Non-destructive observation of bulk Bennu samples in JAXA without atmospheric exposure

Ryota Fukai[1], Masahiro Nishimura[1], Toru Yada[1], Kentaro Hatakeda[1], Yuma Enokido[1], Rui Tahara[1], Kasumi Yogata[1], Akiko Miyazaki[1], Seiya Kawasaki[1], Koki Yumoto[1], Yuichiro Cho[2], Seiji Sugita[2], Yuta Shimizu[2], Hideaki Miyamoto[2], Masanao Abe[1], Tomohiro Usui[1]

[1]*ISAS/JAXA* [2]*The University of Tokyo*

Introduction: The OSIRIS-REx (Origins, Spectral Interpretation, Resource Identification, Security-Regolith Explorer) mission by NASA launched a spacecraft to the B-type asteroid (101955) Bennu in 2016. It returned the sample capsule to the Earth on September 24, 2023. Bennu sample and remote-sensing analyses are valuable for determining the origin of the volatiles and life on Earth. JAXA also collected the samples from asteroid (162173) Ryugu, which is stored in the JAXA curation facility.

The comparison between Ryugu and Bennu will constrain the material distribution and compositional diversity of the mainbelt and near-Earth asteroids. Data obtained from optical spectroscopy show a similarity between asteroids Ryugu and Bennu, suggesting that they may originate from a similar asteroid family [1]. Isotopic and elemental compositions [2–4] and mineralogical information [5] will further constrain the origin of asteroids. Ryugu is estimated to have originated from the outer Solar System, based on the O, Ti, and Cr isotopic systems [2–4]. Furthermore, it will be possible to quantitatively estimate the thermal and collisional history of asteroids through the study of Ryugu sample analysis. For example, it remains controversial whether the difference in thermal inertia between the Ryugu samples and the surface layer of Ryugu is due to cracks on boulder surfaces formed by thermal fatigue or microporosity within boulders [6–8]. Furthermore, it is crucial to observe how the characteristics of boulders originating from exogenous planetary bodies [9–10] are represented in the returned samples. Sample analysis, including spectroscopy, mineralogical description [5, 11], and identification of organic matter composition [12–14], could provide more detailed information about the evolution history of asteroids.

NASA allocated 0.5 wt.% of Bennu samples to JAXA based on a Memorandum of Understanding (MOU). The basic description of the Bennu sample in the JAXA curation without atmospheric exposure plays an essential role in future Ryugu-Bennu comparative studies. Also, the bulk description with an optical microscope and spectroscopy in the visible and infrared wavelength provides a seamless bridge between remote-sensing and sample analysis. In this study, we assess the representativity of the Bennu samples delivered to JAXA by comparing them with the remote-sensing and sample analysis data from the OSIRIS-REx team. We also characterize the Bennu samples to compare with the curation data of Ryugu samples.

Method: Bennu samples allocated to JAXA were selected based on the MOU to fulfill the criteria of total weight (0.5 wt. % of total mass). The five individual dishes were transported from JSC to JAXA curation using the Eagle stainless containers. The clean chambers (CC5-1 and CC5-2) for Bennu samples were installed in an ISO class 6 clean room within the JAXA curation facility. This study described Bennu samples with instruments within the CC5-1 and CC5-2. An optical digital microscope Keyence VHX-8000 is set above the window of the CC5-2 to take optical sample images. Microbalance A&D AD-4212D is installed into the CC5-2, which can weigh one μg in minimal digit display to measure weights of bulk and individual samples with a customized outer cover made of 6061 aluminum alloy. μ-FT-IR JASCO IRT-5200/VIR-200 is installed over a chamber attached to the CC5-2 to obtain infrared spectra (2.0–13 μm in wavelength) through a BaF_2 viewport using apertures with a diameter of 10–500 μm. The detector of μ-FT-IR is covered with the acrylic N_2 purge case to avoid interference from the ambient air (e.g., H_2O and CO_2). A multiband spectral microscope can also be installed above CC5-2. This microscope, equipped with a monochrome CMOS camera and six-band filters at 390, 480, 550, 590, 700, and 850 nm, is identical to that used for the initial descriptions of Ryugu samples [14].

Results: We obtained the sample weights for the individual dishes with a microbalance. The total weight for the Bennu samples in JAXA is 0.665 g. The weights for the individual dishes obtained at JAXA curation are 0.183 g (OREX-800058-0), 0.135 g (OREX-800111-0), 0.152 g (OREX-800116-0), 0.047 g (OREX-800120-0), and 0.148 g (OREX-800125-0). These values match with the values reported by NASA JSC curation. We identified ~30,000 Bennu particles from the digital microscope images of the bulk dishes. So far, no inclusions such as chondrules and calcium-aluminum-rich inclusions were observed in the bulk dishes. We obtained the bulk Bennu sample dishes' reflectance spectrum in the visible to infrared wavelength range. The Bennu sample has a dark reflectance and a positive spectral slope in the visible range. The reflectance in the infrared is similarly dark and has several absorption bands, around 2.7 and 3.4 μm.

Discussion: First, we should confirm the representativity of Bennu samples allocated from NASA. In the symposium, we will discuss sample representativity using data from the size distribution, color, and reflectance spectrum of bulk Bennu samples. So far, the initial description data of Bennu samples in JAXA has revealed several similarities to the findings from the first report by the OSIRIS-REx team [16], such as the visible reflectance and absorption in the infrared range. We will also assess the similarities and differences between the Bennu and Ryugu samples after we confirm the representativity of the Bennu samples.

References

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