REPRESENTATIVE SURFACE SAMPLES RETURNED FROM NEAR-EARTH C-TYPE ASTEROID (162173) RYUGU AND THEIR INITIAL ANALYSIS. S. Tachibana[1, 2], H. Yurimoto[3], T. Nakamura[4], T. Noguchi[5, 6], R. Okazaki[6], H. Yabuta[7], H. Naraoka[6], S. Watanabe[8], Y. Tsuda[2] and the Hayabusa2 initial analysis team, [1]University of Tokyo, 7-3-1 Hongo, Tokyo 113-0033, Japan, [2]ISAS, JAXA, [3]Hokkaido University, [4]Tohoku University, [5]Kyoto University, [6]Kyushu University, [7]Hiroshima University, [8]Nagoya University.

Introduction: Carbonaceous chondrites record the evolution of the early Solar System prior to planet formation. Some groups of carbonaceous chondrites contain water in the form of hydrous minerals and organics, and such materials may have been delivered to the proto-Earth as ingredients of ocean and life. C-type asteroids have been hypothesized to be parent bodies of carbonaceous chondrites based on their spectroscopic similarities. However, this hypothesis has never been proved.

JAXA's Hayabusa2 spacecraft explored near-Earth C-type asteroid (162173) Ryugu for 17 months [e.g., 1–5], and returned surface sample from two locations of the asteroid on December 6, 2020. Proximity operations have shown that Ryugu is a rubble pile body with a low albedo and that hydrous minerals are ubiquitously present on the surface.

The total amount of returned sample exceeds 5 grams, ~3 and ~2 grams from the first and second sampling sites, respectively, and their low reflectance and spectroscopic features are broadly consistent with the observations at Ryugu [6, 7].

We report representativeness of returned sample for Ryugu surface material and the overview of their initial analysis led by the Hayasbusa2 project.

Returned sample: Hayabusa2 made two landing operations for sample collection. Hayabusa2 fired a 5-g projectile made of tantalum metal at the surface [9], and a small monitor camera (CAM-H) observed the ejecta beneath the sampler horn a second after the touchdown [8]. For the first touchdown, the ejection angle of some ejecta particles with 1-2 m s^{-1} ejection velocity was 50-60°, consistent with projectile-shooting experiments on ground and numerical simulations [8, 10]. Image analysis combined with simulation results [10] suggests that 0.1-1 g of surface samples could be collected [8]. This is consistent with the estimate from projectile-shooting experiments onto glass beads both at Earth's gravity and at microgravity [9]. This estimate of collected amount of samples was made based on the particles observed, and could be the lower limit, consistent with the mass of returned particles for the first touchdown (~3 g) [6]. A similar observation of ejecta was made for the second touchdown, which also supports that ~2-g of samples were collected by the projectile shooting [8].

CAM-H also observed pebbles that were lifted due to thruster operation for the spacecraft ascent after both touchdown operations. These flying pebbles show a morphological variation from rugged to smooth, as seen in surface boulders [2] and from equant to flat [8]. Similar morphological features were found in returned samples. This morphological similarity between returned samples and observed Ryugu pebbles suggests that returned particles are representative of Ryugu's surface material [8] along with visible and infrared spectroscopic similarities [6, 7].

Initial analysis of Ryugu sample: A fraction of retuned samples were allocated to the Hayabusa2 project for scientific analysis in June 2021 after six-month initial description in a nitrogen-purged clean chamber at JAXA [6, 7]. The mass of the allocated sample was 0.3 g, which is ~6 % of the total returned sample mass, and the analysis is limited to one year before the samples will be open through Announcement of Opportunities.

Twenty-two grains, which were individually photographed, weighed, and spectroscopically examined, were allocated both from Chambers A (1st touchdown) and C (second touchdown) of the sample container [9], respectively (11 grains from Chamber A and 11 from Chamber C). All the initial description was made in the nitrogen-purged clean chamber without exposure to air [6, 7]. A particle C0002 (93.5 mg) is the third largest particle (~9 x 5 x 4 mm) among all the returned particles.

Ten sets of aggregate samples were also allocated. They consist of grains smaller than 1 mm in size, and were examined in the clean chamber not individually but as a batch.

The allocated samples were distributed to six sub-teams that analyze the samples with different approaches and focuses: Chemistry (elements and isotopes), Petrology and mineralogy of coarse grains (mm-sized grains, 'stone') and fine grains (<100 μm-sized grains, 'sand'), Volatiles, Organic macromolecules, and Soluble organic matter (organic molecules) sub teams. Results of various sample analysis such as bulk elemental and isotopic analyses, mineralogical and petrological observations, surface observation, volatile analysis, structural and morphological analysis of organics, and extracted analysis of organic molecules will be presented at the

conferentce [e.g., 11-16], where characterization of Ryugu samples as the first returned C-type asteroid and its implication to the Solar System science will be discussed.

