

Low molecular-weight organic molecules from a Ryugu A0535 grain: More pristine than carbonaceous chondrites

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Ryugu samples resemble CI chondrites, but TG-MS (thermogravimetry coupled with mass spectroscopy) analysis of Ryugu (A0040) and Ivuna indicates that CI chondrites underwent terrestrial weathering [1]. To investigate volatile release from Ryugu and carbonaceous chondrites, we performed pyrolysis experiments of a Ryugu grain and carbonaceous chondrites in vacuum.

We analyzed a Ryugu grain A0535 (0.9 mg), and ~1 mg grains of Orgueil (CI1), Murchison (CM2), Allende (CV3), Tarda (C2-ungrouped), and Oued Chebeika 002 (CI1). In addition to the natural samples, synthetic saponite and Orgueil, soaked in methanol and ethanol (1:1) after removal of the interlayer water and decomposition of terrestrial weathering products (ferrihydrite and gypsum) by mild heating (200–300°C) in vacuum, were analyzed. Oued Chebeika 002, which was soaked directly in methanol and ethanol (1:1) was also analyzed. The samples were heated to 1000°C at a rate of 20°C/min under a pressure of $\sim 10^{-5}$ – 10^{-4} Pa in a vacuum furnace. Released gases were monitored by a quadrupole mass spectrometer (MKS Microvision2; m/z 1–100).

We found that Ryugu A0535 showed similar H₂O, CO₂, and SO₂ release patterns as A0400 [1]. The amounts of H₂O released below 200°C and SO₂ from Oued Chebeika 002 were lower than Orgueil, suggesting Oued Chebeika 002 has undergone less terrestrial weathering than Orgueil.

In the analysis of Ryugu A0535, ions originating from organic molecules, such as CH₃⁺, CH₃O⁺, and C₂H₅O⁺, were detected at ~120°C. No carbonaceous chondrites showed such releases at ~120°C except for the interlayer water of saponite from Orgueil. Synthetic saponite and CIs with alcohol replacing interlayer water clearly released fragment ions from methanol and ethanol at ~80–130°C. X-ray diffraction pattern of swollen saponite shows the (001) reflection shifts toward a lower 2-theta angle than synthetic saponite. These results indicate that low molecular-weight organic molecules were present in the interlayer of saponite in Ryugu [2] and that CI chondrites may have lost interlayer organic molecules due to terrestrial moisture. This finding suggests that Ryugu may preserve more primitive organic molecules than CIs.

[1] Yokoyama T. et al. (2023) *Science* 379, eabn7850. [2] Viennet J.-C. et al. (2023) *Geochem. Persp. Let.* 25, 8–12.