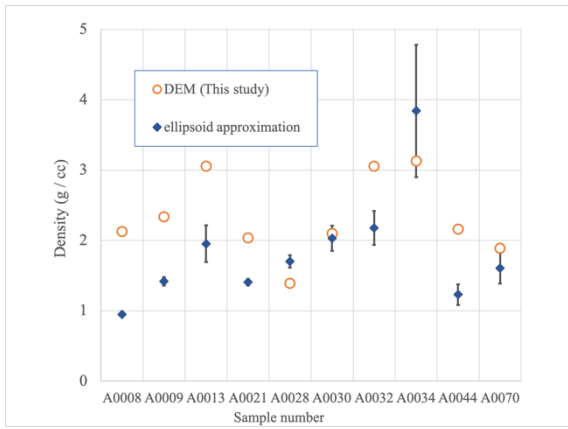

Figure 4. Comparison of Ryugu sample densities estimated from our new DEMs and previous ellipsoid approximation[6]. The volume of an ellipsoid πabt was calculated using the major diameter a, minor diameter b, and the thickness t of each target grain when the particle was viewed from above. The volume of the particle was estimated by multiplying the ellipsoid volume with a correction factor specific to the roughness of volcanic rocks. Details for the ellipsoid approximation are given by [6]

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References: [1] Sugita et al. (2019), *Science*, *364*, eaaw0422, [2] Tachibana et al. *Science,* submitted. [3]Tatsumi et al. (2021) *Nature Astron*. 5, 39-45, [4] Sugimoto et al. (2021a) *Icarus* 114529. [5] Sugimoto et al. (2021b) *Icarus* 114591. [6] Yada et al. (2021) *Nature Astron*. 1-7 [7] Cho et al. *PSS*, under review. [8] Yumoto et al. (2022) 52nd *LPSC*.