Moderately volatile element variations among asteroid Ryugu and CI chondrites

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Isotopic analyses of samples of asteroid Ryugu returned to Earth by JAXA's Hayabusa2 mission reveal a close genetic link between Ryugu and CI (Ivuna-type) carbonaceous chondrites. Thus far, this genetic link has almost exclusively been determined based on nucleosynthetic isotope anomalies for several elements, particularly for Cr, Ti, Fe, and Ni [1–3]. To this end, the isotope anomalies in Fe and Ni are particularly useful, because for these two elements Ryugu and CI chondrites are distinct from all other carbonaceous chondrites. Moderately volatile elements offer an alternative way for assessing the link between Ryugu and CI chondrites [4], because carbonaceous chondrites are systematically depleted in these elements compared to CI chondrites. This depletion most likely reflects mixing of volatile element-depleted chondrules with CI chondrite-like matrix [5,6]. The volatile element depletion is associated with mass-dependent isotopic fractionation, where CI chondrites are isotopically heavy compared to other carbonaceous chondrites [6,7].

To assess whether Ryugu is characterized by similar moderately volatile element concentrations and isotope compositions as CI chondrites, we determined mass-dependent Ge and Te isotope compositions of Ryugu sample A0220. Our results indicate that the Ge and Te concentrations and isotopic compositions of Ryugu are most similar to CI chondrites and distinct from all other carbonaceous chondrites (Fig. 1). Our data also reveal some differences between the Ryugu sample and CI chondrites. We find that our Ryugu sample is modestly enriched in Te and Ge compared to CI chondrites, and is isotopically lighter (i.e., has lower $\delta^{128/126}$Te and $\delta^{74/70}$Ge values) (Fig. 1). This difference might indicate a more pristine nature of the Ryugu samples, or alternatively is the result of small compositional heterogeneities at the sampling scale of the Ryugu fragment. Evidence for such sample heterogeneity is provided by variability in nucleosynthetic isotope anomalies among different Ryugu subsamples, which have been attributed to the redistribution of isotopically distinct materials during aqueous alteration on the parent body [8]. As to whether such processes are also responsible for the observed variability in moderately volatile element systematics will require the analyses of additional Ryugu samples.

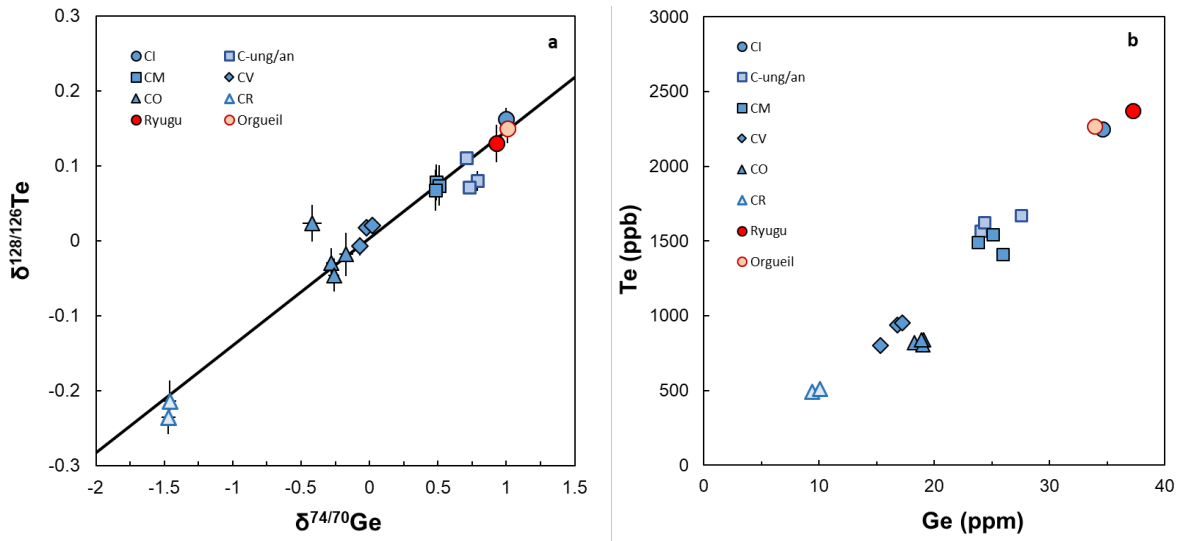

Figure 1. Mass-dependent Te versus Ge isotope fractionation (a) and Te versus Ge concentrations (b) in carbonaceous chondrites and Ryugu (A0220). The open red symbol represents Orgueil, which has been processed and analyzed together with Ryugu A0220.

References

[1] Hopp T. et al. (2022). Ryugu's nucleosynthetic heritage from the outskirts of the Solar System. Science Advances 8, eadd8141. [2] Yokoyama T. et al. (2022) Samples returned from the asteroid Ryugu are similar to Ivuna-type carbonaceous meteorites. Science, 379, eabn7850. [3] Spitzer F. et al. (2024) The Ni isotopic composition of Ryugu reveals a common accretion region for carbonaceous chondrites. Science Advances, in press. [4] Paquet M. et al. (2023) Contribution of Ryugu-like material to Earth's volatile inventory by Cu and Zn isotopic analysis. Nature Astronomy 7, 182-187. [5] Alexander C. (2019) Quantitative models for the elemental and isotopic fractionations in chondrites: The carbonaceous chondrites.

Geochimica et Cosmochimica Acta, 254,277–309. [6] Hellmann J. et al. (2020) Origin of volatile element depletion among carbonaceous chondrites. Earth and Planetary Science Letters 549, 116508. [7] Pringle E. et al. (2017) The origin of volatile element depletion in early solar system material: Clues from Zn isotopes in chondrules. Earth and Planetary Science Letters 468, 62–71. [8] Yokoyama T. et al. (2023) Water circulation in Ryugu asteroid affected the distribution of nucleosynthetic isotope anomalies in returned sample. Science Advances 9, eadi7048.