The magnesium isotope composition of samples returned from asteroid Ryugu

Martin Bizzarro[1,2]*, Martin Schiller[1], Tetsuya Yokoyama[3] and the Hayabusa2 Initial Analysis Team

[1]*Centre for Star and Planet Formation, Globe Institute, University of Copenhagen, Copenhagen, K 1350, Denmark.*email: bizzarro@sund.ku.dk*

[2]*Université Paris Cité, Institut de Physique du Globe de Paris, CNRS, 75005 Paris, France*

[3]*Department of Earth and Planetary Sciences, Tokyo Institute of Technology, Tokyo 152-8551, Japan.*

The nucleosynthetic isotope composition of planetary materials provides a record of the heterogeneous distribution of stardust within the early Solar System. Thus, nucleosynthetic signatures can be used to infer genetic relationships between early formed bodies and, ultimately, provide constraints on their accretion regions. In December 2020, the Japan Aerospace Exploration Agency Hayabusa2 spacecraft returned to Earth the first samples of a primitive asteroids, namely the Cb-type asteroid Ryugu. This provides a unique opportunity to explore the kindship between primitive asteroids and carbonaceous chondrites. Based on chemistry, mineralogy, petrology and isotope systematics of various elements, it has been proposed that Ryugu samples are closely related to Ivuna-type (CI) carbonaceous chondrites. Indeed, the bulk nucleosynthetic isotope compositing for tracers like ^{54}Cr and ^{50}Ti as well as the chemical abundances of most elements are within the range of CI chondrites. Moreover, like CIs, Ryugu samples experienced extensive aqueous alteration in the presence of water and mainly consist of hydrous silicates (serpentine and saponite) and other secondary minerals (i.e., carbonate, magnetite, and sulfide) interpreted to have formed during asteroidal fluid circulation.

High-precision Mg isotope measurements can provide a novel perspective on the kinship between Ryugu with CI chondrites and, by extension, the accretion region of Cb-type asteroids. Magnesium isotope variability in Solar System materials can originate from the decay of the short-lived ^{26}Al nuclide as well as primary nucleosynthetic processes. Moreover, Mg isotopes can also be fractionated according to their masses by high-temperature events in the protoplanetary disk or, alternatively, by low-temperature parent body secondary. Thus, the combination of high-precision mass-independent and mass-dependent Mg isotope compositions is useful to understand genetic relationships and accretion history of planetary materials.

Here, we report high-precision μ^{26}Mg* and μ^{25}Mg values of Ryugu samples together with those of CI, CM, CV and ungrouped carbonaceous chondrites. The stable Mg isotope composition of Ryugu aliquots define μ^{25}Mg values ranging from –160±20 ppm to –272±30 ppm, which extends to lighter compositions relative to Ivuna-type (CI) and other carbonaceous chondrite groups. We interpret the μ^{25}Mg variability as reflecting heterogenous sampling of a carbonate phase hosting isotopically light Mg (μ^{25}Mg ~–1400 ppm) formed by low temperature equilibrium processes. After correction for this effect, Ryugu samples return homogenous μ^{26}Mg* values corresponding to a weighted mean of 7.1±0.8 ppm. Thus, Ryugu defines a μ^{26}Mg* excess relative to the CI and CR chondrite reservoirs corresponding to 3.8±1.1 and 11.9±0.8 ppm, respectively. These variations cannot be accounted for by in situ decay of ^{26}Al given their respective ^{27}Al/^{24}Mg ratios. Instead, it requires that Ryugu and the CI and CR parent bodies formed from material with a different initial ^{26}Al/^{27}Al ratio or that they are sourced from material with distinct Mg isotope compositions. Thus, our new Mg isotope data challenge the notion that Ryugu and CI chondrites share a common nucleosynthetic heritage.