INITIAL ANALYSIS ACTIVITY OF HAYABUSA2-RETURNED SAMPLES FROM C-TYPE NEAR-EARTH ASTEROID (162173) RYUGU.

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Introduction: The JAXA's asteroid explorer Hayabusa2 investigated Cb-type near-Earth asteroid (162173) Ryugu from June 2018 to November 2019 [e.g., 1–3], during which the spacecraft made two touchdown operations onto the asteroid surface for sample collection with projectile shooting [4–8]. The spacecraft returned its reentry capsule to the Earth on December 6, 2020 [8, 9]. The mass of the returned samples was ~5 grams in total; ~3 grams from the first touchdown site and ~2 grams from the second touchdown site [9]. At Institute of Space and Astronautical Science (ISAS), JAXA, particles larger than ~1 mm in size were individually photographed, weighed, and investigated spectroscopically inside the nitrogen-filled chamber system. Particles < 1mm were inspected in a sample dish as bulk aggregates. The initial characterization phase of the returned sample shows that it well represents the finding from spacecraft investigation of the asteroid surface [8–10].

Initial Analysis: After the first six-month of initial description at ISAS, ~300 mg of returned samples (~6 % of total mass) were allocated to the Hayabusa2 initial analysis team in June 2021 for one-year priority analysis led by the Hayabusa2 mission [11]. The number of allocated particles larger than 1 mm were 11 from the first touchdown site (Chamber A grains) and 11 from the second touchdown site (Chamber C grains). Ten sets of aggregate samples, consisting of particles smaller than 1 mm, were also allocated (5 from Chamber A and 5 from Chamber C).

To characterize the Ryugu sample and to maximize the science output of the Hayabusa2 mission, the initial analysis team consisted of six sub-teams: Chemistry [12], Mineralogy and Petrology for coarse grains [13], Mineralogy and Petrology for fine grains [14], Volatiles [15], Macromolecular Organics [16], and Soluble Organic Matter [17]. The overall analysis activity went smoothly thanks to the dedication and hard work of the team in spite of challenges presented by a lack of in-person communication during the COVID-19 pandemic.

What is Ryugu? All the results from the initial analysis are interpreted to support the hypothesis that Ryugu comes from a parent body of the most chemically primitive CI chondrites (least fractionated from the Sun's elemental abundance) [12–17]. Ryugu's volatile and organic contents are highest compared to the meteorites in our collections except for micrometeorites and interplanetary dust particles [15–17]. Because C-type asteroids are a major group of asteroids, the close relation of Ryugu to the rarest type of chondrites (CI) suggests that the Earth's atmosphere works an effective filter for the influx of fragile meteorites, resulting in a biased sampling of meteorites on the ground. A notable mineralogical difference of Ryugu samples from CI chondrites [12–14] indicates that all CI chondrites recovered on Earth experienced significant terrestrial weathering since their fall.

The Hayabusa spacecraft retuned surface particles from S-type asteroid (25143) Itokawa in 2010, which was found to be a parent body of equilibrated LL ordinary chondrites [18, 19]. Therefore S-type asteroids and C-type asteroids are likely to be composed of the non-carbonaceous (NC) and carbonaceous chondrite (CC) group materials, representing isotopically dichotomous components in the early Solar System [20]. Coexistence of S- and C-type asteroids in the present main belt thus requires small body migration in the (early) Solar System, likely caused by migration of giant planets [21]. Comparison of Ryugu samples with the sample from B-type asteroid (101955) Bennu [22] will further constrain the dynamical and chemical evolution of small bodies and the (early) Solar System.

References: [1] Watanabe S. et al. (2019) *Science* 364:268–272. [2] Sugita S. et al. (2019) *Science* 364: eaaw0422. [3] Kitazato K. et al. (2019) *Science* 364:272–275. [4] Tachibana S. et al. (2014) *Geochemical Journal* 48:571–587. [5] Sawada H. et al. (2017) *Space Science Reviews* 208:81–106. [6] Okazaki R. et al. (2017) *Space Science Reviews* 208:107–124. [7] Morota T. et al. (2020) *Science* 368:654–659. [8] Tachibana S. et al. (2022) *Science* 375:1011–1016. [9] Yada T. et al. (2021) *Nature Astronomy* 6:214–220. [10] Pilorget C. et al. (2021) *Nature Astronomy* 6:221–225. [11] Tachibana S. et al. (2022) *LPSC LIII,* Abstract #1265. [12] Yurimoto H. et al. (2022) *LPSC LIII,* Abstract #1377. [13] Nakamura T. et al. (2022) *LPSC LIII,* Abstract #1753. [14] Noguchi T. et al. (2022) *LPSC LIII,* Abstract #1747. [15] Okazaki R. et al. (2022) *LPSC LIII,* Abstract #1348. [16] Yabuta H. et al. (2022) *LPSC LIII,* Abstract #2241. [17] Naraoka H. et al. (2022) *LPSC LIII,* Abstract #1781. [18] Yurimoto H. et al. (2011) *Science* 333:1116–1119. [19] Nakamura T. et al. (2011) *Science* 333:1113–1116. [20] Kleine T. et al. (2020) *Space Science Reviews* 216:55 (27 pp). [21] Walsh K. et al. (2011) *Nature* 475:206–209. [22] Lauretta D. S. et al. (2019) *Nature* 568:55–60.