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# Constraining the processes responsible for the origin and evolution of extraterrestrial organic matter: evidence from the asteroid Ryugu.

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C-type asteroids and comets contain organic matter and represent the collisional fragments of icy planetesimals, which accreted shortly after the formation of the Solar System. At least some planetesimals would have accreted enough radionuclides to melt their ice components, but not enough to undergo melting. The resulting water-rich fluids caused aqueous alteration of the mineral and organic phases. Nevertheless, multiple origins for organic molecules have been suggested. Amino acids were formed in both irradiated ice experiments, reminiscent of the interstellar medium and outer protosolar nebula, and laboratory simulations of planetesimal aqueous alteration. Similarly, nitrogen heterocycles are thought to form during aqueous alteration, but may also be the products of irradiation processes [1].

To further investigate the origin and evolution of organic matter, without significant terrestrial contamination, the Hayabusa2 mission was tasked with returning samples from the C-type asteroid Ryugu. During Phase 2 curation at the Pheasant Memorial Laboratory, 16 Ryugu particles were comprehensively analyzed to elucidate their organic and inorganic phases and the processes that formed and affected them [1]. During the investigation, a unique particle, A0022 from the first touchdown site, recorded a large abundance of the unusual amino acid dimethylglycine (DMG). The DMG enrichment correlated with high abundances of carbonates in the particle, compared with other Ryugu samples, and this was interpreted to result from the formation of DMG on the parent body in association with high abundances of CO or $CO_2$-rich ice [2]. Additionally, the C and O isotopic data supported the involvement of higher abundances of CO or $CO_2$-rich ice in the formation of the carbonates in A0022, compared to the other particles.

Meanwhile, the Raman spectra of insoluble organic matter and the spatial distribution of nitrogen heterocycles was recorded for a number of the particles and the results suggested that later asteroidal irradiation, may have affected the organic matter closer to the surface [1]. Here, the various processes that could have contributed to the formation and evolution of organic matter in Ryugu will be discussed.

[1] Nakamura et al., Proc. Jap. Acad., Ser. B. 98, 6, 227–282 (2022).

[2] Potiszil et al., Nat. Commun., (Accepted).