Introduction to Ryugu Reference Project

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Accurate determination of the initial composition of the Solar System is critical for advancing our understanding of the formation and evolution of the Solar System objects including planets, moons, asteroids, and comets. Additionally, the chemical composition of the Solar System serves as an important baseline for studying the chemical composition of other stars and exoplanets, as well as the interstellar medium and galaxies. The elemental abundances of the Sun have been used to represent the chemical composition of the Solar System, since more than 99% of the mass of the Solar System is locked up in the Sun. Another robust method for determining the chemical composition of the Solar System is the measurement of chondritic meteorites. In particular, the Ivuna-type (CI) carbonaceous chondrites have been perceived as a unique group of meteorites with a chemical composition similar to that of the solar photosphere except for highly volatile elements and Li. In fact, direct comparisons of relative elemental abundances between solar photosphere and CI chondrites showed excellent agreement within ±10% difference for nearly 40 elements [1-2].

On the other hand, sample return missions are superior to meteorite analysis in that samples can be collected with no or a minimum of contamination from well-documented extraterrestrial objects. The Japan Aerospace Exploration Agency's (JAXA) Hayabusa 2 spacecraft, targeting the Cb-type asteroid (162173) Ryugu, sampled ~5.4 g of asteroidal material and returned the samples to Earth in December 2020 [3]. These samples were collected during the two landing sequences on the asteroid Ryugu. During the first touch-down operation (TD1), samples were collected from the asteroid surface and stored in sample Chamber A, while the other samples stored in sample Chamber C were collected from the vicinity of an artificial crater created by the small carry-on impactor during the second touch-down operation (TD2). The TD1 and TD2 samples were stored and handled separately at the JAXA curation facility [3]. Initial analyses of the Ryugu materials in both chambers revealed a mineralogical and chemical kinship to the CI chondrites (Fig. 1) with a composition similar to the solar photosphere for non-volatile elements [4-6]. Nevertheless, the abundance of some elements (e.g., P, Ca, Mn, and rare earth elements) in individual Ryugu particles were found to show large relative dispersions compared to the other elements in the returned materials studied so far, presumably due to the nugget effect of aqueously formed minor secondary minerals (e.g., dolomite, apatite, magnetite, and pyrrhotite). Therefore, the mean elemental abundances of Ryugu calculated using currently available Ryugu data requires a substantial update. For this reason, there have been scientific demands to establishing a new consortium to determine the representative elemental abundances of Ryugu by measuring aliquots from a large homogenized powder sample that can mitigate the nugget effect.

In response to such scientific demands, JAXA has launched the Ryugu Reference Project (RRP) that aims to create an international reference for the elemental and isotopic abundances in the solar system using Ryugu samples as well as CI chondrites [7]. The newly obtained, more precise chemical composition of Ryugu and CI chondrites will be used by multidisciplinary communities in various scientific fields including astronomy, astrobiology, cosmochemistry, geochemistry, geology, and planetary physics.

References

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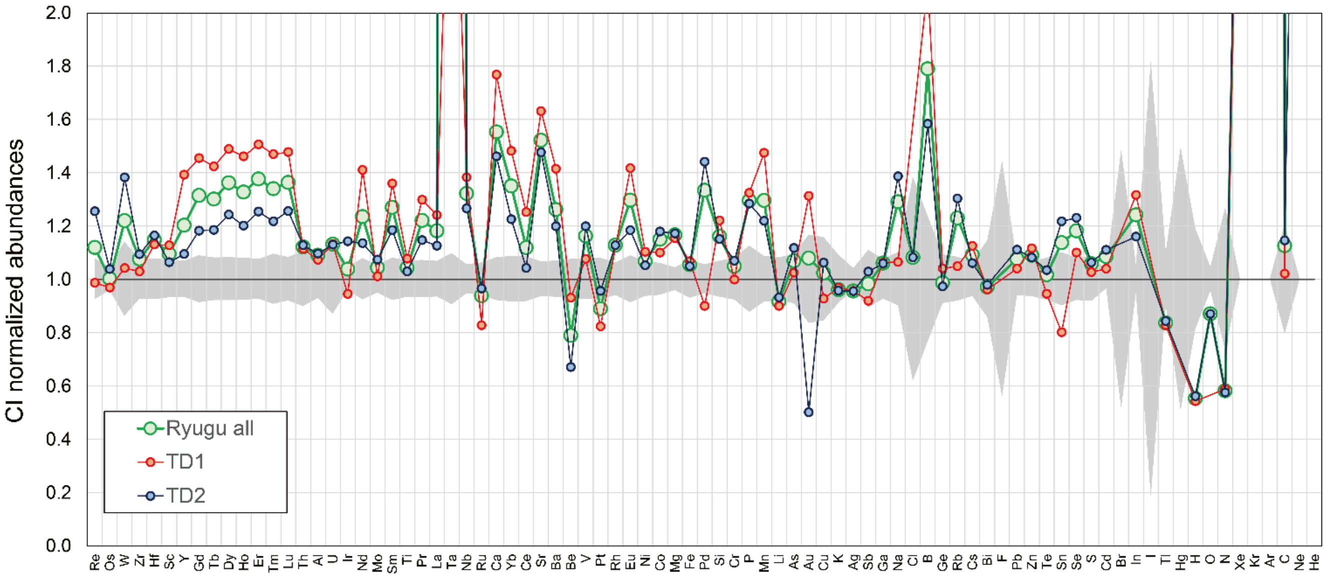

Figure 1. CI-normalized elemental abundances in bulk Ryugu samples.