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The Hayabusa2 initial analysis team member list is available at https://www.darts.isas.jaxa.jp/pub/hayabusa2/paper/sample/ia_member.pdf

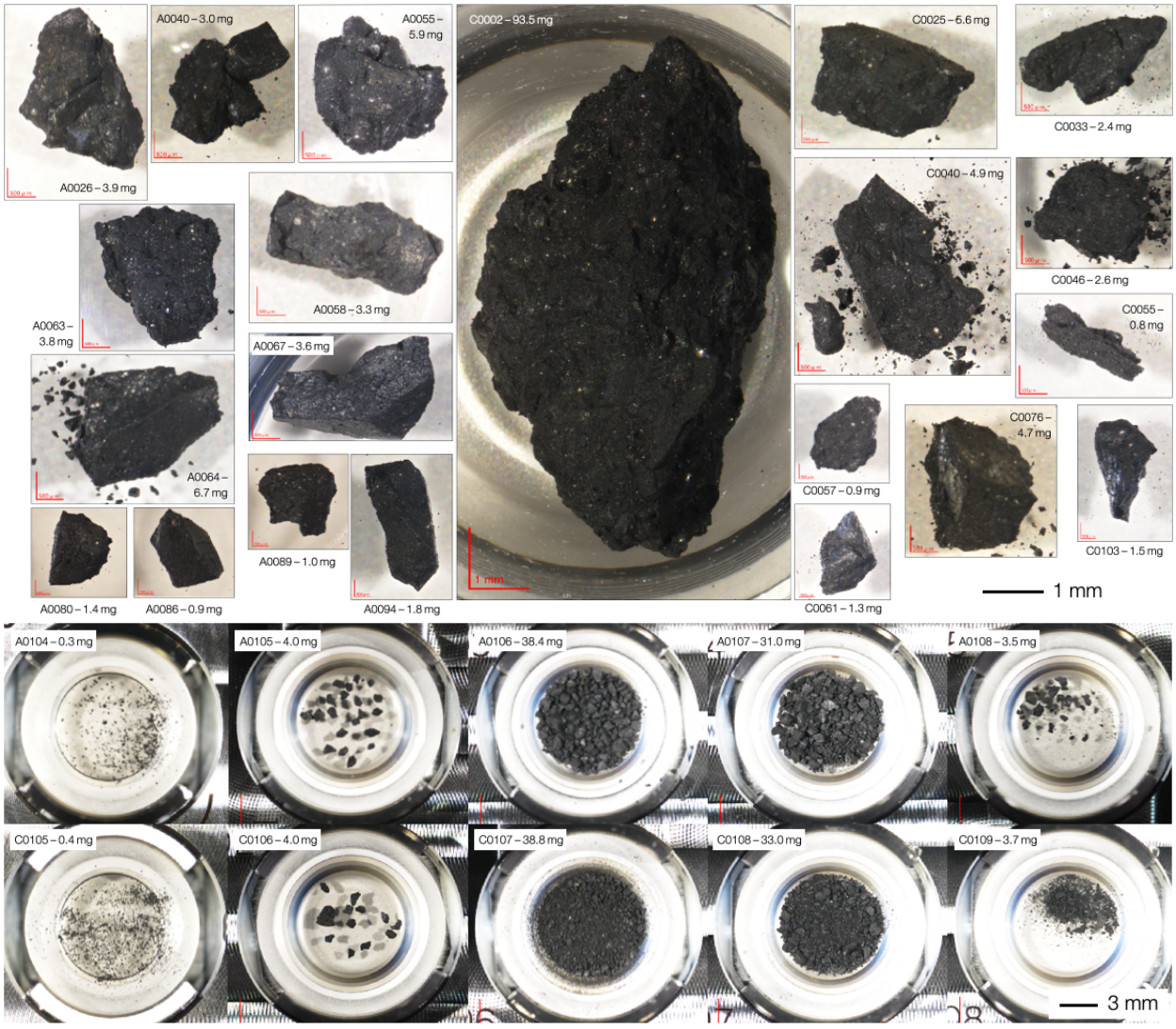

Fig. 1. Ryugu particles allocated to the Hayabusa2 initial analysis team (~0.3 g in total); Twenty-two individual grains and ten sets of aggregate samples consisting of particles smaller than 1 mm in diameter. Sample names starting with 'A' and 'C' represent those collected at the first and second touchdown sites. A 1-mm scale bar is for individual grains and that for 3 mm is for aggregate samples.