OXYGEN-BEARING ORGANIC COMPONENTS IN RYUGU SAMPLES

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Introduction: The Hayabusa2 mission visited the near-Earth Cb-type asteroid (162173) Ryugu and has returned to Earth with the surface material of Ryugu. Ryugu is an airless rubble pile asteroid exposed to space weathering [1]. Initial organic analyses indicate that Ryugu contains aliphatic rich [2], ketone and carboxyl functional groups [3], in associated with phyllosilicate and carbonate minerals. Here we investigate the alteration history of Ryugu by comparing the organic content of carbonate-bearing Ryugu samples to that of naturally and experimentally heated meteorites.

Samples and Analytical Techniques: We studied Ryugu samples allocated during the Hayabusa2 preliminary examination (A0063-FC016, A0063-FC017, A0064-FO012, A0067-FC008, C0002-FC014, C0002-FC015, C0025-FC003, C0033-FC003, C0046-FO003) and AO1 (A0009 and C0011), plus raw fragments of naturally long-term (CIs: Orgueil, Ivuna; CMs: Murchison, Murray; CV: Allende; CRs: Grosvenor Mountains 95577; OCs: Yamato (Y)-74191, Queen Alexandra Range 93010) and short-term heated meteorites (Belgica-7904, Jbilet Winselwan, Y-793321, Y-86720, Y-982086) [4]. We also analysed samples of Murchison, Murray and Orgueil experimentally heated to 300, 400, 500, 600, 700 and 900 °C for 1, 10, 50, 100, 500 and 1000 hours.

μ-Raman analysis was conducted using a Raman microprobe with a 514 nm laser. The mineralogy of the samples was characterised using low-voltage scanning electron microscopy with energy dispersive X-ray spectroscopy (SEM-EDS) and μ-X-ray diffraction (XRD). Using μ-X-ray computed tomography (μ-CT) we identified regions of interests, which were prepared into electron-transparent sections using FIB-SEM. The FIB sections were studied by scanning transmission X-ray microscopy X-ray absorption near edge structure (STXM-XANES) to determine the structural moieties, and by Nanoscale secondary-ion mass spectrometry (NanoSIMS) for their isotopic signatures. Euhedral sulphide crystals were lifted and mounted on W-needles by the focused ion beam (FIB)-SEM, which were analysed by synchrotron radiation-based X-ray computed tomography (SR-CT) to identify potential fluid inclusions.

Results and Discussion: SEM-EDS and μ-XRD shows the presence of hydrated phyllosilicates, suggesting that the particle did not experience significant heating above ~300–400 °C. The Raman spectral features of the organic matter in the Ryugu samples are similar to those observed from CIs, consistent with previous studies [5]. However, the Raman features of the diffused organic matter within localised areas of A0009, A0064 and C0011 show a wider G band, which suggest the presence of carbonyl moieties, similar to those exhibited by astromaterials heated by short-term heating like interplanetary dust particles [6], and to Orgueil experimentally heated to 300 °C for 500 h.

Analysing these more "evolved" particles with STXM-XANES helped us understand the organic structure corresponding to the Raman features. C-XANES spectra of A0009 and C0011 indicate the presence of aromatic or olefinic groups (C=C) at ~285 eV and carboxylic groups (COOH) at ~288.5 eV within the matrix associated with carbonate grains (CO_3 absorption at 290.3 eV). Such organic matter in associated with carbonates is comparable to the carboxylic-rich diffuse organic matter in CM and CI chondrites [7]. μ-CT and SR-CT scans indicate that C0011 contains a sulphide grain hosting a potential fluid inclusion, suggesting that the grain has experienced extensive aqueous alteration that has not been subsequently metamorphosed [8].

Possible Scenarios: Two possible scenarios can explain these observations: (1) Ryugu had experienced post aqueous alteration short duration heating (impact induced and/or solar irradiation), resulting in the presence of thermally stable oxygenated moieties like furan and phenol that were formed via dehydration and cyclisation of polyalcohols. These "evolved" materials were subsequently disrupted and redistributed by impacts and/or mass wasting processes [9]. Alternatively, (2) the formation of the macromolecular organic matter occurred at the final stages of aqueous alteration in low-temperature, highly oxidizing fluids, e.g., fluid with OH radicals contributing through H_2O_2 dissociation [10], co-precipitating carboxylic enriched components in the immediate vicinity of carbonate. We are currently acquiring NanoSIMS data for the organic matter which will help evaluating these scenarios.

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