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Geochemistry and Cosmochemistry of Asteroid Ryugu Samples

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The Hayabusa2 spacecraft made two successful landings onto asteroid Ryugu to collect asteroidal materials in 2019 and delivered the collected samples to the Earth on December 6th, 2020. The colors, shapes and macro-structures of the returned samples are consistent with those acquired by remote sensing observations indicating that the returned samples are representative of the asteroid Ryugu [1]. The initial analyses of the samples have been recognized that Ryugu mainly consist of carbonaceous chondrites and the material is show kinship to the chemically most primitive meteorites, CI chondrites [2-7].

The characteristics are: (1) Ryugu samples show strong similarities to CI (Ivuna-like) carbonaceous chondrites in chemistry, but poor in H_2O (Fig. 1). (2) Mineralogical and physical properties of Ryugu samples occurred early to progressed aqueous alteration in its parent asteroid. (3) The macromolecules of Ryugu record various organics-water-mineral interactions during the aqueous alteration. (4) A variety of prebiotic organic molecules including amino acids were identified in Ryugu samples. (5) Ryugu grains have resided at a certain depth until sampling, and only a limited number of the Ryugu grains were exposed to solar wind irradiation. (6) Ryugu grains recovered show unique surface modifications related to space weathering.

These results show that Ryugu samples are more primitive than any CI chondrite group samples and therefore represent the most pristine Solar System material available for study. Materials observed in the CI chondrites may have been significantly changed or modified on Earth from their primary states in space. Such modification likely resulted in the alteration of the structures of organics and phyllosilicates, the adsorption of terrestrial water, and the formation of sulfates and ferrihydrites for the CI chondrites fallen on the Earth.

This research was conducted by the Hayabusa2-initial-analysis team.

[1] Yada, T. et al. (2022) *Nature Astronomy* **6,** 214-220. [2] Yokoyama et al (2022) *Science* in review. [3] Nakamura et al. (2022) *Science* in review. [4] Noguchi et al. (2022) *Nature* in review. [5] Okazaki et al. (2022) *Nature* in review. [6] Yabuta et al. (2022) *Science* in review. [7] Naraoka et al. (2022) *Science* in review.