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Aqueous alteration on the progenitor body of the asteroid Ryugu revealed through H-C-N-O isotope systematics

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The comprehensive analysis of 16 representative particles returned from the asteroid Ryugu (seven and nine from TD1 and TD2 sites, respectively) was carried out at the Phase-2 curation facility at the PML[1]. Most of the constituent minerals of the Ryugu particles were formed during aqueous alteration on the Ryugu progenitor body, which occurred <2.6 Myr after the formation of CAIs. Here, the aqueous alteration processes that operated on the Ryugu progenitor body are discussed mainly based on the H-N-C-O isotopic data. The $\delta^{18}O$ values of the main oxygen reservoir phases, phyllosilicate (19 ‰), carbonate (34 ‰), and magnetite (-2 ‰), were determined through mass balance calculations using the bulk $\delta^{18}O$ values and mineral modal abundances of three representative samples, one from TD1 and two from TD2. The calculated $\delta^{18}O$ values of carbonate and magnetite are identical to that determined by SIMS for particle C0008 (TD2). This result indicates that the oxygen isotopic compositions of the fluid involved in aqueous alteration were not significantly different among both sites, and the equilibrium temperature decreased from the phyllosilicate to carbonate-magnetite formation processes in both sites. However, an exceptional particle (A0022 from TD1) has higher $\delta^{18}O$ values for bulk, carbonate, and magnetite. Additionally, while there is no significant difference in the $\delta^{13}C$ of organic carbon or the bulk δD values for the 16 Ryugu particles, A0022 shows a higher bulk $\delta^{13}C$ value. Furthermore, A0022 was found to be abundant in dimethylglycine, a rare amino acid in extraterrestrial samples, which can form under high partial pressures of CO_2 [2]. These results reveal that large amounts of ^{18}O and ^{13}C-rich fluid derived from CO or CO_2-rich ice were involved in the alteration of A0022. TD1 particles tend to have a high carbonate-C/organic-C ratio and degree of elemental fractionation compared to TD2 particles. Variation in the fluid/rock ratio and CO or CO_2/H_2O ratios in the ice components among the Ryugu particles could explain the aforementioned findings and the evolution of organic matter in the Ryugu progenitor body.

[1] Nakamura et al. (2022), Proc. Japan Acad. B, 98, 227-282.
[2] Potiszil et al. (2023) Nature Communications, in press